A Study of Illegal Housing of Lisbon Built in 1974 to 1984: From Description to Computation

By
Luís António dos Santos Romão

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Signature of Author:

Department of Architecture, MIT
28 July 2005

Certified by:

William J. Mitchell
Professor of Architecture and Media Arts and Sciences
School of Architecture and Planning, MIT
Co-chair, Dissertation Committee

George Stiny
Professor of Design and Computation
Department of Architecture, MIT
Co-chair, Dissertation Committee

Accepted by:

Yung Ho Chang
Professor of Architecture
Head of the Department, Department of Architecture, MIT
Chair, Committee on Graduate Students

DISSERTATION COMMITTEE

Committee Co-Chairs
William J. Mitchell
Professor of Architecture and Media Arts and Sciences,
School of Architecture and Planning, MIT

George Stiny
Professor of Design and Computation,
Department of Architecture, MIT
School of Architecture and Planning, MIT

Committee Members
Terry W. Knight
Professor of Design and Computation,
Department of Architecture, MIT
School of Architecture and Planning, MIT

José P Duarte
Assistant Professor of Design and Computation
Department of Civil Engineering and Architecture,
Instituto Superior Técnico, UTL

A STUDY OF ILLEGAL HOUSES OF LISBON BUILT IN 1974 TO 1984: FROM DESCRIPTION TO COMPUTATION.

By Luís António dos Santos Romão

Submitted to the Department of Architecture on July 28, 2005, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Architecture: Design & Computation.

ABSTRACT

A morphological description of illegal housing built by homeowners in the Metropolitan Area of Lisbon between 1974 and 1984 is presented. This description is based on a parametric set grammar that attempts to formulate both topological and geometric aspects of the house. Therefore, the grammar is made of shapes, symbols, and their relations in space. The architectural description herein considers aspects of structure, function and use.

The main characteristic of this illegal housing is that design and building are here the inhabitant's responsibility. These houses are usually seen by society as a chaotic and ugly constituent of the built environment. Yet for the users these are dream houses, shaped with symbolic references that helped assure each homeowner a good assimilation into the big city.

Three basic goals led to this study: first, to search for a better understanding of these dream houses despite their many contradictions, second, to find a formal representation despite the chaotic appearance and genesis of these illegal houses, and third, to contribute to the formalizing of a computer implementation that could help to prevent further echoes of this scenario.

As analyses and synthesis may not have the same type of description, relating the substance of representation, both inside or outside computation, and the processes that should work with that representation became an important issue for the work herein. The result creates a speculative framework which, it is hoped, will help to define a computer representation of an architectural chain that can deal with the complexity of scaling house representation from abstract to concrete. Therefore, some considerations are made regarding shape grammars and their ancillary grammars, as well as the heuristic processes that may operate with those grammars.

Thesis co-Supervisors:

William J. Mitchell
Professor of Architecture and Media Arts and Sciences,
School of Architecture and Planning, MIT

George Stiny
Professor of Design and Computation,
Department of Architecture, MIT
School of Architecture and Planning, MIT

BIBLIOGRAPHICAL NOTE

Luís Romão was born in Lisbon, in April 1958. He graduated in Architecture, in 1985, at the School of Architecture of Technical University of Lisbon. Since 1989 until 2000, he has worked in liberal practice in the areas of Health Care and Housing. Since 1991, he has divided his activity with teaching at School of Architecture of Technical University of Lisbon. He is currently a senior lecturer. He also collaborated as a lecturer with the Glasgow School of Art and the Centro Português de Design in postgraduate courses.

To my family Miguel, Alexandre and Isabel

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CONTENTS

1 INTRODUCTION

A morphological description of illegal housing built by homeowners in the Metropolitan Area of Lisbon between 1974 and 1984 is presented. This description is based on set grammar formalism, and attempts to formulate both topological and geometric aspects of this housing type. The description is made of shapes, symbols, and theirs relations in space. The architectural description considers aspects of structure, function, and use that are coded in two algebras.

This research aims to understand the phenomena of particular illegal housing structures in Lisbon and to propose representation of such housing through computation. The primary goal of this work is to capture the essence of the phenomenon in a grammar that could describe a language for these houses. Therefore, an important question arises regarding how to represent such an apparent chaotic occurrence within a formal device. The importance of representation for architectural design is well known, and different types or codes are used for different purposes. For computation, some, definitions were given by Terry Knight and George Stiny (2001). The type of representation in the computation selected was chosen from his understanding of what these dream houses are. Yet some considerations helped further clarify the chosen research path.

There were several reasons that drove him into this study. First, housing is still the paradigm of an architect's assignments and social aspects that are related with housing are important. A house's shape could have a meaning that corresponds to wills of who lives in it. This work leads to an understanding of this meaning by looking at what homeowners did instead of asking what they want. Furthermore, people's basic needs are as dynamic as everything else. To understand people's wills and needs, one must known how ideas within a project have been carried out. Analyzing how homeowners solved their needs instead of asking is another form of knowledge creation. Most of the time, homeowners know what they want by seeing what has been done previously. Finally, architects and state authorities must be prepared to answer for housing shortages in the Lisbon area and to do so they need means to answer properly to solve problems accordingly in the relevant time and place.

A second consideration in his choosing this particular study was the challenge of encoding this apparently chaotic built environment, designed by many people, draftsmen, masons, engineers and architects and concluding with the homeowner's approval.

The third reason for choosing this project was his interest in discussing ideas about the creation of a flexible tool that could be used to evaluate similar designs. By defining descriptions through computation this study might become a syntheses tool for similar research in future conditions for housing, by introducing different rules, which represents different thoughts.

During the work, which was a seemingly straightforward process, different questions and considerations have arisen. First, the selected formal device for representation has as limited a scope as any other type of representation. Second, the author attempted to replicate not only the shapes, which can be seen, but also the process of conceptualization that allowed those shapes, i.e. those houses, to emerge. The resultant grammar is associated with both the spaces and boundaries that the homeowner had in mind. If we could comprehend how designs were done perhaps we could try to represent them in other ways. For example, the process of describing illegal housing can be accomplished in three steps. For each step there were different conditions, which corresponded to different types of representation. Representations are made to accomplish different goals and each representation is dependant on the way we may want to later edit them.

A third question which comes from his work is related with shape itself, including its properties and designs. Designs are made from a vocabulary which each designer defines. It can include sets of points, lines, planes or solids, but can also be made of sets which include doors, windows, slabs and objects of the kind. Most of the time designs can be a combination of both of these two sets. The last and fourth question that has arisen in the process of his work is related with an assumption that formal machines described into computers are an extension of human knowledge. We can mirror our skills on them but never expect to learn anything new of them. However, they may work as a source of inspiration as Leonardo suggested when we look at lines in a wall.

Computers may become a medium to translate different kinds of information. In this case the architect would act in the role of a mediator. Combined computation and industrial manufactory technology can help to produce cheaper building components. This is possible in a ground where user, architect, authorities and building construction industry might interact together pursuing suitable goals. In the field of architecture relating to the construction component, pioneer examples have been made.

In the beginning of the previous century, housing was democratized by and for the power of machine. One single project served to build affordable houses for everyone, supported by a massive and outstanding building management. In this time, the process of building controlled designs. Le

Corbusier stated that designs of the minimum house should be adapted to industrialization, standardization and taylorisation (Aymonino 1971). The main motivation was related with economic factors as Engels had prophesized. However, people felt uncomfortable due to the aggressive lack of individualization. After all, basic needs of the people are not static and work in synchronic and diachronic ways.

Now, at the age of information technology can we apply different directions? How can we reach the goal of producing affordable housing despite economic factors and without apparent mechanical reproduction? Can designs be made without mechanical constraints? I.e.: Can work be carried out which has a project for each house and for each user. Can we integrate or reintegrate the two aspects of traditional dwellings defined by Le Corbusier: an organized system of circulation and a structural method? Le Corbusier also called these aspects the biological and geometric issues of the house. Can the existent flexibility processes of this epoch be used to solve problems of housing without loosing the fundamental characteristics of a home?

A last remark is made on the scope of this work. During the study, three steps were identified for a complete definition of this housing. The first step was a land division, made by speculators. The second was the house, made by the homeowner. Finally, the third step corresponded to the attachments for living spaces that were built outside of the "symbolic" house up to the limits of the lot. This last step did not work for all cases. After quick analyses of these three steps, the author have decided that the first step would be best represented by a standard shape grammar because the designs in question derived entirely from a graphical representation of the land and therefore visual representation was important to decisions. The second step could be defined by a set grammar because its intent was to convey a house wherein every shape or space was already described early in the mind of the user, which implies that during designing no emergent shapes appeared.

Additionally, the last step could be described using the same method as in the second or as it is proposed as an extension of the grammar.

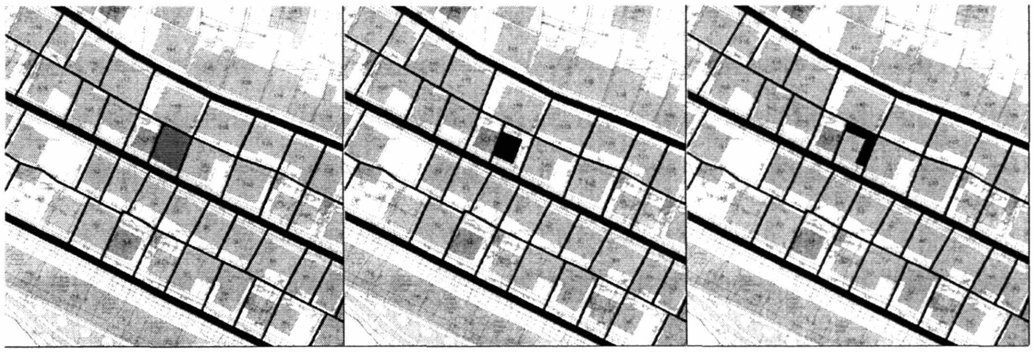


Figure 1 Three stages of housing; allotment, house and inner space

To conclude, many works have carried out which use flexibility methods to achieve a good level of satisfaction for users. The Malagueira Grammar of José Duarte (2001) is a good example of such work. In the end, users should know better what they want in a way to reach the maximal level of satisfaction. However, what can be said of these illegal houses? They had fulfilled the dreams of the owners, yet are these houses well integrated in the built environment? Anyone can see that the results have left us with a failing solution. Architects, users, authorities and the building industry should work together to look for answers.

It would be interesting to have a medium, with tools, to allow an easy communication between all actors in the creation of housing as studied herein. One could say that there are already in the market several tools that fulfill all users' needs. There is software that allows everybody to design a house by giving proper values to variables. It can be done graphically or verbally. Therefore, someone can accept a given vocabulary and perform the roll that software expects. In such processes, the user accepts a language and plays along with it, even if the user does not acknowledge that language. Yet maybe this tool is not sufficient for his goals and he has to choose other software with a different language, say, for example, Palladian grammar. To overcome this drawback, the better tool would allow him to build his own language, be it Palladian or otherwise. Still, as architects are uniquely trained to understand and define what architectural languages are, the architect might work together with the user in the process of building a language that can be accepted by both. Ultimately, then, if the tool described above could have the tools to translate the language and the desires of potential users into to representations that authorities and the building industry could understand, we could have a close circle of information related with each housing program.

For architects the language defining tool we are describing could be a tool to research and to test several ideas. In this way, architects' aesthetic control in the design will not be impeached. The architect would have the ability to control the tool and the outcome through the rules he applies at all times.

While the author has mentioned them only briefly here, all of the above questions and remarks raised by his topic are discussed in this work. The core goal of his work herein is a computational description of a group of houses which were intended by the user to represent the map of a dream house. At the end, the author expects to be clear on these three groups of questions that summarize the previous:

1) Can computation, using a shape grammar tool be helpful for evaluating this illegal housing morphology? What can we learn from this process of research?

2) Can this tool be flexible enough to allow a relationship between topological and geometric components of the houses? Can anyone accomplish that relationship in a straightforward manner?

3) Which are the limits of a grammar? Can a given grammar be generous enough to respond to all designer and user needs? What design strategies could be attempted using this formalism?

In conclusion, the author would like to present the language of a housing type formulated by a set grammar that describes dream houses for the users involved in this study. Holding to the belief that every architectural shape carries meaning means that our representations are related with peoples aspirations about housing, being that it is representative of the needs and the wills of homeowners.

This text should allow a discussion ground where users, architects, authorities and building industry could work together. Different representations of the same entity could overcome the needs of all, creating a tool of imaginary output for user testing, a tool to support designs for the architect, a tool to control and evaluate for the authorities, and a tool to produce and test components for the building industry. A tool of this nature would correspond to different instances of designing and to different scales of representation.

METHODS AND SOURCES OF RESEARCH

The author used both quantitative and qualitative methods. To understand the illegal phenomena he used background literature of housing, for instance, the quarrel between Engels and Proudhon, usually translated to English. He used Portuguese, Spanish and English literature to understand the social aspects of this particular theme and epoch. Census data was also used, which were collected from literature and from the Portuguese entity that makes surveys, the Instituto Nacional de Estatística, (INE). The author uses survey, though not exhaustively, from direct contacts with users, and with local authorities, (Câmaras Municipais). To understand the limits of illegalities I have kept track on the building and urban codes, including general laws and specific ones. Lastly, he also looked for newspapers to get news of this illegal phenomenon.

For representation, the author supports his work on four doctoral researches of his colleagues in the School of Architecture of Lisbon, which were directly and indirectly the reasons that lead him to this work. Each doctoral work is related to different qualities of representation. He also used the Portuguese text of Francisco d'Ollanda reporting the dialogs that he had with Michelangelo Buonarotti in Rome.

To formulate the grammar, the main source of his work was the English literature about computation in general: the foundation work of William Mitchell that bridges architecture and computation, the seminal work and discussions with George Stiny on shapes, and the decisive and pedagogic works of Terry Knight. The works of Peter Testa, William Porter and Jose P. Duarte, with his Malagueira Grammars were also important references.

In fact, his research has many issues in common with the work of Duarte. Differences as you will see in the next chapters are related with the universe of the grammar and how it is related with a clear differentiation of the foundations of the grammar, limited to representation alone.

To define the universe of his grammar the author has chosen twelve examples of illegal Lisbon housing. His sources were collected from a work that focuses on the same subject from a social sciences perspective. The selection of each sample was made in a stochastic basis, and each is representative of the studied subject.

The Computer is the constant medium in and through which his architectural research was made. Many tests were made with the support of this machine: writing, programming, calculating, rendering and so on.

STRUCTURE OF THE CHAPTERS

In each chapter, the author has tried to answer some of the previous questions. In the second chapter, he attempts to describe illegal housing in Lisbon using a discursive and a verbal description. He uses different methods to support that description. Portuguese and English literatures are his main sources. Direct surveys in the field are also used and a bit of his personal experience, too. The universe of illegal housing in Lisbon is complex and a single study cannot encapsulate knowledge of the whole phenomenon: only a fragmentary part of this reality is represented here. The author has also tried to describe in the later parts, why he chose this particular subject, and he tried to display user's needs and their cultural backgrounds.

In the third chapter, he describes the importance of representation in the field of architecture. Both novel and traditional representational elements are analyzed. Yet, the author illustrates that the use of computation in design should derive from the will of the designer.

In the fourth section, he describes the computational frameworks he has been using, and justifies why he chose shape grammars. Particularly he discusses why he thinks shape grammars better satisfy the representation qualities he is pursuing.

In the following chapter, he defines the ground of shape grammars in order to describe, formally, the illegal housing described in the second chapter. In this section the author attempts to join the topological and geometrical (or metric) aspects of the house. As for the last chapter, in conclusion he speculates about the shifts a defined computational tool might need if we want to apply it to different goals.

Six appendixes are presented at the end of his work. They are related with complementary studies that support the main line of his investigation.

SOME DEFINITIONS

As the author will use some words persistently during throughout this document, it seems important to here describe what meanings they have in this working context.

Body -This is the entire physical structure of an organism, especially an animal or human being, but in architecture it can be both related with the body that is encapsulated in the space or with the architecture body. The author once thought that the body was of decisive importance in the building of these houses. He has realized, in the meantime, that the body was a fringe issue related primarily to instances when people built attachments from the main house until the borders of their lots. Those spaces are now delaying the legalization of the settlements.

Cell - Any small compartment; as in "the cells of a honeycomb", meaning the basic structural and functional unit of all organisms. As cells may exist as independent units of life, as in monads, or may form colonies or tissues as in higher plants, Architects have utilized this metaphor as a powerful tool for design. For Le Corbusier houses had biological properties.

Description - This word describes a statement that represents something in words or in images. The better description is the one that allows a better testing of the thing that is represented. Types of descriptions also depend upon related goals.

Dream house – This term describes the house that homeowners wanted and had the possibility to obtain. A dream house is conceived of or imagined as a perfect house. Therefore, a perfect house is one that is already defined. It corresponds to a collection of objects, some of them are spaces and most of them are boundaries. William Mitchell argued that houses should close both architect and user: *The dream is that new houses could be designed and built in a completely different way – a way that puts the responsibility for design not just on architects but on the people who will buy the dwellings and live in them.* This would prevent the results of this illegal housing.

Geometry - In this context he uses the word both in the analytical and graphical sense: as something that we see and which the machine might calculate. There is a relation between both uses of the term. He uses the word geometry in opposition to topology. Geometry in this case being the study of the properties, measurement, and relationships of points, lines, angles, surfaces, and solids: i.e., the parts that we can see. On the contrary, topology is related only with relationships of points in the space. The word of geometry, in this context, has the same interpretation as that of Le Corbusier'. He called structure that which is in opposition with the biological characteristics of the house.

Illegal - In this context, he could use another word, which pretends to mean almost the same thing: informal, which designates illegal procedures that were tolerated by the state, for different reasons.

Informal – Another word used in place of 'illegal'. Without any formal or informal agreement, illegal housing was tolerated. Since 1995, Municipal authorities are legalizing these houses with the commitment of the owners. For example in 2004 the Municipal Authorities of Loures reported 180 illegal quarters almost legalized.

Rules - This word is used in different contexts: grammar rules, code rules and building rules. The word 'rules' represents decisions that can change over time. For Le Corbusier rules are important to follow until they become useless to us.

Topology - This is the study of geometric figure properties, including solids, which do not changed by homeomorphism, such as stretching or bending. Nevertheless, the meaning that the author prefers, in this context, is an old one that says: *The art of, or method for, assisting the memory by associating the thing or subject to be remembered with some place,* (Webster's dictionary 1913 edition). For his work, this definition fits well, and corresponds to the signs and symbols that people loaded and brought to the city through architectural shapes.

The term is used to describe space qualities, which cannot be described by topography, i.e., social, economical, spatial or phenomenological interactions. Relating topology and architecture Giuseppa di Christina (2002) stated: *Architectural topology means the dynamic variation of form facilitated by computer-based technologies, computer-assisted design and animation software. The topologising of architectural form according to dynamic and complex configurations leads architectural design to a renewed and often spectacular plasticity, in the wake of the baroque and of organic expressionism.*

Unpredictable - This term could also be defined as 'emergent'. Usually in this and related research, both 'unpredictable' and 'emergent' are terms related to expectations that the computer alone can produce the unexpected; i.e., as we introduce things, computer feedback is completely unpredictable.

Verbal - Author has defined this word in terms of descriptive knowledge, which includes image symbols. The definition made by Knight and Stiny (2001) and its opposite, the visual, is used here.

SUMMARY

This introductory chapter is intended to describe goals and processes that are applied to this work. It serves only to introduce and to clarify: to point out his motivations, and the information which supports this investigation. Correlating issues of research and related discussions are also mentioned herein and representation is cited as an important and key issue.

2 A Study of the Illegal Housing of Lisbon

Buildings and cities symbolize and embody culture, make evident its traditions, its history, imply its future. They externalize, reify personal feelings, ideas and beliefs. They tell about themselves, their materials, their assembly, they comment on themselves, their truthfulness; they speak to the history of similar building and of architectural aspiration. Buildings are expressive!

William Porter (2001)

Introduction

This chapter aims to examine the morphology aspects of the illegal housing built in the Metropolitan Area of Lisbon between 1974 and 1984. This chapter supports the search for grammar syntax of the houses. This analysis puts in confrontation the concept of dream houses assumed by the owners and the state response to the problem during the same period along with the measures applied against this phenomenon. It is also describes why this illegal housing is different from other illegal situations.

Architects usually ignore the illegal housing sample as it lacks quality and includes a deliberated dose of bad taste. However, this author believes that under this illegal housing mask, aspects of human behavior and design solutions may be found that could have some interest for architectural practice and research.

The reported period occurs between 1974 and 1984, during which many state regulations were made to prevent the illegal housing phenomenon. In 1974, Portugal's dictatorship ended and a time of excited social and political turbulence started. Only in 1984, a law was drawn to address illegal housing, which stopped the phenomenon, though not completely. Other social and economic aspects, such as decreasing stress in the region in question, forced the ending of illegal constructions.

The actors in this illegal housing phenomenon are many: the state, the speculator and the homeowner all share some part of responsibility for the illegal results. This research, however, focuses primarily on the homeowner's role in illegal housing. In the process of this work, it was hard to find a homeowner that does not describe his house as a dream house, despite all contradictions. It was interesting as a designer to understand this human behavior.

Housing shortages are a persisting and well-known issue; Frederick Engels discussed it in his work, *The Housing Question*, of 1872. Housing shortages in Engels time were related with an influx mass of rural workers, suddenly drawn into big towns, which had developed into industrial centers. Accordingly to Engels the housing shortage was a problem generated by the rising capitalism. In his work, Frederick Engels confronted the Proudhon perspective, which states that houses should be owned by the user, rent would be abolished because was immoral, even though, the value of the rent should transform tenants into purchasers. One can see an implementation of that idea in the illegal housing phenomenon. Engels' study focuses on houses that were built on owner's lands saying this process negatively alters the political position of people. Manuel Castells views are in accordance with

Engels as both see this solution as a stake for the people (Castells, 1976). Others see it in a shared perspective with the violated owners, as a way for the people to become a part of the capitalist system. Therefore, in terms of popular perception the choice and election of right wing Municipal Authority representatives is clearly understood. A study by John L. Gilderbloom (1995) elucidates this point for the U.S. scenario:

Today in the U.S. homeownership has a consistent and important impact on political participation (voting) but not political attitudes. Maintaining political attitudes requires a psychological commitment to a set of interrelated ideas and values formulated over an extended time period. Because they are transitional and move frequently, tenants vote less and become less engaged in political issues. Adherence to a set of political attitudes is not substantially affected by homeownership, but apparently by demographic and personal variables (education, age, religion).

LOCATION OF THE SETTLEMENTS

Although these clandestine phenomena crossed all over the country, the problem of illegal housing was most acute in the Metropolitan Area of Lisbon. Lisbon is the capital of Portugal, implanted on the North bank of Tagus River. Due to its geographic location, many industries settled there. The illegal housing problem described evolved during a time and a response by poor population in an attempt to solve their own housing shortage problem. The same phenomena later evolved in the middle class as they sought second residences near the seaside.

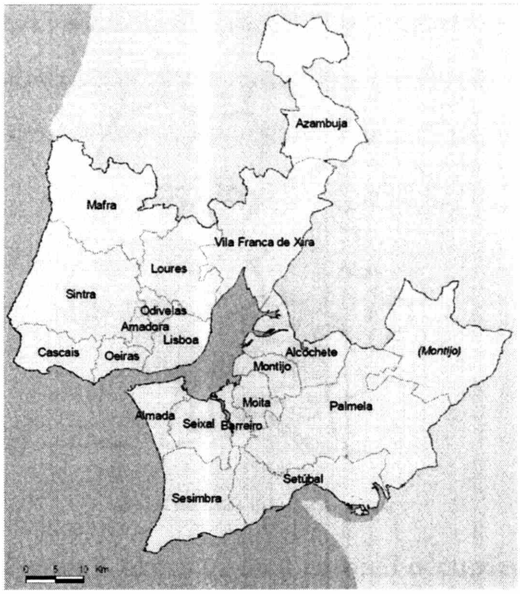


Figure 2 Metropolitan Area of Lisbon 2004*

As we may see in the figure 2, the Metropolitan Area of Lisbon is composed by the North Councils and the Southern ones. While the North Councils comprised places of primary residences, second residences were constructed on the left bank of the River, in order to be closer to the beaches.

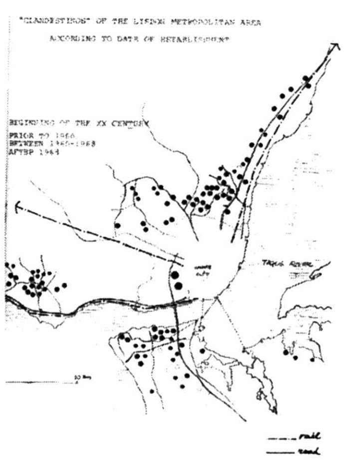


Figure 3 Importance of roads and railway *

In the Figure 3, the importance of roads and railroads in the implementation of the illegal settlements can be seen. In Figure 4, we can see how much land in each council was occupied by these illegal settlements.

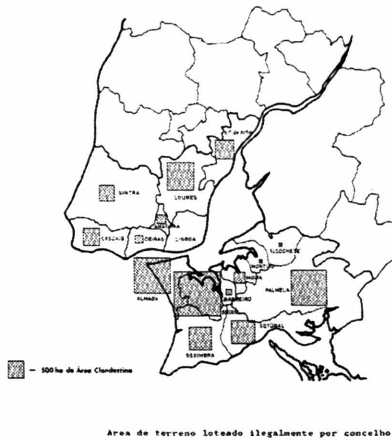


Figure 4 Areas in each council occupied by these housing districts *

In the following pictures, the three administrative Councils influence, including Cascais, Almada and Seixal respectively, illustrate the amount of occupied land in proportional terms. Another aspect that can be seen in this figure is the distance from these quarters to the administrative centers of the council, marked with a red circle.

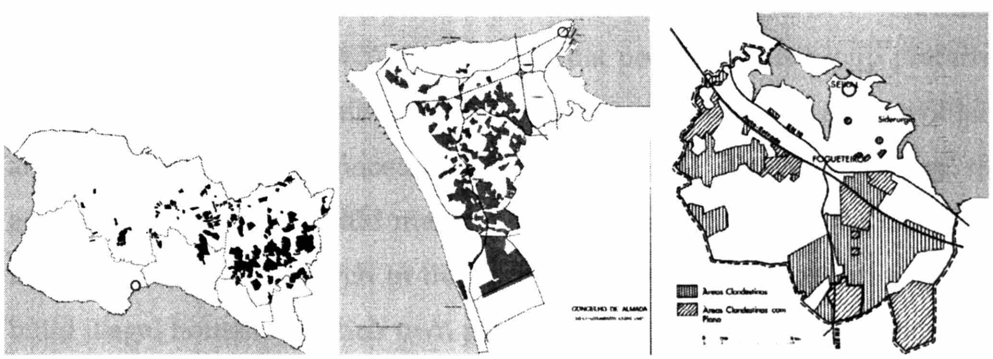


Figure 5 Area of implantation and the distance from the administrative center.

We can conclude then, the following characteristics of illegal housing as deduced from the above figures and data: Illegal housing is constructed around the city of Lisbon, closer to the network of transportation, away from the administrative council center, with enormous areas of implementation and near to the beaches in particular second residence situations. We also know that these last second residence situations appeared only in the last years of the illegal housing phenomenon.

BACKGROUND

Due to worldwide economic conditions, big cities such as Lisbon and Porto grew quicker in the early 60's than state authorities expected. The city of Lisbon and its neighborhoods suffered most from illegal housing constructions. The lack of state decisions enabled this phenomenon to occur as a unique answer to a huge housing shortfall. The actors of this performance crossed different groups in society, yet the most prevalent were the poor class that had no economic support to buy or rent a house in the legal market. If the phenomenon before 1974 revolution was undersized, after the fall of the government, it exploded rapidly.

Despite of the common sense reasons for illegal housing phenomenon, some authors argued that people refused state housing alternatives because they disliked them (Ferreira 1985). It is argued that people in this group preferred sanitary conditions and failing building code in order to own a piece of land and detached houses. Choosing the latter over the state's proffering, this group of homeowners could make their own decisions about the designs of their lived spaces. Research in this area also states that those who chose to build illegal houses had their own paradigms which mixed the homeowner's rural background insights (Rodrigues, 1989) with their desire to become members of the city, but without destroying the city. For all the illegal housing cases, the constructing homeowners fulfilled a dream; they designed and built their homes as they wished in such conditions that no one could take them away. The permanence of these constructions made this solution a non-standard type of illegal housing.

THE CARNATION REVOLUTION OF APRIL 25TH 1974

As the dictatorship was unable to find a solution for the housing shortage, the informal alternative of illegal housing was tolerated. The same conditions followed the new political forces of democracy as they entered government positions as well. At the beginning, it was thought that state had all the formulas to solve the problem, but they soon realized they were wrong and the state gave space for private entities to solve a problem of their own.

This revolutionary period in Portugal happened in parallel with other worldwide changes. In the other parts of the world, the welfare state was being reformulated, and so the social housing solutions. Meanwhile, Portugal was the first European country to introduce the right to housing in its constitution (1976).

...

Article number 65

1. *All have right, for itself and its family, to a habitation of adjusted dimension, in conditions of hygiene and comfort and that it preserves the personal privacy and the familiar privacy.*

...

Yet, in 1974, nearly 30% of all population lacked minimally decent housing (1970 census). The provisory governments that followed the revolution did not have enough aptitude to solve this problem. Over the following ten years, the country had a very special political and social environment: people openly assumed their rights and the power was almost on the streets (Guerra, 1988). As household economic improvements occurred, everyone started to look for an affordable housing solution.

AFTER 1984

Since 1984, illegal settlements are called AUGIs, which stands for "Área Urbanas de Génese Ilegal"- Urban Quarters of Illegal Genesis. AUGIs are considered *the building or sets of contiguous building that, without the competent permit of land division, when legally demanded, have suffered of a physical operation of land division towards construction until the date of the Decree n ° 400/84, of 31 of December*. Ultimately the state accepted the AUGI phenomenon as it could not stop it by primitive repressive measures or otherwise. Beyond passive acceptance however, respective municipal plans for the territory (PMOT), classified these illegal developments as urban or urban development areas. The PMOT code allowed for the initiating process of legalization for all of those formerly illegal houses. However, the process of legalization was not always eagerly embraced by homeowners, as it is too time-consuming and expensive for some users.

Nevertheless, introducing the AUGIs code did not immediately clear up the illegal housing problem. On June 20th 2002, a major Lisbon newspaper reported what it saw as the last drop of this illegal occurrence: it was a code, to be implemented in August of 2004, which prevented public deeds without the certificate and approval of the Local Authorities. The implementation date was valid in all areas except in the Autonomic Regions, such as Azores, where the application of the law started only 15 days after the date of implementation on the continent. To get around the law, speculators managed to take advantage of this fortnight delay to make public deeds of Lisbon land in Terceira Island, Azores. According to the newspaper, 339 deeds had been made by the June 20th, 2002 printing. The illegal housing phenomenon, which started with a small and local speculator, reached its end with the implication of big enterprises.

Nevertheless, during the 10 year period in question, there was an important reason to stop the course of illegal home construction: as the population gently decreased, stress on the lands vanished. As we can see from the chart the need for houses slowed over time. On the other hand, stress over the land in the last years of this period shifted toward beach areas in the South council. Therefore, although the practice started as a means of ensuring shelters for families, over time and changes to the motivation for illegal housing, societal tolerance for the illegal housing market shortened.

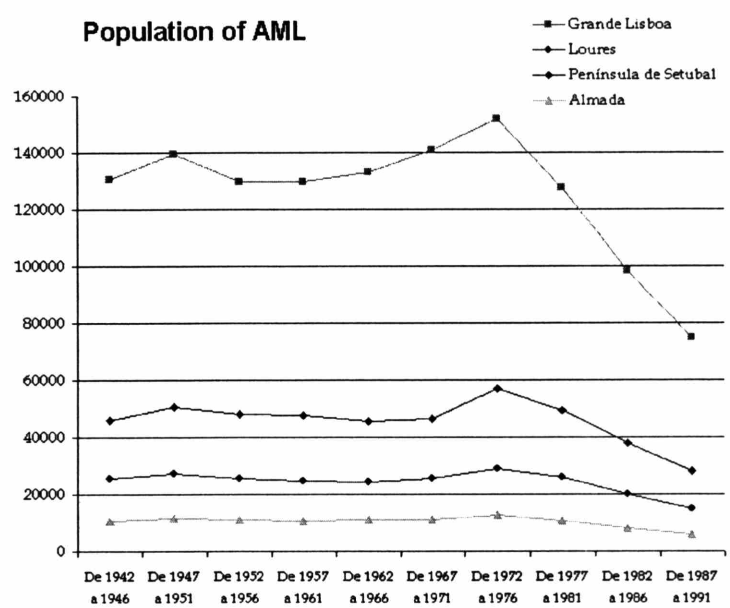


Figure 6 Population decreased in AML (INE)

HOMEOWNERS

The following is a description of illegal housing owner characteristics, taken from investigations made in the first years of the phenomenon. For the most part, illegal housing owners were born in a small rural village, where they worked at rural tasks. At the time of the survey and their move, they then began work as masons or clerks; they had a defined model of property and a model of habitat. They have a low education degree, and they married with someone of the same village or with a similar background. Homeowner's aspired to possess a lot of land, to have a familiar habitat and to keep the feel and habits of their previous rural environment, many houses have yards.

For João Farinha these illegal homeowners surpassed the psychological characteristics of poverty groups, which are: despair feelings, fatalism and lack of faith in the future; lack of confidence in self-capacities and inferiority feelings; low degree of literacy, education and professional capacity; isolation from general society and non-participation in social organizations. In general, homeowners have a strong self-esteem, when compared with those who are living in state dwellings solutions. These homeowners, in particular, feel they are completely integrated in society, as Proudhon predicted, by asserting that home users should become homeowners in order to solve the housing shortage problem.

In addition, these illegal homeowners carried a set of diverse 'dream home' references, usually made up of past and rural experiences, along with other references for future well-being. The translation of these dreams, and their geometric configuration, into reality differed in regard to the homeowner's economic constrains. The house of his dreams was, however, materialized with the aid of a small community who shared similar dreams, including neighbors and mainly relatives. Friendship ties were fortified in this act of collective materialization. Official rules were accepted or rejected in accordance with personal evaluations and in accord with the ideas of the small community involved: ultimately, only the rules that interested the homeowners were used.

Each homeowner proceeded differently throughout the time of the illegal housing phenomenon, and his results depended on the social and economic politics of the country. First between 1969 and 1970, future homeowners had to bribe the agents of the state to build their houses. They bought out of sight plots and called this period the "heroic times of clandestine". From recent and past contact with these owners, author may say that this "clandestine" case was a course in process: over time the reasons, motivations and the needs that had originally determined the phenomenon evolved. The people involved have changed their individual and social identity positions, and the characteristics of the people themselves have evolved with experience. Getting a home for the family made people more confident and successful.

In the second stage of legalization procedure, there was a liberalization policy, and if homeowners worked in groups they realized they could build their houses with fewer restrictions. Moreover, the last phase of illegal construction, lasting since 1974 when authority was nonexistent, and when potential homeowners had better incomes, enabled users to build their houses without any constraint: they did what they wanted to do. Additionally, as Local Authorities started to try to legalize some of the illegal settlements, the illegal homeowners started to have more confidence.

These illegal homeowners never thought of solving the problem by applying to social public housing. That was a solution for others. They interacted with different nets of solidarity, which they preferred, starting with groups of neighbors (Comissões de Moradores), which would later become home owner associations. These illegal homeowners also had solidarity, as they say, with the construction materials reseller, and especially with land speculators. While for the municipal authorities the speculator was the source of the illegal housing evil, for many home users he was a very nice fellow. Many homeowners were able to pay these speculators for their lots over the years.

ILLEGALITY OR INFORMALITY

The houses under study are illegal because they lack land division permits. While it was legal to for many co-owners to buy this same land for rural purposes, in illegal housing circumstances, rural land becomes urban land without the authorization of the state. The process began illegal when people physically divided the land by putting in markers, streets, walls and buildings. The public deeds for this land, however, were accepted in spite of the speculated illegalities; everybody knew the land was not for agriculture purposes.

These settlements can be compared with other methods of illegal housing. We can roughly say that there were two housing types: informal settlements and shantytowns. In the first, homeowners purchase their plots from a speculator, while both knowingly commit a code violation. The second group made of shanty builders, occupied land of private or state ownership. While the first group builds houses with good materials, the second one builds with light and perishable materials. While shantytowns grow inside big cities, near business regions; informal housing occurred, in this case, far away from the city. Both informal housing and shanty phenomena lack structured urban conditions such as clean water supplies, sanitation, and solid waste systems.

The illegal settlements in our study grew on the periphery of the big city of Lisbon and on the neighborhood of councils, where land was low-cost and distant from big population nucleus, in places that could not be easily seen by authorities, and where the jurisdiction of local authorities was in a limbo. Before 1973, plots of land were bought next to villages, in the traditional way of urban centre growth. This land was usually located on a side road, on the outskirts of a little village. Yet the stress to occupy such land grew too high and such purchases have since been forbidden.

Comparing illegal housing in Lisbon

	materials	spontoneous	land owner	Location	sublent	infraetrutures	geometry of the settlem	regulations	possible legalization	examples	international examples
Illegal settlements, clandestinos	good	yes	yes	periphery of the city close roads	yes	no	1) align with the road, 2) almost a grid	almost	yes	Unhos,Loures, Portugal	
Shacks or shanty towns, bairros de lata	bad	yes	no	inside the city	yes	no	chaotic, random	no	no	Casal Ventose, Lisbon	Favelas, Rio de Janeiro, Brazil

Figure 7 Comparing two types of illegal housing

REGULATIONS AND LAND DIVISION

The houses in this study were designed and built with future legalization in mind. Actually, over 20% of the settlements in this area are legalized now. Consequently, designs were made according to regulation code with the accordance of the users. Masons and draftsmen were aware of the regulation guidelines. Houses were built with good materials and to last. Later some users occupied the remaining space of the lot, but these attached constructions illegalized the houses as well and today, the process of legalization is more difficult due to those situations. Until 1973 the slow process of urban growing allowed small detachments of land in the limits of the city and villages. The dichotomy between rural and urban dynamics was slow developing, therefore rural land become urban by detaching large and small rural lots around the outskirts of towns without affecting regular growth. Urban infrastructures were supported by the extension of previous infrastructure. This process ran quite well for all towns except for Lisbon and Porto. After 1973, this traditional method for detaching land stopped. The stress on the urban land in Porto and Lisbon was huge. Local authorities were not prepared to answer the resultant housing demands. Tools for supporting a rapid growth did not exist. The state's answer was an attempt to prevent land division. The state was betting that private sector of construction would propose strategies to development of the population nuclei lawfully, though this did not happen.

The legal process of land division, the transformation of rural land into urban, are defined by Teresa Heitor (c1994) in two steps. First, local authorities should elaborate plans of urban expansion for localities and submit them to a Central Administration. After approval, private and public housing promoters should submit their plans for housing. After approval and consolidation of terrain with all urban services, the land can be finally divided. Outside the limits of state plans, building is allowed, but promoters must support the cost for urban infrastructures.

Private promoters found a better way to solve the problem using the informal tool. They claimed that the bureaucracy of the authorities and resultant delays cause them to lose money. After 1973, in order to divide land for rural purpose without need for any authorization from Local Authorities, the divided land needed to consist of at least five thousands square meters of area. This lot, with 5000 sm. or more, was then divided and sold to co-buyers. Marks on the land were made to check that subdivision, tough later such markers were forbidden local authorities. To overcome this restriction, co-buyers started to plant orange trees, etc in order to subdivide the land anyway.

In conclusion, first, land was divided into small plots, from the outskirts of various towns. This was the traditional way of a natural urban growth. After 1973, it was forbidden land subdivisions into small lots without a Local Authorities permits. The smallest subdivision allowed in an area greater than five square meters was for agriculture purposes. People started to subdivide land into, more or less, five hundreds square meters in an informal way. Each one was a co-buyer of the land. This method was in effect until a new regulation was published. To control this phenomenon, state and local authorities started to work together with owners to legalize houses. Owners were required to commit to solve the problems that a neighborhood could have in terms of streets and alignments. In the end these measures had a reverse result.

The legislation regarding clandestine settlements flowed as follows. The Decree-Lei nº 278/71, 1971, proposed regulation to demolish some clandestine houses. Yet, in the same year the Decree-Lei nº 560/71, stated that local authorities should proceed with the design of plan proposals for main and secondary towns in the council, though not in the entire territory - this could explain why illegal settlement occurred far from urban areas. In addition, the Decree nº 561/71 required techniques that obey the general and partial plans of urbanization and plans of detail. Then in 1973, the Decree-Lei nº 289/73 promoted radical alterations to the process of land division, though it was later revoked by the Decree-Lei nº 400/84. Illegal housing started to be located outside the range of the code law of 1971. In 1976 the Decree-Lei nº 804/76, and the Decree-Lei nº 275/76, once again defined measures against these settlements. Decree-Lei nº 90/77 improved the 804/76 decree. The Decree-Lei nº 208/82, 1982 defines the prescribed picture of the plain municipal directors. Decree-Lei nº 100/84, of 1984, revises the Lei nº 79/77, seeking an update and reinforcement of attributions from local autarchies and the respective abilities of each agency.

Figure 8 these are the schematic drawings given to users by the speculators

Following code regulations partition of land should proceed in this order: from subdivision, to infrastructure and construction. Yet, the informal process had a different order: subdivision, construction and infrastructures.

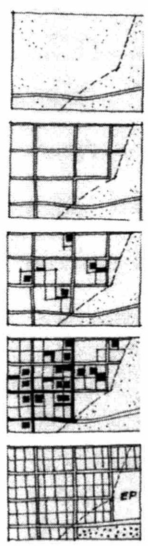


Figure 9* this image shows a land crossed by a road and the implementation of illegal quarters.

The division made by the speculator defined the quarter. From an area of land equal or greater than 5000 square meters, he sold plots with an area from 100 square meters up to 5000. Usually the plots had four categories in terms of area: 100 to 300, 500, 1000, and 5000 square meters.

The informal process simplified the task of the promoter/speculator. He sold rural land to co-owners through public deeds, sometimes he also gave a diagram for land division where lots were numbers and his job stopped. Ultimately the implementations of urban infrastructures within these plots and for the relevant houses were now solely the owner's responsibility.

At this stage, after land acquisition, the informal process had roughly three distinct steps in terms of implantation: allotment, building the main house and the attachment spaces in the remaining lot space. Sometimes these small attachments were introduced first. They were the first shelters for the family involved.

In brief, the characterizations of the Informal settlements were the following:

1. An adapted orthogonal grid to the limits of the register in cadastre of a detached land
2. The topography of the land was not taken in account
3. The occupation was maximized to fit the best number of lots
4. They were located on the border of the council administrative limits

In the chapter on computer representation, the author attempts to explain this division of land by formal means.

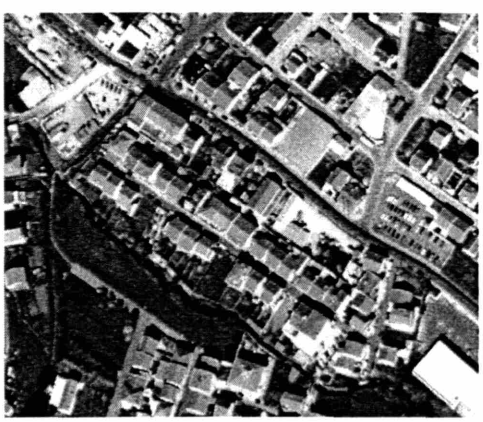


Figure 10 this image illustrates the previous schema*

Over time divisions of the lots have evolved to other divisions. Despite the smallness of each lot, they were still further divided in two ways: dividing on the ground or dividing by different levels of the house.

Most commonly, a house is built in the lot

The house is semi-detached

A first shelter is built only later the house is built

The house is built first and later small shelters are added

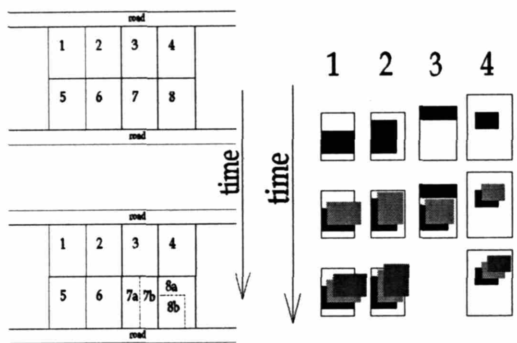


Figure 11 Subdivisions is done on the lot and on the house

It is possible to deduce from this phenomenon that the informal housing in question is a progressive self-help housing which worked fairly well. According to the text of Laboratório Nacional de Engenharia Civil (LNEC), this style of construction is a system based on simple rules of design and building which are able to assure a first phase of implantation. The illegal houses are, however, designed in a way that does not prevent qualitative evolution in the area as a whole and within individual houses in stride with the socio-cultural evolution of the home users. Phases of this evolution could be introduced by homeowners either by self-construction or with the help of small contractors. Yet a true lack of land reaps one of negatives aspects of this solution. However, doing a final balance at this time, it seems easy to understand why a controlled solution, such as this, would be better then accepting the AUGIs, as the state has done since 1995.

THE HOUSES

The illegal houses described above were representations, idealized by their owners. Depending on their budget, a metric evaluation resulted upon the application of the symbolic elements that they carry in mind. The formal characteristics of the houses came from the vernacular references of the user. The materials that were chosen were the easiest to get. For José Manuel Fernandes (1998) there are no other differences between the vernacular architecture except the materials. However, we could not find topological similarities between vernacular examples and these. A small collection of images of vernacular buildings can be seen at Appendix C. Fernandes adds that to make distinctions from others illegal home owners used an excess of decoration. He also stated that homeowners, for instance, modeled a house on the Costa do Sol. The other reference that he saw was in the house of Raul Lino, an archetype of the Portuguese house, with many small roofs. It was easy to reproduce and gracious. It become of the paradigm of a dream house.

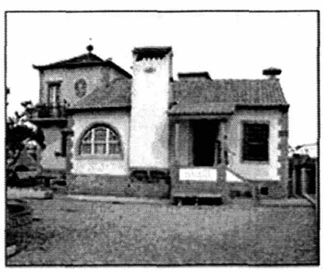


Figure 12 A house of Raul Lino

The process of building these illegal settlements was similar to steps used to construct progressive housing. During the specified, researched time, people were building depending on their needs and economic capacities. For João Farinha (1983) this type of housing could well be supported by the state.

So that self-help can be an alternative to produce more and better housing at lower costs, and having an extremely positive impact in the fight against poverty, it is not enough that governments and responsible entities leave behind the lower classes to *their own luck – as it happens in Portugal and in undeveloped countries were illegal quarters, beyond the degraded life conditions, are the reflex of initiative and of self-determination sense of lower classes. It is necessary to give professional support and to guarantee the access to possible financial resources and to land duly urbanized and free of speculation.*

However, user perceptions and aspirations changed during the process of taking in city life, via exposure to cross-cultural influences, including the media and telecommunications. In this way, affordable novelties and appliances, such as cars, color TV, and VCRs, became necessities. Meanwhile these same users maintained their traditional rural gestures by raising poultry and maintaining some rural land.

The media plays a strong role in enabling users to formalize models of reference. Market messages from new housing models, like luxury villas, provided the owners of the illegal housing in question with models for standards of designs and aesthetic references. Therefore, monetary gains made by renting units of the house emerged as short term goals. Homeowners with renting in mind managed a good articulation of the space to ensure different degrees of privacy.

Homeowners previewed prototypical layouts when they built their house. Each house was built with a reinforced concrete frame with concrete infill, and most of houses use a structural system. A staircase, when conveniently located, often provided access to other independent flats, for current or future use.

Topologically everything from their dream house formalization is in these illegal homes, although it is in smaller format. Most of the time, homeowners do not even use the formalized dream space because it is meant only for show. The space they use in fact is the kitchen, as this room corresponds to memories brought from rural environments when and where families gathered around the fire.

In response to the housing shortage, the State and various architectural initiatives produced flats, and some terraced. These initiates were usually formulated around an idea of community housing, wherein people could share many housing services together. Yet many rural people were not prepared to this type of housing. In fact, state residential areas characterized by the predominance of social and/or public multi-storey buildings, lack basic services and generally function as something other than a residence, with serious economic, social, and crime problems, along with a progressive deterioration of the public housing settlements in the absence of integrated maintenance program.

The example that follows is typical of the illegal housing built to avoid such state initiates as mentioned above. Most illegal structures were two stories high, and the ground floor is designed for garage and storage. The stairs are inside the building. From a topological point of view, such houses are not reminiscent of rural houses in villages.

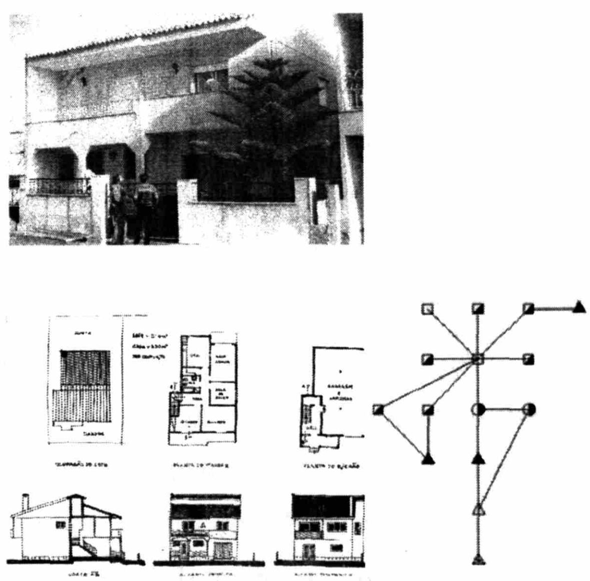


Figure 13 These images show one of the houses and its topological scheme

The space of vernacular houses, by comparison, was not as hierarchically distributed.

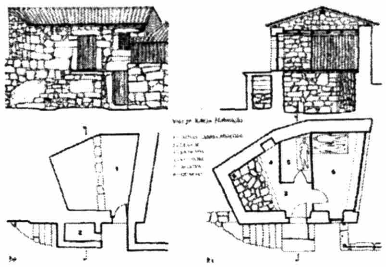


Figure 14 A vernacular house in the North of Portugal

Homeowners seemed to know exactly what they wanted. Clare Cooper (c1995) described the imagination of many people. The houses that they have built are rural and urban symbols that were adapted to their lives, but only in terms of geometric issues, as topological aspects are different.

THE STATE APPROACH

In the final remarks of a 1960 meeting, promoted by the state to address the housing shortage, we can see that the central administration had a good understanding of the problem. This meeting produced a document containing a good analysis of the situation and a list of significant measures to be taken toward solutions. Solutions for the problem were divided into six topics which expressed ideas and processes for overcoming the housing shortage for that moment and for thirty years into the future. Responsibility for the depleting housing scenario, in the social and economic development aspects was given to the state. It was deemed that the resolution of the shortage should be solved in accordance with the economic status of each family. Second, to the organizers, only the integration of the house in the urban plan made sense and the authors of the report foresaw a need to apply a set of urban rules. Third, it was said that the state should control speculation and land policies. Fourth, economic funds for housing should result from people's needs. Fifth, the group agreed that a process to control the building and the construction industry was necessary. To conclude, efforts on the part of the state institution, to control the previous shortages and to sort through different interventions from the central administration and the local authorities, were made. The resultant ideas helped found and implement a state institution created some months earlier, called the "Fundo de Fomento da Habitação" or Housing Promotion Fund, (FFH). Unfortunately, all research and Portuguese literature agrees that the state took insufficient initiatives to meet the above goals. Instead, too much expectation was put on private initiative.

Margarida Sousa Lobo stated that the informal house offer was part of the global solution for housing shortages. The state did not have other way to solve it (LOBO 1975).

The proper explosion of "the clandestine" construction lays as it known to a large extent in solidarity nets that facilitate the credit, the work, the helping, and the organization of the population in common shares, as well as it favours the multiactivity and the development of diverse forms of sociability of the one in the urban formal fabric.

Local Authorities failed to control the informal market and this failure promoted several economic effects, including further speculation on the land and an accelerated densification of the existing urbanized zones. The proliferation of informal settlements through fringe developing and leapfrogging was insupportable, and the legal market corresponded only to one quarter of annual offer of housing (DEGOT 1989).

A lack of state planning, for different reasons, allowed this phenomenon to become huge and more difficult to handle. After the Revolution, local authorities could not do much. The new elected people could not handle, by that time, the problem of illegal houses. Only by 1977/78, the government promoted a survey for the entire national territory. They needed to know how big the problem was. A congress 1981 was also formulated to discuss the problem. Meanwhile, Maria Clara Mendes (Mendes 1990), predicted for the future of the Portuguese urbanism, the same context that allowed the existence of illegal housing: including the same technical and economic constraints, absence of urban knowledge, and a lack of bases for decision of the elected people.

SAAL UNIQUENESS

The state took some actions taken by the "sounds" of the revolution. i.e. due to the shortage of housing and euphoric revolutionary period the state took quick measures to go against the illegal occupations of private and state houses by the people who by that time lived in shantytowns. The SAAL–Serviço Ambulatório de Apoio Local (An Itinerant Service for a Local Support Program) was created on the August 6, 1974, as a special brigade of the FFH. The main responsibility for this service fell to Nuno Portas, one architect that then held the position of a Secretary of State, (a position just below a minister in Portugal). A nationwide program included all shantytowns and rundown areas in all major urban areas (DOWNS 1983). The goals were to recover and legalize the illegal housing all over the country, including the Lisbon area. The services strategies, however, were outdated. In the opinion of Portas (Portas 1993), there was a conflict between the applied measures and the aspirations of users. If in the 20s some people thought that everybody should have had the same type of house, the same kitchen, and the same habits, by 1974, users did not think that way. By that time, 1974, the hierarchy in the territory vanished. Many statements of the Athena Letter of 1933 (ICMA) or of the International Style that architects by 1974 had in mind as urban and architectonic references, were questioned. Many post-war housing state solutions had failed in other countries of Europe. In a time of transition there was no a straightforward path to follow.

The main goal of SAAL was described as: *its purpose was to get support from municipal administrations for initiatives in favour of people living in bad housing conditions, through collaboration in the transformation of their livings areas, by investing theirs own latent resources and also, if necessary, monetary ones too.* However, involved groups realized there were some contradictions on this program. Alexandre Alves Costa (another architect of the group) said: *It acted as a part of the state apparatus identified with the people's aspiration for a change, which channels these aspirations against the state apparatus itself.*

Some controversies between elements of the group and the inhabitants were reported. The technicians had to negotiate with users, and it was not easy to confront different aesthetic visions with functional requirements. In the end, the dominant situation resulted with inhabitants who saw the technician as an ally of the power, imposing its points of view by pointing to his credentials and diplomas over and above the opinions of the inhabitants.

Kenneth Frampton (1986) reported what Alvaro Siza did in his work with the SAAL program. He said that Siza was advised against the simplistic populism of "giving the people what they want". Frampton also quoted France Valaethem saying ….to *enter the real process of participation meant to accept the conflicts and not to avoid them. These exchanges then become very rich, although hard and often difficult.*

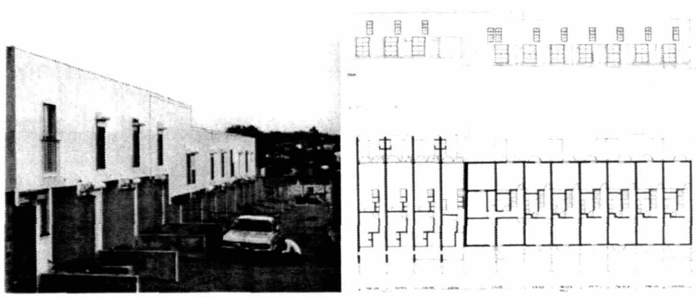


Figure 15 A project of Siza Vieira for Porto

In the end this was a very rich experience because, despite all controversy it, began a dialog between the two main agents involved in house design; the architect and the home user. Nonetheless, the SAAL operation ended abruptly in October 27th, 1976.

STRUCTURE OF THE HOUSES

The level of construction technology of these illegal houses is low. Stone of low quality is used for foundations, concrete, brick, ceramic and painting. For openings, they used aluminum in windows and wooden work for doors.

Each roof is commonly made of two slopes, but sometimes four and the roof is always made of roofing tiles. Rafters and purling are made of precast concrete beams. The garage roofs are usually of compressed fiber cement sheets or of roofing tiles.

Although they were built without a building permit, each house within those studied from the illegal schema has a general plan, which was tested by a known mason. The house was made of slab, beam and pillar concrete, and brick division walls. The slab was made of precast concrete beams. Load-bearing walls are common although some attention is given to structural design. This system is supported by a raft foundation.

A report of LNEC (1990) was made to respond to small buildings structural designs used in the illegal neighborhoods. The rules of thumb focused building on types on the following building types: masonry confined to concrete, which is constituted by sections of simple masonry bordered entirely in the perimeter by wrap and framing of concrete, solidified into masonry. The limits of implementation of these thumb rules were:

Used for housing
No more than three stories high
Distances between stories should be less than 3.20 meters
Walls are placed in two orthogonal directions
Maximal plan dimension was 20 meters in both directions

In terms of conceptual structure building must have the following properties:

1. The walls placed in main directions should have similar characteristics and being connected in a way to assure an effective gathering in the set.

2. Walls should lie in almost symmetric shape in regard to the two main directions.

3. The walls should distribute in nearly uniform way in plan and its allocation should not change between levels greatly.

The concrete border elements should be placed:

In the corners of the building

At the endpoints of wall section that are important to support

When wall intercepts and they are distant from other 1.5 meters

When distance between vertical borders are more than 5 meters

It is important to consider that vertical borders are connected with foundations.

Regarding building services the houses in this study have water distribution, sewers, and electrical installations, but poor or no thermal or sound insulation.

CONCLUSIONS

In this chapter, the morphologic characteristics of the illegal housing of the region of Lisbon built between 1974 until 1984 is described. He argues that the phenomenon could be prevented if the state had a framework that could use concepts such as self-building in a practical manner.

We also see herein that illegal housing pattern is different from state solutions. Houses designs corresponded to symbolic references that homeowners brought from rural background, even as much was taken from urban references as users desired to become part of the city.

Finally, he hopes he have shown that the state and architects on one hand and homeowners, on the other hand, have need for further dialog to handle the problems of illegal housing.

SUMMARY

In this chapter, the object of study and its social framework have been described. The alternatives given by the state were also presented. Differences between dream houses, and housing provided by the state were described. In this context, dream houses were designed and built by the homeowners. A draughtsman transposed their dreams into paper, then family and friends built the house. The design of these houses was a mix of the draughtsman taste and the taste of the owner and their friends. In the end, when the homeowners found that the space they'd built was not good enough they made their own convenient alterations.

The house worked as a symbol of the inhabitants self. Yet additional and outside support for the user is required to help him/her make the best decisions. The state could have a more fundamental role in this. This entire situation is far from being solved. Negative aspects of this housing solution remain and most of the houses are not legalized yet. There are many quarters that municipalities will never accept for legalization.

This chapter details a complex situation that architects should discuss to deal with the required complexity. A framework to support information for house design is proposed. The involved factors are many, including the existent structures and the user, with all his/her idiosyncrasies. Although we can define a hierarchical approach, the subsidiary contribution in terms of network relationship will also be explored.

3 REPRESENTATION

It is necessary to study the methodological unit in design. Researches on phenomenological field methods may help to create a unit method in order to respond to our plurality and universality society. It is not the same goal of the international style that become academic and mercantilist attitude. The goal is to overcome specialization sectarianism, and social and cultural boundaries towards a more global envision about world open to communication. There will be necessary go back and re-evaluate the foundations of design in order to define a sustain approach. Donald Preziosi (c1979)

INTRODUCTION

The goal in this chapter is to discuss representation in Architecture and its related issues in teaching. The author will use as his case study The School of Architecture at the Technical University of Lisbon over the last 10 years. This chapter serves to justify his interests in shape grammars and the reasons that drove the author to select the class of grammar of the illegal housing. Also, this chapter aims to analyze the importance of his relation with teaching, as it is different from being only a designer, in respect to design and computation backgrounds.

HOW SHAPES ARE SEEN

As a teacher of Geometry and CAD disciplines, and as an architect, the author's interests in the process of designing are particularly focused on representation, more than any other particular problem of architecture. His work on the grammar for illegal houses was built with this focus in mind.

Michelangelo Buonarroti suggested that drawings played a key role in design, though not in the same way for everybody. *The drawing, also called by the name debuxo, consists and is the source and the body of painting, sculpture, architecture, all other manners of painting and the root of all sciences Michelangelo Buonarroti (Ollanda, 1957).* The early stages of design, where drawing has a particular interest, are part of the design process that an architect cannot miss. Representation in architecture should not be confused with painting, though drawings are part of architecture representation. That is why architecture is different from other professions. However, the relation that architects have regarding shapes may have two approaches that are distinct and lead to different results, which can be used in these early stages. The text of A. Lawson is clear enough about what designers do. *... we notice that designers use words purposively to evoke and communicate subtleties of design concepts. The evocativeness of words is the key. Shön observes that experienced designers use design archetypes during their design process. These archetypes come in the form of very evocative words. Suggestions have also been made that the lack of character in built landscape is due to the insufficient vocabularies of graphically oriented designers to describe and evoke multifaceted design possibilities and emotional responses, so others who are involved in implementing their ideas cannot share their visions. (Lawson, 1997)* The author states that shapes are subordinate to words and shapes do not have enough power to be a medium of communication. However, in his point of view, most of the times designers use both languages of words and shapes simultaneously to express ideas and to develop designs.

Many authors refer strategies for shapes that have been used in visual art which can be synthesized into this expression: some grab shapes as objects with which to design, while others formulate objects from shapes. One of the authors that mentioned this different relation with shapes was Francisco d'Ollanda (1955) through the words of Michelangelo Buonarotti, when he described generic differences between the Flemish painters and the Italian ones. According to Ollanda, Michelangelo said that the Flemish drew objects back and forth to compose a painting, using landscapes, saints, and other symbolic references in opposition to what Italian painters did. Another statement that can help to illustrate this argument better is from Kurt Badt, quoted by Rudolf Arnheim in this work of (1996), regarding how impressionist and pos-impressionists painters saw shapes. As he pointed out, both strategies apply for creativity but not in the same way: *The Symbolists derived their representation of the world from individual objects; they built it around single figures, composed it of objects, in Latin: res. Their intention was that of realists, regardless of the meaning they attributed to the objects. The Impressionists proceeded from impressions of the whole, from a connexion of things, into which these things had grown and which they had created by their natural growth. ... In their conception of the world and in the intention of their art, which had the task of showing that conception, the Impressionists were naturalists (using the word nature in its original sense of nasci: being born, wanting to become, growing.) This means that there was in fact a profound difference between the two artistic tendencies. But there is no difference of rank or value between the two conceptions of reality. They are two equally good aspects of the same thing. For this reality of the world exists, in man's conception, as connexion but also as segregation because the two can be thought of and represented only in mutual relation. (Arnheim, 1996)*

One can easily accept that architects work with both verbal and graphic representations for architectonic description and also work with shapes as if they were verbal representation. The predominance of one type over the other depends on the group and individual needs. Nevertheless, the architect is seen as a professional who uses images to communicate ideas. Those images or registries have different qualities and goals. Therefore the construction or representation of those images may differ regarding the context.

THE LANGUAGE OF IMAGES

Susanne Langer and many other thinkers noticed that images or drawings convey knowledge. However not all describe shapes in the same way. Images have a language with a similar importance of text or verbal communication. For example, William M. Ivins (1964) can not describe our culture without noticing the key role graphic language has in it.

In his work he described some examples to illustrate the importance that images had in our culture. Ivins defined differences in quality between mathematic geometry and perspective geometry. He related the first with our Greek heritage and the second with a modern way to understand reality. He gave more importance to the second because it is a way of not missing part of our capacity to understand the world. The world of drawings is not only measurable; there are spatial relations that can alter the way we look at the meaning of drawings. How important can these spatial relations be for an artist? It is common to ask to a graphic artist for a definition of his work wherein he cannot give it. This lack of verbal definition cannot be seen as a lack of intelligence, as some people may accuse. Ivins stated that in spite of the difficulties we could reproduce a hand drawing in words in order to be meaningful, but in the end, we would lack part of the information encoded in the original drawing. He described the methods of engraving and photography as media to communicate particular drawings, apparently without meaning, as is now is done in computation. Any of the listed methods result in a perfect copy of the original. Therefore, the way to represent the meaning of images is by reproducing those images.

It is therefore quite clear that drawings convey knowledge that cannot be translated into words. Nothing is wrong with that. Consequentially we should understand how shapes are important to us and how we car work with them, within or without computation. Text can be used to complement the meaning of a shape, or used to represent shapes. Instead of working with shapes as measurable things, we could work with shapes with their spatial properties. We, as designers, must know how we work with shapes. Mixing shapes with semantic description, may allow a full definition of architectural shape.

Even Noam Chomsky recognizes the importance of graphic representation and the difficulty of translating their meaning to a verbal format. Below is a part of an interview where he identifies other *intellectual structures:*

...

QUESTION: Supposing linguistics could describe one such structure, would the findings apply to all our intellectual activities? Do we think only in language? Alternatively, do there exist nonlinguistic forms of thinking too?

CHOMSKY: The analysis of linguistic structures could help in understanding other intellectual structures. Now, I don't think there is any scientific evidence about the question of whether we think only in language or not. But introspection indicates pretty clearly that we don't think in language necessarily. We also think in visual images, we think in terms of situations and events, and so on, and many times we can't even express in words what the content of our thinking is. In addition, even if we are able to express it in words, it is a common experience to say something and then to recognize that it is not what we meant, that it is something else.

What does this mean? That there is a kind of nonlinguistic thought going on which we are trying to represent in language, and we know that sometimes we fail.

... Interview with Noam Chomsky (1984).

Chomsky has no doubts that images convey thoughts and knowledge, part of which cannot be translated into linguistic representation. One can wonder if same day it will be possible to translate all information between representations. Maybe this will occur; meanwhile designers have to be attentive and open to cultivate the language of drawings.

REPRESENTATION IN ARCHITECTURE

It is difficult to describe how architects create designs. The author could reproduce many ideas retrieved from studies made by architects or students of architecture where attempts were made to define or understand what happens in the process of creation. But he did not follow this route of inquiry because the process that really matters in this study is how architects deal with graphic information. And they may have different qualities due to different goals. In our disciplines of drawing, teachers appeal to students to create their own methods of expressing and thinking. However some emphasis is made on the relation between drawings and decisions.

We do not need to go back to Alberti to verify that architecture needs representation in image format. Drawings can be only descriptions, as Alberti thought, but drawing can also be stances of decision, and work as a powerful tool in design. We can look at the arguments of Pancho Guedes, a Portuguese modernist architect that was largely influenced by Picasso and other painters. He sees drawings as a continuum to support decisions when he wants to use drawings for an architectural goal.

Representation, since the Renaissance, is an important vehicle for communication, perhaps even more now than ever. Perhaps now we are on the verge of a swift as the computer is seen as one more tool to convey graphic knowledge. Eduardo Corte-Real, a former teacher of the Lisbon school, stated that an architect might even change his role and name in the near future, due to the influence of computer representation. But it was William Mitchell that drew our attention to inevitability of revaluating the realm of architecture. Alternatively, Françoise Choay, who has read

Mitchell's work, stated that now is a good moment to make another "renaissance": *Le De re aedificatoria me semble une clé susceptible de rouvrir a l'architecture d'aujourd'hui les chemins perdus de la contextualisation et l'articulation, et le rendre ainsi sa place régalienne a cet habitacle premier, le corps humain. (Choay, 1998)*

Meanwhile, architects will work with different tools of representation to draw lines, angles, planes and volumes, and some of them will work as Greek architects who described designs orally to a contractor (Spencer 2001). Augusto Pereira Brandão, another Portuguese author, said that for Alberti, architecture is a mental abstraction (Brandão, 1964). Therefore, drawings are a tool to communicate those ideas. Alberti divided the architectural design into two parts: lineament and structure. For Brandão, structure means knowledge of construction, and lineament means knowledge of representation.

Alberti proposed a separation between representation and the thing that is represented. Architects had to show skills in representation, i.e. they must reproduce representative models of the thing itself. In this context, drawings become an important way to design. The ability to draw gave power to designers. For instance, Daniel Boorstin (1992) described in his book a story wherein Giotto, to prove his capability as a painter before the Pope, drew a perfect circle by hand on a sheet of paper. In the end, after this demonstration, he was approved for the Pope's task.

The ability to reproduce reality accurately in shape has become an obsession exemplified in the development of computer games. This idea led humans to making representations so close to the object but now there are the computers doing it easily. Due to the power and amount of memory the games can now be reproduced realistically. Some years early the photograph machine was produced with its reference in the perspective system. Years before, many painters used photographic concepts to provide better insights to their paintings (Steadman, c2001). The demand for accurate representation goes now to even more abstract levels.

The power of representation is very clear to us. Drawings or models are good because they describe things with accuracy. A model is good because it may look real. It may be tested with some parameters or qualities. Manuel Tainha (1989), another Portuguese architect and teacher stated that this is why drawings are so important: they describe a correct procedure for building architecture. Comparatively, he said, conceptual drawings are dangerous. In design stages, drawings can be prejudicial. They can lie. They can lead us out of reality. Not all designers share this fear. Precisely this characteristic is often an interesting part of the drawings that should be explored.

Computer graphics are the current paradigm for the visualization of architecture. Computers can lead us to paths like those described by Marcos Novak. He calls Liquid Architecture a fluid, imaginary landscape that only exists in the digital domain (Novak, 1991). As such, it appears so easy to reach it. However, some are suspect about that apparent easiness. Without a critical attitude, nobody can use a technique or a process in order to achieve good solutions. There is a reality in those spaces we create; this is why drawings are separate somehow from what we define as architecture.

In fact, CAD programs did not bring any quality to architecture, just as drawings by hand or by traditional tools did not do so before, either. Many people are expecting that commercial architectural software, which gives us a pre-defined vocabulary of architectural shapes, may bring some improvements. In this software, portions of architecture or rules are pre-decided and transposed to allow visualization. This huge amount of graphic information has astonished architects, though they have adhered to the given vocabulary almost without criticism. One may think then that architects creating designs controlled by the construction system following Le

Corbusier' advice, are now following the design vocabulary given by commercial architectural software.

A good alternative to this uncritical acceptance could be to use in those computer implementations unique vocabulary and processes that have proved their validity in computations such as the Palladium Grammar of Mitchell and Stiny. Other good examples of this alternative exist as well.

SHAPE AND DESIGN

The introduction of computers in design studios and offices has dramatically changed the form of shapes. The complexity of shapes is now controlled by the computer. Computer also serves as a medium to translate representation of shapes that are only ideas into build possible architectonic shapes, by the introducing of software for calculus and structural analyses. Texts by Giuseppi di Christina show that architects often work as sculptors of shapes, through processes of computation. The next important step, however, is to introduce the control of architectural complexity, as stated by William Mitchell at the CADDs Future that occurred at Vienna, Austria.

Architectural topology means the dynamic variation of form facilitated by computer-based technologies, computer-assisted design and animation software. The topologising of architectural form according to dynamic and complex configurations leads architectural design to a renewed and often spectacular plasticity, in the wake of the baroque and of organic expressionism. (Christina, 2001)

Two colleagues of the School of Lisbon came out with thoughts about his uncertainty regarding shapes. Eduardo Corte-Real, in his doctoral thesis (Côrte-Real, 2001), which was about architectural drawing, described the early history of architectural drawings through the differences between Leonardo da Vinci and Michelangelo Buonarroti point of views about paintings and drawings and reality representations.

He said the first used drawings to describe and understand nature. The visual interest of Leonard was focused on descriptions of the world, when, for example, he studied the mechanics of a bird wing. Drawings were a way to reconfigure or understand the world. He painted nature because it is a fountain of beauty that was related with an acknowledgement of reality.

On other hand, the second, Michelangelo, declared that nature could not be imitated because it was a God's creation, although he stated nature was a good source for subjects. This view is justified by Jan Mukarovsky (1978) opinion: *A work of art in itself is organized intentionally, whereas a natural object, in contrast to it, lacks intentionally; its organization is accidental.*

Michelangelo stated *"a vision as a compass"* and those who can give an aesthetic measure through spatial relations of the whole and the parts have an advantage over other creators. This approach arose against a common use of Pythagoras geometric inflexibility, where every shape should be measured without any concerns for its spatial relation with others. To see or to look at drawings for him was a way of measurement. Corte-Real also made a review comparing the work of Henry Moore and Michelangelo saying: *The figures of Moore, lacking any physiognomic trace are clearly limited, they are much closed with an underneath idea. Its configurative character is stronger than Michelangelo figures, which are loaded of contradictory expressions, are more fragmented and adverse to any limit; they correspond not to ideas but to impulses. (Corte-Real 2001)*

Another colleague of mine, Jorge Spencer, stated that architectural drawings are helpful to design. Sketch drawings are powerful instruments to design architectural goals. Drawings have ambiguity enough to play with an architect's decisions, and to help him define good solutions. He replied that relations with drawings are made using heurist processes, which he could not quantify, though he did justify that they exist. Cautiously, he also said that architecture is not only represented by drawings but, drawings are very important to design at early stages. A statement that is easy to prove and to agree with.

One area in which the author do not agree with Spencer is on relation that he makes between drawings and musical notation, wherein he concludes that they are similar. The ambiguity of drawings and symbolic marks that represent notes are not the same. Early architectural sketches have qualities that architects use to create designs within a heurist process. Spencer gives examples of those characteristics of drawings. The missing rigor or rigidity of shapes gives us an ambiguity that helps us to make better decisions. He gave an example where computer drawings were plotted with "loose" pens. The irregularity of the traces embedded drawings with a lack of "accuracy" that aids ambiguity. But the author questions in what ways these drawings are different from rigid or computational shape drawings. Alternatively, how different are they from a photographic machine viewpoint? What kinds of characteristics have those hand drawings that others do not? The ambiguity that Spencer talks about is related with shapes created, more than the look of the drawings.

From the author's point of view it seems that there are two issues here: 1) a representation for shapes, with more or less accuracy, where he do not know yet what accuracy is, and 2) a relation between our eyes and hands which work to make registries of existent or non-existent space. Shapes are ambiguous in themselves. In architecture, they can have two meanings, those being the shape itself and what that shape may represent, even if both seem to be very clear to us at one time.

The other issue involved here is how we relate to drawings that give meaning to space in a particular way. For example, Pancho Guedes recently gave a lecture in the School of Architecture of Lisbon, in which he said that he has studied Le Corbusier drawings and concluded that some perspective drawings which were thought to have one vanishing point instead have two.

It seems to the author that it might be an important subject to analyze in another work, and he is not sure if an architecture sketch drawing can only be considered good when we are able to reproduce it from the camera viewpoint.

His point in the Le Corbusier case is the following: drawings or shapes in a drawing have spatial qualities that do not depend on an apparent rigidity, so ambiguity can still be seen in all types of drawings. Freehand sketches have others qualities that are different of those we make by hand when we draw something with the intent to reproduce it like a camera image. For William M. Ivins, photography (1964) becomes the norm of appearance for everything. He adds that we have even started to think with images produced by the machine.

To conclude, shape can exhibit two different behaviors; it can work as only a shape or as a symbolic shape. The first can be parsed and have different meanings, yet the symbolic shape cannot change in meaning or in shape. The ambiguity between these two behaviors can enable us to improve the final shape.

On other hand, the ambiguity of shapes seems to be greater when drawings are made by hand then in a formal drawing. It is not clear yet if this ambiguity of the hand drawings is given by a different representational system not yet described or understood.

COMPUTER PROCESSES AND APPLICATIONS

A computer is a machine that can be programmed to manipulate symbols. Computers can perform complex and repetitive procedures quickly, precisely and reliably and can quickly store and retrieve large amounts of data. (Dictionary of Computing 2005)

Computers can process great amounts of information faster that may be interesting to humans. They raise our "vision" on knowledge. The information we get from a computer will depend on the direction we choose to look in for it. So, the question is what kind of information should we look for or what should we input? This is the main issue that goes beyond computation, and of course, computer applications. What directions should be chosen afterward? It seems that there are two ways of seeing shapes: as a whole without possible alteration and as a possible parsed entity that can take many meanings.

Our attention is focused on how architectural designs are described. There are many other issues related with architecture like the advice given by Michelangelo saying not to paint *as some flaming painters do looking only for pleasing the eyes* and: *And master there is, and excellent one, who never painted more than one figure, and without do no more other paintings he deserves more credits and honors than those who painted thousand retables, [because] and he knows better to do what he does not than others know what they do. (Ollanda 1955)*

We have to understand that the architectural realm is not only images in order to work with a full description. But at some point, we may detach parts for various purposes. In current practice, we look at shapes and we alter their descriptions in our head, drawing other shapes. The following examples have full description and others have only shapes.

John Koza, a computer scientist is working to build computer software that allows machines to make their own decisions in creative ways. He formulated a genetic programming approach applied which he applied to software applications in order to produce designs creatively.

In the group of genetic algorithms theories that follows Charles Darwin concepts for life, Koza created the genetic programming approach. The results obtain amazing and unexpected designs from computers, (given a minimal initial condition, which is the point of all computation). Koza adds fitness conditions to what he expects to obtain from a finite number of possibilities, which computers choose from an infinite universe of choices. *One of the central challenges of computer science is to get a computer to do what needs to be done, without telling it how to do it. (Koza 1999)*

The goal of Genetic Programming is stated in the previous sentence, which corresponds roughly to an Artificial Intelligence research goal. A population is bred from a gene and with operations such as reproduction, crossover (sexual recombination), mutation, and structure altering. These operations are patterned after gene duplication and gene deletion, as they are in nature.

Induction introduces uncertainty or ambiguity into the results, and deduction is stated by the truth of the premises that shapes an idea. John Koza plays his automatic programming from the point of view of uncertainties. He also calls it program synthesis or program induction. He is trying to introduce an imitation of nature in his work. In addition, there is the idea that each organism he creates should have a proper life. A good algorithm should allow for the creation of things that were not pre-defined, with non-deterministic results.

Peter Testa is an architect concerned about the use of computation in the design environment. His main goal is to introduce new materials and systems to production and construction. He has been exploring Evolutionary Programming (EP) and Genetic Programming (GP) software to architecture and design education with the support of his computer scientist team: Emergent Design Group. This previous concept is derived from the original concept of Holland, who defined the Genetic Algorithm (GA). The following examples are related with two different ways to play with GA. The first is Agengy based on EP and the second GermZ based on GP.

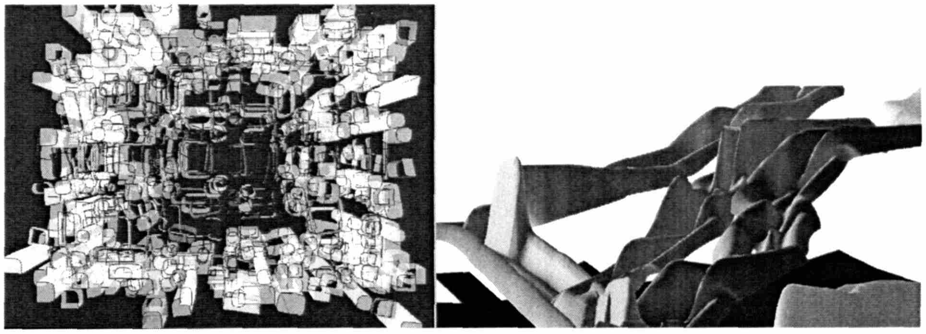


Figure 16 Peter Testa drawings that were made from different approaches

For example, Agency involves a methodological component, researching evolutionary programming techniques, and a design component, applying emergent technologies to the development of distributed systems. The software is noteworthy for its agent-based evaluation of fitness and allowance for direct user interruption and reintegration of phenotypically modified individuals.

The author considers Jon Maeda, however, to be the present paradigm setter for the relation between the computer and art. Maeda is an artist and a computer scientist, and he sees the computer not as a substitute for brush and paint; his book "Design by numbers" is an outstanding work to demonstrate the power of computer on art using emergent strategies. There are plenty of similar experiments with astonishing results that can be evaluated in the areas of graphic design. These are the most visible approaches that we know of, and, in our opinion, the more attractive ones.

The work of John Frazer, cited by Jorge Spencer, which can be understood by his book *An Evolutionary Architecture* (c1995), is also worth note. Frazer elaborated a theoretical basis for architecture using analogies with nature's processes of evolution and morphogenesis. Organically constructed buildings are Frazer's vision of the future. He also tried to model architectural units.

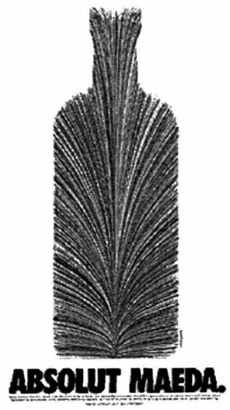


Figure 17 A work of John Maeda

In addition, an approach that makes an analogy with nature is that of Corte-Real. Linden Mayer systems were conceived as a mathematical theory of development. Thus, geometric aspects were beyond the scope of the theory. Subsequently, several geometric interpretations of L-systems were proposed in order to turn them into a versatile tool for fractal and plant modeling.

As stated above, architects do not only play with symbols or verbal representation, they work in combination with shapes. The author means shapes not symbols. Can both be equivalent for practical reasons? At least should we be aware of the differences?

In design thinking literature, we see that architects play with symbols, shapes or both at the same time. The examples the author have reported thus far only played with symbols, even if these symbols are images. To be more specific in order to understand the difference we can find some clarity in the work of Terry Knight and George Stiny (2001). In this article written by both, they express concepts for classical and non-classic computation regarding object and process descriptions. They state that verbal/linguistic object representation is classic and visual is non-classic. The computation process is classic when we understand what is happening in the computer, and non-classic when we have do not a total understanding of how things are done within it.

With respect to architecture, a design can be made by applying different strategies, using symbolic or non-symbolic shapes, or both. We may agree with Manuel Tainha when he said, *"drawing is built"*, and with Jorge Spencer regarding how important representations or hand drawings are for design. In terms of process the author thinks they both agree that it is quite difficult to understand how final products are reached.

The author has selected two groups of techniques from which to approach design computation: production systems and self-organizing systems. The first we can exemplify with Stiny and Mitchell's Palladian Grammar. For the second, any of Peter Testa software can be an example.

These two groups have different behaviors. The first pulled his attention because it uses and works computationally with shapes to produce designs in addition with symbolic information. In this group of production systems Shape Grammars are used to work with shapes. We may find several written works about how to describe designs, though there is not so much work about how to create new designs with it.

Several works were software implementations of both groups. However, there are differences amongst these two grammars: one is from verbal language and the other for visual. Buonarotti noted the same differences. By the speech of Francisco de Ollanda (1955) in *Dialogues from Rome*, he stated that the simultaneity of view in painting is greater than in poetry. In poetry, we are reading the last verse when the first could be already forgotten, and as a consequence, we may miss the whole point of an expressive idea.

Shape Grammars have the ability to work with shapes through computation, which goes with Jorge Spencer concerns that drawings and their spatial relations are important to designs. However, the problem is that computers are not able to play with shapes as easily as we do in traditional ways such as sketching, or through projective techniques.

Moreover, if we want to convey meaning in architectural design we must associate meaning to shapes. George Stiny and others have provided several tools to deal with architectural shapes computationally, for example, parallel parametric shape grammars. And recently the framework of communicative Parallel grammar was introduced by Terry Knight (2004). Shapes and labels are linked in ways that, in terms of computational machinery, provide completed interpretations of designs. The work of Li and Duarte are important examples of this.

Some may ask: Why do they insist on this difficult task? If computers are not able to play with shapes let us work only with numbers. Is it worthwhile to work to solve this? Nevertheless, others realize that it would be a big issue if we only pretend to reach creativity in art or in architecture using computers. In the least, this is a process that designers use outside of computation and therefore it should be attempted from the inside too.

EDUCATION

In an education environment, these issues become important to discuss. When we decide what information flows to students, we are somehow contributing to the future definition of architecture. The author would like to contribute to such a discussion, making some arguments regarding a practical teaching situation in the light of three issues: a new general approach about drawings, the integration of computer with drawings, and a discussion of some ideas about teaching and learning in the architectural realm.

Representation courses are given in architectural schools which are aimed at defining graphic expression foundations for architecture students. They exist for input and output purposes, to allow good communication with others and within themselves. Architectural programs also have other courses where verbal communication is important, but it is the graphic expertise that makes the difference between students of architecture and students of other areas. Many techniques and processes are taught, and recently computer techniques were introduced in the program course at the Lisbon Technical School. This emergent discipline, as other new techniques or procedures, was not accepted easily by all, some with good reasons and others with not so well founded.

The three disciplines related with visual communication are: hand drawing or sketching, descriptive geometry and CAD. By now they work with representation on its different qualities in a cleaving way. In general, they never mix practices. Drawing and geometry have been, for a long time, fundamental parts of architectural education in this School. CAD disciplines however, have only been taught since 1991, and it was not always clear what position it would take within the school. At first, CAD disciplines depended on the Computer Centre Laboratory. Later this corpus was accepted in the Group of drawing/geometry/CAD of Architecture Department but with some qualms. It was never assumed as a new branch of knowledge and neither was it seen as a valid partner in architectural design. But recently, CAD work has become a new optional discipline for computation and shape. This development shows the shift that is happening in this school.

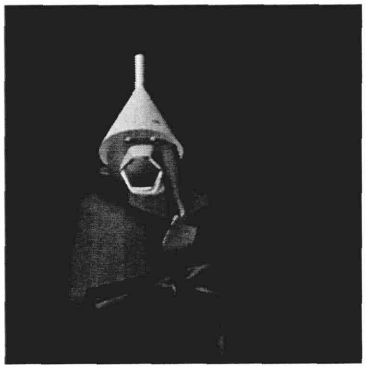
The performance of each discipline has been very clear, except for that of CAD. Drawing or sketching disciplines roughly try to promote a personal code of representation. Students are invited to express the built environment through their senses and interact with the potentialities of the drawings. The body is used as a subject and as an object. These registries are meant to be ambiguous, and none are coded. On the other hand, geometry disciplines are taught with codes, which everybody has to know and interpret, even if perspective systems are not taught by traditional methods. There is a switch in the method of teaching perspective in this school. It is not geometrical but topologic. The method applies for both directions and relations. Meanwhile

CAD disciplines have been "fighting" to win a proper place in the context of graphic representation. Some exercises were proposed to explore freehand sketches and geometric drawings by using different tools. Often teachers of CAD were accused of teaching more then it was expected. And it becomes more difficult when students are asked to create new shapes out of computers. This conflict could be surpassed if both geometric and sketch disciplines would incorporate one more tool in their programs: the computer.

Several examples in figure 18 show how the CAD discipline deals with a surface representation from an exercise made in 1998. The other was made by sketching with a mouse in 2004. The first was inspired in a personage in the painting of Hieronymus Bosch, the Temptation of St. Anthony, where the control of surface creation was questioned. The second is a hand drawing that suggests spatiality and allows student to be "in". The exercises were defined to teach students how to deal with both techniques.

In some respects, the syllabus for the discipline was teaching computer graphic techniques by reproducing traditional techniques, which for many was the goal of computer. However, the program evolved to teach some language programming to adapt students to emergent demands. In addition, this new tool could encourage the introduction of new processes and expand the old. Different directions were emerging. Ways to represent and deal with the complexity of the architecture discipline were introduced into the teaching of architecture.

Meanwhile, in the last year, the above described courses were reformulated, although they maintain more or less the same characteristics, and a new discipline was accepted. In the programs of all six graduate courses a course called the *Computational Syntheses of Shape* was introduced. This is a non-mandatory discipline for students in the last years of each course. The discipline aims to discuss shape in computation.



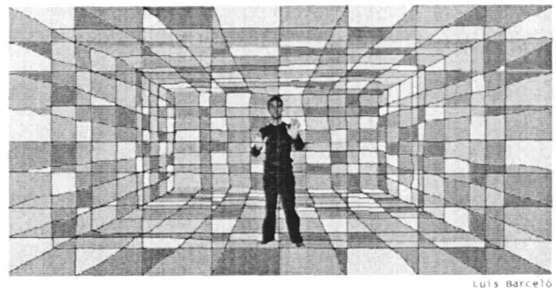


Figure 18 Some works made by students of CAD disciplines

This disciple manages the part of representation that does not overlap the others and the author believes it has created a good space where students and faculty can discuss the representation of shapes and computation. It is an optional course and raises the question as to whether designers should work with computers and computation if they feel that they must sometime abstain from use. Any tool must to be used with a purpose. Currently, CAD systems are used as a sophisticated drawing board. Others are using computation to design through descriptions of drawings, as if they were only elements to measure. Meanwhile, others say that drawings are not only for measuring things; they have spatial qualities that should be evaluated and used. Acting as a designer, we need to decide clearly how he can get some benefit from such work. At some point, designers need to participate in the creation of CAD systems themselves, instead of simply using them without any criticism.

At the design stage, some designers could profit by looking at a model in order to decide what they might want to change within it. Peter Rowe stated that representation matters to design. The problem of the medium is that it constrains the design process. He believes that traditional plan, section and elevation may be sufficient to describe a work but surely it is limiting for interpretation's sake and for the spatial qualities of a work.

It seems that students may profit in several ways from further work with computer representation. They can play with computer representations of a pre-defined model that they have idealized. They can test these representations as they could no do with only the drawings. In this way, student designs can be more accurate through the use of a model. Ambiguities of shapes are important as well for a correct definition of the thing that is represented. Computation rigor can then be used not as a limitation but as a goal. It is important that students could do the proper questions regarding computers and computation.

The second reason that students may profit from computers is comes when they work with representation and computation. Shapes in all senses can be defined and controlled by design descriptions in terms of heurist processes, with addition of rules, or pre-definition of shapes, and its spatial relations to a whole. In terms of visualization, tools offered by computers are not in the hands of designers. Author hopes that his former students, who work in a private practice transposing architectural information to computer to make money, give it up and start using visualization techniques and architectural knowledge for their own architectural works, without losing money.

CONCLUSIONS

Courses of representation have a key role in enabling the architectural student to understand entities and processes that help to mold architectural shape.

Computers could be a good medium to integrate different types of strategies for visual disciplines. Computer could be the tool that traverses all disciplines. Information technology could be introduced according to the needs of each discipline. Now, in studio design information technology is used for presentation only and not always improves communication. Yet, unfortunately in this way, computation has no other meaning for the discipline.

New course syllabi could be proposed for each course and discipline. Therefore, for more general proposes, an introduction to the computer discipline should be taught on the first semester of the course to give minimal information to students who work with any software.

For example, students could learn different projective systems with computation drawing tools. Linear perspective and orthogonal axonometric could be used in CAD software. Second, students could be introduced to use new techniques to register and to edit their hand sketches.

An introduction to programming for built macros can easily fulfill a geometry requirement. For example, not all surfaces or solids can be easily built. For this case, tools could be created to make this task easier.

In design studios, one could introduce particular exercises that could appeal to computation. Some teachers should be allowed to use computation as a tool to support design decisions. In this case, we could introduce into shape grammars a complete description for architectural designs: besides shapes, we could introduce new algebras related with architectural meaning. The work of Stiny and others already give good support for this type of work.

For general purposes information technologies could be used in each discipline, as they were needed, wherein tool use could be taught along with a parallel critic of how to use such tools well.

SUMMARY

Briefly the author has tried to discuss different topics on shape representation. First, architects work with shapes and symbols for different goals. Second, the type of representation with shape depends on the things we want to communicate. Third, the type of representation for analysis may be different than the type of representation for syntheses. Fourth, representation should be gathered in one medium or tool in computer. All of these ideas could be the subjects of student's discussions.

4 COMPUTER REPRESENTATION

… 4. The development of plain language programs so that users can converse with their computers easily and even suggest modifications to programs which will then be incorporated. …

Geoffrey Broadbent, (1973)

INTRODUCTION

In this chapter, the computational background for defined representation and processes in computation are discussed in order to formulate a process of design. Herein the author tries to emphasize the importance of shape and symbol representations in design description, and the importance of shapes in the conceptual stages of design. Following this, the next step seeks out the best strategy to apply in the universe of computation. He also mentions the importance of this topic in education and the relations that are needed to integrate computational tools in design.

HOW TO REPRESENT THINGS THROUGH COMPUTATION

To select representations for evaluation and editing which allow better simulation of the real world, the author needs drawings and notations or designs and descriptions? Yet drawings, notations, designs and descriptions are simply designations, given by different authors, which correspond to different meanings. In this work, designs correspond to points, lines, plans, and volumes arranged in a proper system, while drawings include these elements but do not have relations between. Traditional representations that an architect uses to study a similar case usually include a set of texts and drawings or, alphanumeric or graphic formats. For computation, we know that the minimal format is a set of text descriptions, or symbols as this is the only way that we have to communicate with the computer. Descriptions can be stored in a database structure and be retrieved as text or graphic formats, and there are different processes of computation to simulate different formats.

Computer implementations are created to codify information, as needed. For text descriptions, we have word processors, for numeric information, spreadsheets, and for drawing there are applications dealing with pixels or vectors. In this case, we have a double representation; algebra and shapes.

Despite the fact that our process of communication with the computer is zero-dimensional we can explore different strategies. We know that the way we communicate with computer is based on symbols. We use a programming language to tutor the computer and many languages exist to achieve many types of goals. The evolution of programming languages gives us an idea of the process of adaptation between the man and the computer. For example, FORTRAN language was created because it was similar to mathematical notations. Following the same lines, COBOL was created several years later, because it employed words and syntax resembling those of the ordinary English. Now, there are others for different possibilities; object-oriented programming languages, such C++, allow us to incorporate the concept of self-contained collections of data structures or computational instructions, called "objects". With this type of programming language we could create software that enables storing, editing, valuing, and retrieving collections of information that have different formats: text, image, etc., but this process flattens the graphic information into a zero-dimensional format.

Roughly, we can classify programming languages into two groups: procedural and declarative. The first are the computer language paradigm. Examples of such procedural languages are those mentioned above. The second group is a high-level language class that allows us to describe problems instead of simply pointing out solutions. In analog situations, we may even define designs. Some examples of this language are Prolog and LISP languages.

On the other hand, different insights from the fields of the cognitive sciences reflect upon the ways people approach computer phenomena. The author summarizes a classification given by George Vignaux below, taken from his book "Les Sciencies Cognitives-une Introduction" (Vignaux, 1991), which seems apropos and includes propositional representations, metaphoric representations, and representations related with "doing actions".

PROPOSITIONAL REPRESENTATIONS

Propositional representations are based on the predicative model. The predicate-argument is related to logic's true or false states, the equivalent to 0 and 1 in a binary format, or on or off in the electronic circuits. In this conceptual approach, there are two subtypes: relational networks and frames. The first is similar to a semantic approach funded in inclusion relations between knots (concepts) and arcs (relations between concepts). The second comes from the work of Marvin Minsky (1975) which organized descriptions as blocks of knowledge.

Below is an example of propositional representations which we can elaborate from a textual description, specifically a poetic text of Borges. It is followed by a possible translation into a first order code.

The universe (which others call the Library) is composed of an indefinite and perhaps infinite number of hexagonal galleries, with vast airshafts between, surrounded by very low railings.

The Library of Babel, Jorge Luis Borges, (2000)

For the first sentence of this tale, we could represent its meaning in the first order logic statement that follows:

(Universe (count (hexagonal galleries, y)) (count (airshafts, (y - 1)) (high (railings, low))))

V

(Library (count (hexagonal galleries, y)) (count (airshafts, (y - 1)) (high (railings, low))))

Where y ε N and y >0

Instead of using the previous English grammar structure, the statement is translated to a computational description for an "if then" language. In the process, however, the original connotations are lost or changed: the poetic allusion to the world would be difficult to understand with this computation language format. The same can be said if we try to translate graphics into words.

This semantic logic language is one way to represent architectural descriptions. With the process described above, we could easily describe a study of Illegal Housing, using a similar order. Many applications for architecture use the semantic logic process for representation. Expert systems are able to translate to this language no matter how information is acquired. These strategies and those used in generic algorithms are classified by Knight and Stiny (2001) as classic representation. Classic computer representation means that shapes are treated as symbols. Without a computational tool that provides shapes to be seen as more then points.

While this system enables information storage and the processing of text information, it is not yet a ready tool for editing.

There are many reasons to work with the semantic logic language. For one, it is able to relate explicitly the process of encoding to the output information we get. The work of P Galle and B Kovacs (1992) can be illustrative of a successful application of the semantic logic language. The goal of their work was to explore logic programming for representing "realistic design knowledge in compute systems for support of architectural sketch design." Thus the study seems to show that logical analysis of a specific prototype design can yield 'microcosms' of general concepts, which are meaningful in their own right but also potentially useful in many other contexts than that of the prototype. Was used a bottom-up approach in Galle and K Kovacs' study. Herein the authors claim the power of logical predicates to simulate different steps of evolution and decision in the process of design. These steps code in a Prolog language. The creation of meaningful instances, are on walking lines, and in plazas a good "omen" although some constraints remain, such as boundaries and the knowledge-diffusion problem. The interception was a more successful instance in the study. Overall, the authors suggest the use of a network to avoid this accumulation of unused knowledge. In conclusion, they were editing not visual architectonic shape but 'A useful Language of Architectonic" which suggests the use of linguistic strategies enables grounds for play: particularly play with text descriptions of architectonic units.

In a MIT course the author has tried to study the Genetic Algorithms (GA) process, an evolution-based search algorithm (Bentley, 1999). Chromosomes, genotypes, mapping, phenotypes, images/solutions, and crossover, were the nouns and processes used in this concept, a reference to nature. The reference of nature is abundant in architectural works. In the context of GA, John Koza, a computer scientist, has developed an advanced Genetic Algorithms process called Genetic Programming. The author has tried to use his concept through the AgencyGP application, an implementation developed by the Emergent Design Group (EDG) coordinated by Peter Testa. AgencyGP allows the use of an interesting computational process based on computer generation, evaluation and a user decision. We can start defining an initial shape, a planar nurb curve and current fitness parameters. As the results were evaluated in the process of looking for different solutions, we, the user, can change the parameters. Therefore, parameters values for generations, crossover and fitness, are introduced and tested and throughout, different solutions of shape composition were given back. The process stops when the user founds a possible solution out of results designs, shapes and their relation in space.

This is a powerful algorithm that produces extremely complex designs. During each of these exercises, the author remembered the process that a Portuguese sculptor uses: living near a source of marble for his sculptures, he says that many of his works were inspired by nature, in the same way Leonard da Vinci suggested. The feedback given by the computer could be also a source of inspiration to some goal.

As a balance of the experience, we gain a good visual control over shapes and designs but in terms of computation we are designing by numbers. This is an example of classic computational representation. Computationally shapes are points. The control over shapes that designers do for example in the paper is substituted by a numeric control of parameters. Although a designers process is not represented in computation the process of search, guided by functions of fitness, can be helpful. The genetic algorithm, when combined with a metaphor of memory, could be an interesting tool to explore, due to its search power. Appendix H shows an example of some results obtained by combining a genetic algorithm strategy for process with a shape grammar representation to control shape. Another example of mixing computational tools is given below, wherein the author made an application combining the rules of Piet Mondrian paintings, defined by Terry Knight of one series of Red, Blue and Yellow paintings, and a random algorithm to produce similar paintings in the language. Some examples of the potential paintings are as follows:

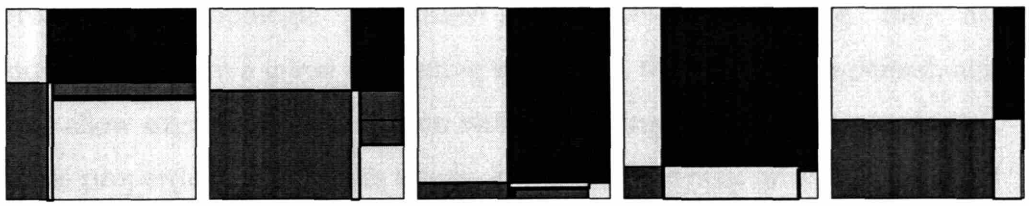


Figure 19 Designs derived from the initial schema

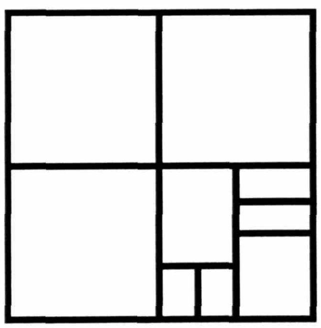


Figure 20 Base schema

Figure 20 shows dissimilar designs, based on the schema of figure 21, formulated by applying rules of proportion. These examples have different dimensions but they follow the restrictions given by the rules, which is the only control they have.

The Piet/Knight grammar was introduced in a computer implementation and runs with a heuristic process of search. All measures are hierarchically related according to the control of the main boundaries. Following the hierarchically tree a random value is given, and if this value is in the range it is accepted, otherwise it runs down or up a certain interval value, until an acceptable value is reached. All other related measures will be acquired in the same way.

METAPHORIC REPRESENTATIONS

Metaphoric representations come from studies of mental rotation. This is a strategy which complements expert systems on representation, as it preserves the spatial qualities of the objects in space. Following the work of Vignaux, the properties of metaphoric representation preserve the shape, position and topologic properties of the objects in space, they are independent from a given perceptive viewpoint, they can not be parsed, and they allow organizing information without having specific space properties. These properties preserve the whole, and allow information to be organized in this spatial environment. We can better understand this idea through the work of Michael Tarr. Tarr says that the studies of Shepard and Metzier's, about mental rotation, lead us to speculate that part of our cognitive process is mental and tied to visual perceptions. Although a common amodal format was assumed in cognitive architecture during the 1960's, this work suggests that Shepherd and Metzier's model should include modality-specific mechanisms that can support mental imagery.

The hypothesis that mental rotation is a continuous process akin to a real-world rotation also has implications for the nature of imagery, namely, that humans have the capacity to make judgments using inherently spatial representations and that such representations are sophisticated enough to support problem solving, spatial reasoning, and shape perception. Not surprisingly, this claim evoked a great deal of skepticism. Michael Tarr (2002)

Shape Grammars (SG) formalism allows us to work with this kind of representation. Definitions of the grammar for the illegal housing accepted these characteristics for the way home users conceptualized their dream houses. They never wanted create any thing new, they simply wanted a drawing that could mirror what they had in their minds. Portuguese sociologic literature about this dream house mentions that homeowners collected house designs from what existed in the neighborhoods, for example, the immigrants collected references of the countries they were from, as well as from some magazines and/or newspapers.

"DOING ACTIONS"

Representations related with "doing actions", are related with doing things and with the control of the procedures involved. Such representations are related with motor activities and cognitive symbolic capacities.

The symbolic (or "top-down") and the connectionist (or "bottom-up") are both approaches in Artificial Intelligence research, and competing methods. The latter seeks *to replicate intelligence by analyzing cognition independent of the biological structure of the brain, in terms of the processing of symbols – whence the symbolic label.* The second *involves creating artificial neural networks in imitation of the brain's structure – whence the connectionist label.* (Britannica 2002)

To distinguish both methods we can look to the creation of a system with an optical scanner, for letter recognition. The bottom-up strategy would consist of training the network, and gradually improving performance by presenting letters one by one. In opposition, the top-down approach elaborates an algorithm to compare each letter with its geometric descriptions. In summary, *neural activities are the basis of the bottom-up approach, while symbolic descriptions are the basis of the top-down approach.* (Britannica 2002b)

The first to suggest that human learning consisted of connections between neurons in the brain was Edward Thorndike, in 1923. The connectionism approach was later developed in 1980s. One example of the bottom-up approach is the work of Rodney Brooks. Taking the humanoid robot, called Cog, he started to develop a work of knowledge acquisition, having in mind that the robot was an eager child anxious to learn. This approach demonstrated very good results. The robot has a human-like shape for two fundamental reasons: first, establishing a better relation with people, because it appears "almost" human, second, facilitating the learning process of the robot, as a representational pattern of a human. These twofold relations made interactions between human environments easier.

The Shape Grammar formalism is also an example of this strategy. The author has previously said that this formalism is related with questions of vision and its properties, which differs deeply from a zero-dimensional point of view. However, the big question is how to compute shapes with the kind of devices we have. We know that computation deals with shapes using points, as if they were words, yet this means we miss to use the whole shape properties when they have i>0. An example of this, in algebra, would be U_{ij} where i defines the dimension of the basic element, and j defines the dimension where shapes are together, and transformations happen. Despite this, we could deal with three-dimensional representations as shapes which are only defined by points. This would mean that what we get computationally is not what we see, and shapes as points "are not there" and they cannot, therefore be fully computable as shapes. To overcome this limitation George Stiny (1999) proposed computing with different algebras. Examples of the combinations between algebras U_{ij} V_{ij} and W_{ij} already give us good ground from which to work. Interacting with algebras of shapes, labels and weights and their basic elements, allows us to reach very close to a traditional approach to media used in art and design.

To conclude, given the limitations of the system, different strategies have been defined in order to represent "things" in a computational model which come as close as possible to the original properties. The result has created several strategies which can be used, depending on the process we want to apply. For the case of Illegal Housing, the representation will be made by descriptions and designs of architecture wherein both processes complement each other, but use a formal set grammar instead of a standard shape grammar.

Representations are both text and image, or verbal and visual. We saw above that we can represent both through a set of tools into different formats. However a problem remains: How can we edit all of this information; i.e.: which method or process do we want use in each context? If an image has its own properties in representation and it is not equal to text, does it signify that we have to "remount" drawings before editing? There must be an appropriated tool for doing such work.

REPRESENTATION

We can represent almost everything in a formal basis. Representation of any kind is an intermediary stage between an abstract idea and the thing that we want build. We will always miss some information from the object that we want to represent. The gap between representation and object enlarges dramatically if we represent verbally or textually an object that is also described as a shape. In the computation environment shape grammars have tools to overcome the limits of computer of the zero-dimensional algebra - even when the tool is built upon that algebra.

In an analogy made about painting by Jifi Veltrusky (1973), the author can infer that the material of the painting is different from the material of the language of what is painted. According to Veltrusky, the meaning of a painting should not be founded on the identification and analysis of the simplest components of the painting. Any combination, any editing we may want to do only should be allowed to work with the whole. Otherwise, it will be a mere imitation of the linguistics model, leading to a compressed meaning of a graphic quality and properties. The decomposition of the model is possible for "transportation," still we have to define a coherent system, similar to that of a brush and ink on canvas. Perception will only be possible, (at least in all its dimensions) when all parts are ready at once. An appropriate system should be created to encode representation accordingly.

The above problem persists when we want to process information with a zero dimension environment for objects that are three-dimensional, as is done in computation in the conversion from shapes to text. We easily understand this limitation, as designers, when something is lost when three-dimensional information is flatted into a plan, as in traditional architectural representation.

If we need to create or edit a drawing, which represents an elevation or a plan, we can do it in two ways. Let's assume an architectonic vocabulary where drawings are not taken as shapes but representations of architectonic units, like windows (with any dimension), walls (with any dimensions), where composition is already constrained by these separate set of elements. An example that fits well is that which Terry Knight and George Stiny (2001) gave in the paper where they defined classic and non-classic approaches to computational representation and process. Therein Knight and Stiny relate Noam Chomsky's phrase structure grammar with a drawn group of openings to compose one façade. Two rules are given: S->aSa, and S->b, and one start symbol S. As a derivation of the rules, we can have aabaa.

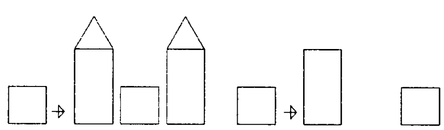


Figure 21 Respectively, rule 1, rule 2 and initial shape.

A similar process can be done for classic architectonic vocabulary, which may result in the following example:

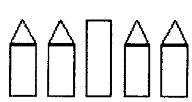


Figure 22 The final design

An alternative to this work could include openings represented with shapes and assuming that wall and openings will be worked to a possible composition where only in the end resultant shapes will assign an architectonic meaning as door, or walls. A similar process could be the one defined by Stiny in his paper "Meaning in Architecture" where shapes and meaning are separate, and they do not overlap: drawings and descriptions. These algebras complement each other for architectonics representation. In a parallel process, rules are applied for shapes and for descriptive rules. This parallel process happens in the designer's head when there is not yet a clear definition for an architectural language.

The author has been discussing two important attitudes regarding shapes and designs that architects may choose to apply. Designs can be made of combination of symbolic references or can be made by visual interrelation with shapes in a perceptive base that he or someone else drawn. For the first, the computational environment gives a fairly good answer but for the second it not a straightforward process, unless computation and an appropriate tool is used. These two positions do not produce the same results, and architects play with both depending on which stage of the design process they are engaged with. The first of these positions assumes that we are drawing with units of architecture regarding with each another, units that were made by someone or by ourselves. More or less these units are encoded in much commercial software. Architect offices use those that seem to represent best the office architectural image. Usually this software is not used by the architect. The second, assumes the concept of *disegno* defined by Michelangelo and furthermore. Shapes can be parsed to shape different shapes. The composition will be more flexible which corresponds to a very early stage of the design where every decision could be taken, shapes do not have by that time unambiguous architectonic meaning. Meanings of shapes are constantly being reprogrammed.

For unity in composition, any shape can be pre-defined and emergent at the same time and thereby we gain more flexibility to proceed with our designs. The work of Stiny gives us many insights to understand this, particularly in his classic work on the three triangles or the chevron. Both examples are good references for a non-classic process for two-dimensional representation. Shapes can transform into other shapes. For example, as shown below, if we apply a translation transformation One can see that a predefined shape is founded in the drawing but that shape is emergent because those three lines were not identified at the beginning of computation. By then, they were part of another shape.

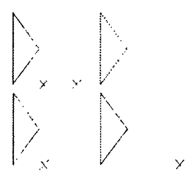
Rule 1  Rule 2

Figure 23

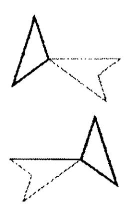
Initial shape  Final shape

Figure 24

Complete derivation, (rules 1, (shape in two states), 2)

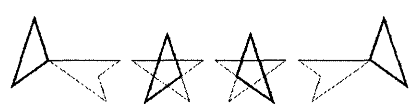


Figure 25

The visual evaluation of two-dimensional information creates and depends upon dynamic knowledge, which cannot exist in a one or zero-dimensional schema. Stiny calls this property emergence. Emergence can be found in other domains. According to J.S. Mill, who illustrates emergence with chemical properties, the product of the reactants is not the sum of the components. Below is a sculpture, found in the city of Porto, which is not very appreciated by the local people. In fact, in context, this shape functions as an emergent and an interesting piece of art.

The context plays an important role in the recognition of this shape as emergent, or novel, in accordance with the whole that Mill described. Drawings are not read up to down or from the left to the right; to be meaningful or to convey knowledge, each of these directions is read simultaneously.

Returning to computational environment of dealing with shapes, using shape rules the difficulties of computing with shapes can be overcome. Shape rules define the process of change from one shape to another. For example: A->B so that in a shape C, when we look for a similar shape A, then we substitute this shape A with the shape B. The shape C will become different. The spatial analogy is completed and part A is to the part of B, as part B is to part A. Additional resources to deal computational shapes are: part relations for each algebra, and Boolean and Euclidean transformations. They are enough to evaluate and execute the actions of rules.

Therefore, from the analytical frame work Stiny built, several tools to simulate a computational shape have been treated as a pencil shape by perceptive methods.

"Shape Grammars are just a good idea of how to capture architecture knowledge, one of the best ideas, I would argue, that we have around now." William Mitchell (Duarte 2001)

SHAPE GRAMMARS

"The relation between algebra and geometry, also called coordinate geometry is known as the mathematical subject in which algebraic symbolism and methods are used to represent and solve problems in geometry. After the work of David Hilbert, at

the turn of the 20th century, the foundations of geometry were generalized and the classical concepts of space and objects in space, which derived from intuition, were replaced with abstract ideas."... "The importance of analytic geometry is that it establishes a correspondence between geometric curves and algebraic equations. This correspondence makes it possible to reformulate problems in geometry as equivalent problems in algebra, and vice versa; the methods of either subject can then be used to solve problems in the other." (Britannica 2002c)

While a visual system for designing is based on visual information plus perception, Shape Grammars is one of the computational systems that design, through computation, with shapes. Stiny and Gips introduced this system in the 1972, as a method of shape generation, which take shapes as primitives and have shape rules. This process has evolved into a formal theory of design and computation wherein shapes and rules are the bases for creating languages of design. Since 1980, Shape Grammars are being used as an analytical architectonic tool with the Palladian Villa plans (Stiny and Mitchell 1978). Other researches with these Grammars have followed Frank Lloyd Wright's Prairie Houses, and Malagueira Housing. Out of this, the computer has become an important tool for architectonic analyzes and synthesis, as we can see from the class of Terry Knight wherein Shape Grammars is not only used as an analytic tool, to know how things were related, but also as a source of exploration as to how things could be related.

A method of shape generation using shape grammars which take shape as primitive and have specific rule" this is the first definition made for Shape Grammars, which others have now followed. In the first book on the subject, Stiny said that Shape Grammars should be visually understandable, and supported with rigorous mathematical models. The likeness with Noam Chomsky's phrase structure grammars emphasized the generative power of Shape Grammars. With this in mind, the author wanted to apply computational systems to the illegal houses which would provide tools to improve creativity in computation. Using formal Shape Grammars with algebras and shapes might accomplish this goal. In this method, Shapes are supported by algebra, a mathematical languages used to communicate with the computer, as related above. However, the field of computation is limited. A Formal Shape Grammar supported by algebra would be possible only when shapes are made up of lines, planes, and solids, but shapes defined with points would limit the full relationship of what we can see. With these factors and hindrances in mind, we need to mount a mechanism that allows us to compute shapes, wherein shape rules have a fundamental roll.

To do this we can again look to the first book by George Stiny on Shape Grammars (1975), where a shape grammar is defined by 4-tuple, as follows: SG=< VT, VM, R, I>. For this set, VT is a finite set of shapes called terminal shapes, VM is finite set of shapes called marks, R the finite set of shape rules, and I the initial shape. Later, after this 4-tuple development, the concept of a label was introduced, allowing for better relations with the world of construction in the act of describing physical components. The universe of algebra U is the following:

Atomic algebras (gray)

U_{00}	U_{01}	U_{02}	U_{03}	**U_{00}**	U_{01}	U_{02}	U_{03}	U_{00}	**U_{01}**	**U_{02}**	**U_{03}**
	U_{11}	U_{12}	U_{13}		U_{11}	U_{12}	U_{13}		U_{11}	U_{12}	U_{13}
		U_{22}	U_{23}			U_{22}	U_{23}			U_{22}	U_{23}
			U_{33}				U_{33}				U_{33}
A				B				C			

U_{ij} i basic elements, j dimension.

A. Universe of algebra U_{iJ}.

B A particular atomic algebra, i=0, points, two shapes embedding=identity, atomic algebra.

C atomic algebras, i>0, points, atomic algebra, infinite number of parts, partial embedding.

Non-atomic algebras (gray)

U_{00}	U_{01}	U_{02}	U_{03}
	U_{11}	U_{12}	U_{13}
		U_{22}	U_{23}
			U_{33}

D

i>0, j>0, infinite many shapes,

Rules are defined with shapes and labels and sometimes with rule descriptions. The rule is defined, A->B, where A is the left side of the rule and B the right side. In the paper "Weights", Stiny explain how the introduction of new algebras will allow a computation device to work with shapes.

In summary, shape grammars are a system of design and computation, supported by perception of shapes and algebras. Shapes are points, lines, plans, and solids, which we can see, and with which we can interact. Algebras are the computational framework wherein shapes and transformations are contained. Rules are a fundamental device which allow for a calculus with shapes, supported by combinations of algebras.

AN TENTATIVE EXAMPLE OF A SHAPE GRAMMAR

The following example with Stiny's Ice-ray grammar, comprised of a strong relation between user and computation, can illustrate his work. The result is a combination of different approaches to be decided upon by the user.

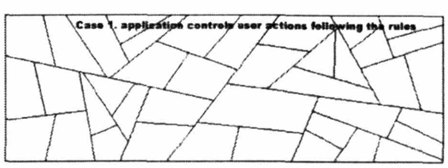


Figure 26 Design 1, original rules applied by a user.

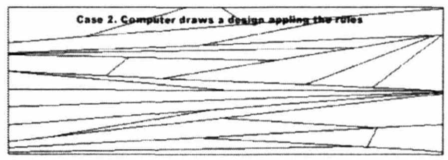


Figure 27 Design 2, original rules without more restrictions.

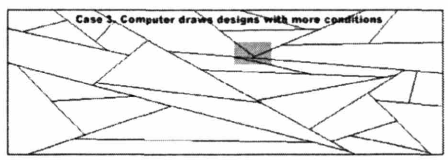


Figure 28 Design 3 made up with some restrictions or new (similar) rules

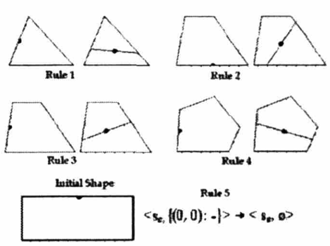


Figure 29 New Rules for Design 3

This application is very simple. It was made with AutoLisp programming language and it runs inside the AutoCAD graphic environment. It works with the rules of Ice-Tea Grammar in three different ways. The first, a user decides where to apply rules, very similar with the work on paper, but in this case the application controls the correct use of the grammar. It could be served for a real case for rapid-prototyping. On the second, the application applies randomly the rules after the user had given a rectangular area. On the last level, it works in a similar way as the previous but in this case rules only can be applied to the previous inserted lines. We can see the conditions for this case on the figure 8.

Given Stiny's definition, the conditions for ice-ray grammar for design 3 are:

This grammar has five parts, the same as in the original.

S is a finite set of shapes

L is a finite set of unordered sets of labeled points and half points.

R is a finite set of shape rules of the form of α->β, α =<u, i> β =<v, j>

I is initial shape that I=<w, k>

T is a set of transformations

w, v, and u are shapes in S. k, j, and i are labels in L.

The application of the rule 3 to the initial shape will use mirror symmetry of the rectangle. One additional rule to termination: when the area of any polygon was less then the value C rule will not apply, them is applied rule 5. The application that generates this grammar does not show the labeled points, L.

In summary, the classification given by Terry Knight and George Stiny (2001) is a good starting point for raising some questions. It was said that computation would be richer if representation and process were used in a non-classic formats. For them classic representation is verbal. Now people are collecting the whole knowledge in verbal formats in computers, as before in the seventh-century encyclopedias. For Saussure (1983): *No ideas are established in advance, and nothing is distinct, before the introduction of linguistic structure.* On other hand, visual representation is non-classical. It is related with creativity and arts. Both play an important role in our lives. Shapes are non-classical and symbols are classical.

A SECOND EXAMPLE OF A PARAMETRIC SHAPE GRAMMAR

The author shows an example of computational strategy to apply emergence to computer. This parameter shape grammar is a formal representation of a land division. The formal process is very similar with Ice-ray grammar of George Stiny.

As it was mentioned in chapter 2, the process of illegal housing had three design steps: first the division of an agrarian land for agriculture goals that speculator sold illegally, second the design of the symbolic house and the third those small buildings that spread from the symbolic house until the limits of the lot.

This grammar is related with the first step, which corresponds to the subdivision of the land with n sides of an agrarian polygon. The initial shape had two conditions: be a closed polygon and had an area greater then 5000 sm. The minimal area for each lot was variable and it could have proximally 100, 200, 500 or 1000 sm. of area. One important goal was to grant a good number of lots. Complementary aspects were circulation but not topography.

These are some examples of drawings of land that reached our knowledge. In Figure 8 was a drawing that served to negotiate with municipal authorities. Figure 9 illustrates a scheme drawing that was given at the time user buy a subdivision of the land.

These two examples show how big the intervention on land was and how they defined urban elements.

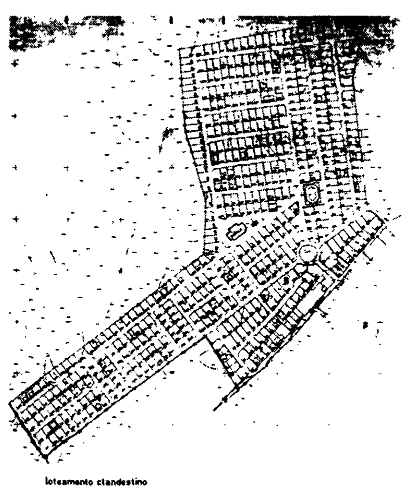


Figure 30 a drawing of an allotment

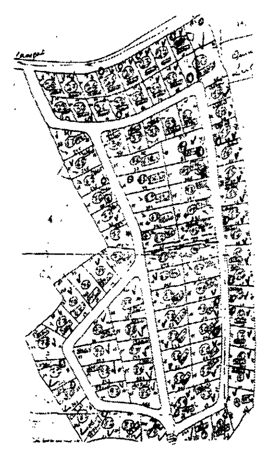


Figure 31 a hand drawing

Figure 31 corresponds to a drawing that was given to municipal authorities to legalize land and lots for urban goals. Due of its small dimensions, it has exactly 5000 sm., street alignments were more or less controlled by the previous divisions. We can see dimensions through the lot and housing dimensions.

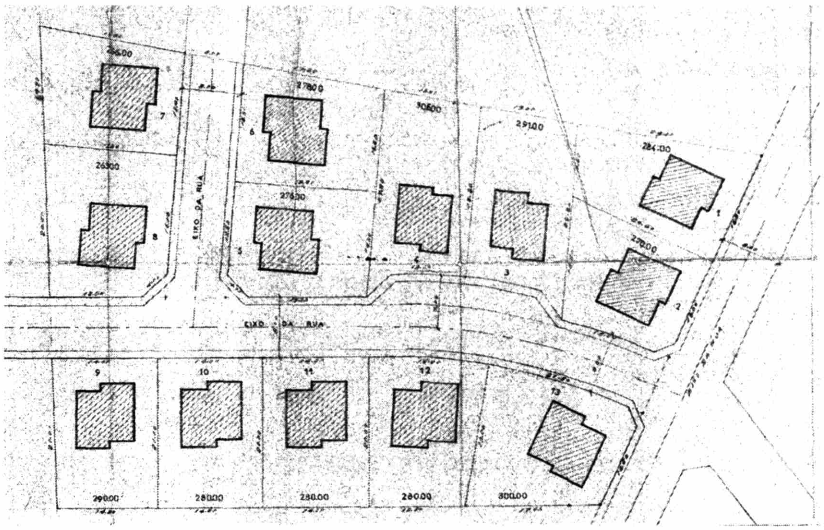


Figure 32 A 5000 sm. subdivided land.

Grammar description

The author has tried to encode the part that allows division and he did not complete the second part of the process, which would have included the definition of relations of this part of land with attached established divisions around. This was particularly important to relate optimized roads with the existent ones.

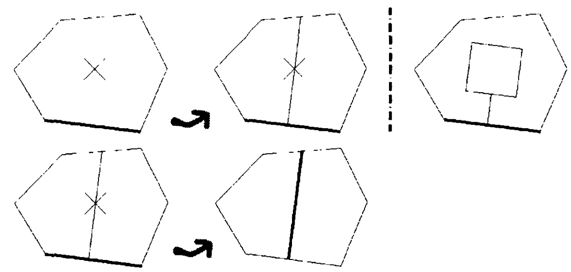
The initial shape of this grammar is any closed polygon of regular or irregular edges. There are four rules and they are applied based on shapes and descriptions. Calculation of the area of the lot controls much of these rules.

If
Area > 5000sm
Is selected a edge

Rule 1

Area is calculated and the centroid is draw

Rule 2



If	Rule 3a
Area > n	Rule 3b
Then rule 3a	
If not rule3b	
Polygon is divided by two following two conditions: 1. Perpendicular to the selected edge: 2. Subdivision should be by equal parts	Rule 4

These conditions were translated in the AutoLisp programming language to a computer implementation in order to work in the AutoCAD graphic software of AutoDesk.

Results from the above chart can be seen in the next figures. This first group only had a rule that relates the polygon to its placing. The first edge is selected because it corresponds to the edge of the street or road. As we can see the geometry of the polygon will greatly define the geometry of the lots, and in the figure 34 we can see that a small variation of the polygon geometry radically alters the geometry of the lots.

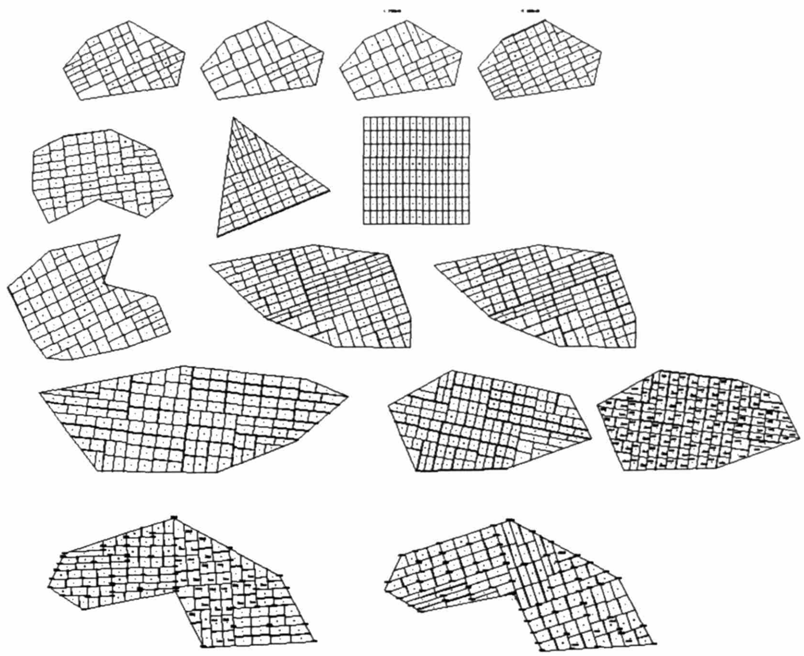


Figure 33 Several examples, the geometry of the polygon decide the lot

Figure 34 An example of an illegal quarter, Amadora*

The above grammar and its implementation were applied to this small polygon area. As we can see, more rules should be introduced to codify exterior and interior conditions.

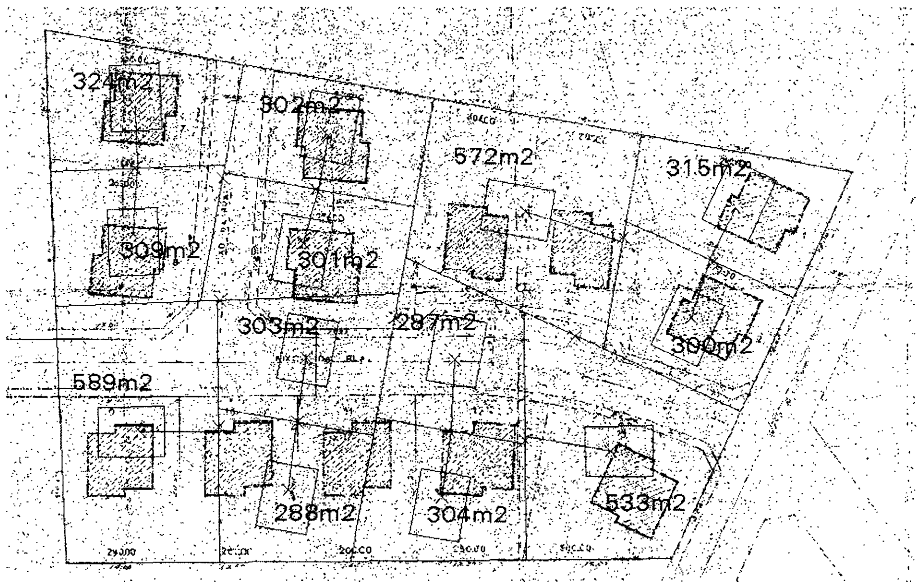


Figure 35 Overlapping the real division and the one given by the grammar

For the image above, the red part of the image, representing the actual structures as they exist is laid over the black shape grammar generated image. This example only serves to illustrate his point that every representation has a set of characteristics that computation should follow. Computation should be used to correspond to the type of representation which is needed.

CONCLUSIONS

The classification given by Terry Knight and George Stiny (2001) is a good starting point for raising questions about representation in computational environment and also out of it. If the non-classic format of computational representation is the one that is closer to design, computational results would be richer. The Shape Grammars approach to shapes is related with the early stages of design where architect act in the complex process of design the built environment.

However there are some reasons to use different and less ambitious grammars as set grammars, such as the grammar that the author has proposed to build. One reason for this might include the single need for a description of what is, with no emergence needed. The other reason, less straightforward reason, was understood from the Portuguese sociologic literature: those houses were conceptualized in a combination of symbols. The metaphoric representation of knowledge, and in this case homeowner's desires, is well described particularly in regard to how the abstraction of an idea was transposed to the built environment of Lisbon. The last reason for using set grammars relates to the designer, who may sometimes prefer to deal with symbolic shapes.

SUMMARY

Limitations of computation can be overcome by building tools that can support our goals. The materials used to paint or represent do not matter in terms of the message of the object that is represented. The Shape Grammars formalism aims to formalize the design process, which is only played out by the designer, who is also using other formal grammars. In conclusion, it is important to recognize the differences in terms of geneses and goals. One may think as interesting to explore object representation accordingly they were conceptualized.

5 Grammar of Illegal Housing

This grammar attempts to encapsulate the morphology and syntax of the illegal houses of Lisbon, built between 1974 and 1984. This research is proposed as an investigation into the nature of man's participation in the building of the spaces around him. It seeks to understand these spaces through its topological and geometric representations through the medium of shape grammars.

This is a descriptive grammar. This grammar is not meant to be used as a design grammar, because it does not have all the predicates for being such - for instance the language lacks the use of shape emergence. This grammar has two main goals. First, it endeavors to understand what users want by examining what they did in the process of building illegal their housing. Second, the grammar questions whether this illegal phenomenon is as chaotic as people think.

The format of this formal grammar will be computer implemented, using a device, developed by the author, called SGtools. In a new stage of further work, the author will test this implementation by coupling the work produced in the SGtools implementation with other formal devices in order to search for other possible solutions and possibly evolve different applications. SGtools is described in a paper presented by the author in Vienna last July, (Romão, 2005) and the process of coupling is an appendix of this thesis, which is a working paper that was accepted to be presented in the next eCAADe congress.

A complementary goal for future work might be to test the grammar presented in this thesis for its ability to produce new housing solutions upon alterations to the initial formal structure of the grammar, through the introduction of new rules. The author predicts that this procedure will help to transform the set grammar formalism into a standard shape grammar, which could allow emergent shapes and far more possible solutions to support new designs.

UNIVERSE OF THE GRAMMAR

The corpus of the present grammar is countless. The author decided to choose a group of houses from examples that were published in a sociologic study in Portuguese literature (1980), for three reasons: first, the difficult contact with homeowner to let someone see their houses, they feel uncomfortable to see their houses be treated as an object of research. Second any selection made by the author could be seen by others as partial. Third, the author thinks that this group of houses was representative of the illegal housing.

In this randomness selection one can see that this group of houses has some topological similarities except one. In general the hall reaches every important space of the house, the kitchen, the living room and so on. The example that does not work that way has a room that is reached by crossing the living room.

This type of hierarchical relation of spaces is not common in illegal housing. They usually appear in two situations. The first is the extension of living spaces from the main house towards the limits of the lot. The second case occurs as a first small construction within the lot that served as a temporary shed for the family until the main house was built. In both cases, the presented grammar has particular rules to respond to those demands.

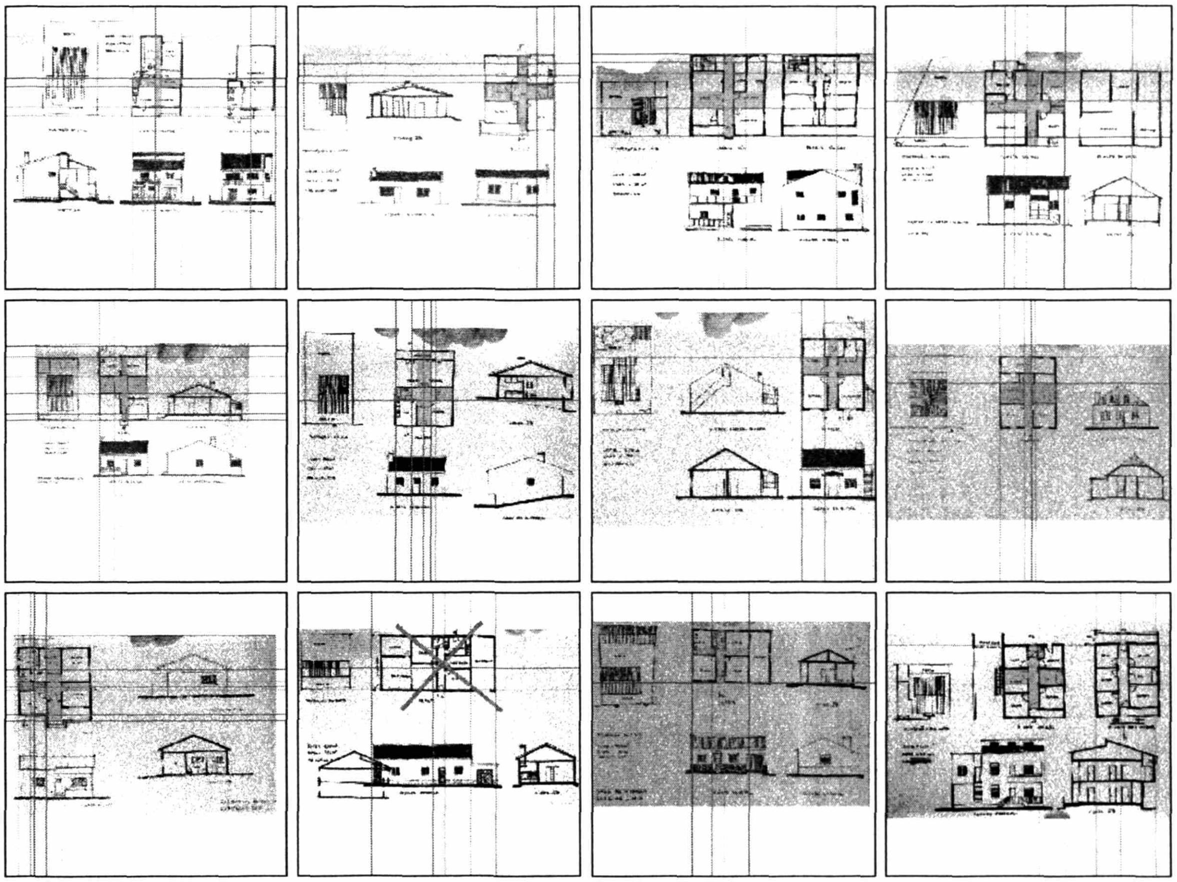


Figure 36 Twelve selected houses

The twelve houses selected were studied in geometric and topological aspects (Ferreira & al., 1985). All have in common the orthogonally direction of the walls. Some are detached and others are semi-detached. This option was regarding the dimensions of the lot. The lot had a quadrilateral shape and its length facing the street was in general smaller. All of main facades are parallel with the street. The garage alignment was made by the quadrilateral shape of the lot. Houses have one or two stories high. The spaces occupied between the house in the limits of the lot and the attic, were made against code regulations and are not seen in the drawings.

Regarding topological aspects the hall distributes the all main functions of the house. In this group there was a case that works differently. This is a particular case of the house that was used for temporary allocation or for spreading from the house. There are rules in the proposed grammar that respond to all cases.

Characteristics of the grammar

This grammar was created under the formalism of the parametric set grammar defined by George Stiny (1982) and under the concepts of a Functional Grammar defined by William Mitchell (1991).

This is a descriptive grammar akin to linguistic interpretation in that it does not make judges of right or wrong. Instead this grammar tries to understand and analyze what homeowners did when they built their dream houses. In opposition with a prescriptive grammar that infers a sort of good/bad value judgment in terms of the grammar's adherence to architectural language.

The grammar was created with symbolic shapes because the author believes that this form of creation represents the way homeowners conceptualized these illegal houses. This symbolic building roughly corresponds to a composition of objects idealized by mental images that were collected by the homeowners from vernacular or contemporary references. Homeowners picked paradigms inside or outside the place where houses were built and mixed them in a predefined shape and hierarchy. In topological perspective, these illegal houses seem like a Greek cross, where the four arms are stretched and shrunk to maintain low levels of depth to each function of the house. In each case, a central entrance can be reached from a main road. The grammar, also, tries to encapsulate the user's behavior in the space; where from the main hall all functions are reached, just as the rules are applied. The following images illustrate the idea of a cross that "exists" in the group of houses that were selected for the definition of this grammar. In schemata the representation of a cross is defined in rules.

The other reason for creating a set grammar rather than a standard shape grammar is that it is easier to define as a computational tool. In the set grammar of my thesis, the architectonic shape was divided into identifiably meaningful levels, but shapes cannot be parsed into more primitive parts of the shapes themselves. At some point in common practice, a shape, described as an icon, could be interrelated with parametric controls in order to create a new instance of the reference shape. The author thinks that the grammar as is may be useful for some research into this scenario, through computer implementation. Adding a search process might make the work even more productive.

This grammar uses a formalism that is close to the formalism defined by Terry Knight as communicative parallel shape grammars. The communicative parallel shape grammar concept seems to be closer to actual architectural shape descriptions and complexity. The result is not only the sum of the parts but also the quality of relations amongst those parts. In the communicative parallel shape grammar the separate components of the architectonic shape interact as a whole. For example, the areas of functional spaces are molded by other areas, i.e., the linear dimension of an interior wall will be dependent of the functions it closes or bounds. In other cases, the overall dimension of the lot and the relevant building code permits play a role in the creating the final outcome.

In this way, the proposed grammar created by this author unfolds architectural shape through morphologic aspects. Different meaningful shapes overlap but they are identified as primitives. Rules are composed with those primitives and A and B parts of the rule may not be equivalent in terms of involved primitives. This means that a rule can be applied if there are some conditions in some primitives that identifies the A part of the rule being transformed into B with more or less primitives then were selected in A. The result may be visual in terms of shapes, and computational, in terms of points that control those shapes and overlap the primitives of the same class or group. Later these primitives may be identified, meaning that they are identified because of labels that have in common and therefore altered.

Accordingly, rules for applications can then be applied in parallel, in the same or different space. The rules for the proposed grammar are described to play in Cartesian three-dimensional space simultaneously. This means a rule can be applied to the same floor or to a floor above or bellow. The effect of rules can be seen as they are being applied in the parametric schemata in different levels.

The application of the rule can be seen simultaneity in different spaces. A verbal example of how grammar runs is given below:

This is rule 1.

bC → BbD

This is the universe where rule 1 will apply.

AbCD

This is the result of rule application.

BbDD

Later in the process the grammar will detect the occurrence displayed above wherein two values are occupying the same space. In the event of this concurrence, a different rule will disambiguate the final result.

FORMAL DEFINITION

The formal definition of this parametric set grammar is:

$$GI = < Um, Ut, Vf, Ww, R, T, I) \qquad (1)$$

Um: Denotes the group of dimensionless shapes that perform the topologic part of the grammar.

Ut: Corresponds to the group of shapes that defines geometric elements which will be tested in the end, wherein dimensions of a shape are related with dimensions of other shapes.

Vf: Every shape has a label. Some labels are visible and others are not. The label of a shape denotes its position in the space as a point, along with its sub-shapes. The visible part is used here in a j=1 algebra for the visualization of functions.

Ww: Each wall shape has a weight in two-dimensional and three-dimensional space. The openings are of the same class but comprised instead of simple entities. They are arrangements of walls which include empty parts.

R: Denotes a group of rules that work in parallel with the vocabulary of shapes: A→B.

T: Defines affinity and Euclidian Transformation that controls rule application.

I: The initial shape, which corresponds to the quadrilateral of the lot, has two types of representation, one is the geometric representation with a given scale and the other is schematic.

Algebras

Initial shape, U_{02}, U_{03}

Grid, U_{02}, U_{03}

Functions, descriptions is V_{01}, shapes for visualization are schemata quadrilateral, V_{02}, V_{03}

Walls, W_{02}, W_{03}

Openings, W_{02}, W_{03}

Dimensions, V_{01}

Production

The rules are applied in this way:

$$[C\text{-}t\ (A)] + t\ (B) \qquad (2)$$

The transformation on the left side of the rule will identify and capture the information on shape C in the space. The rule identifies a set of primitives in C. Given necessary transformations the part A is identified and erased. The set of primitives of B will be introduced.

VOCABULARY:

Functions along with their relations and the construction elements of the house, support the application of the rules. Markers are defined by text and they are used to define relations between functions. They will control the topology part of the houses in terms of functions. Terminal and non-terminal shapes express the geometry or the morphology of the houses. The construction elements, here, are predefined.

A lattice of algebras is used to form both schematic and geometric shapes. For architectonic representation, there are two vocabularies: a schematic notation and a geometric notation. Both share the same rules and are used simultaneously. Each shape is treated as one point in shape algebras, but in analytical terms, sub shapes can interact with other sub shapes of other atomic shapes. Label algebras will provide the support for this framework.

A GRID

A support grid is the main structure of this grammar. Each cell is identified in the plan and in the space. In graphic representation, cells can have any quadrilateral shape. The graphic configuration of the cells will change depending on the legibility of the drawing for a schematic analyzes. Each cell is an atomic shape, a point shape that can be full or empty. Its coordinates are defined in the space and each cell controls the functions and other shapes that are inside it. When rules are applied, we will look for the geometric and for schematic, depending on the vocabulary of shapes. Each cell can have subordinate cells. To name the cells, a direction is chosen: from the left to the right from the button to the top. The subdivision of the grid is controlled by the rules.

This grammar tool took its visual inspiration from some drawing by Alvaro Siza and from plants. In this particular case lines of drawings have two orthogonal orientations; they are related with structural alignments and walls. This roughly corresponds to the definitions of *lineamenta,* (a collection of lines), which, for Gerhard Schmitt (1991), meld architectural drawing and the process of design. Apart from the Palladio foundation grammar, the cellular automata formal model served as a reference for using space between lines. The above images show some drawings by Siza where coordinate lines are used to guide designs. The building in the drawings is the Banco Pinto & Sotto Mayor in Oliveira de Azemeis, Portugal. This is not a preliminary drawing yet, due to the complex articulation of the alignment it was necessary to "input" non-tangible lines into the drawing.

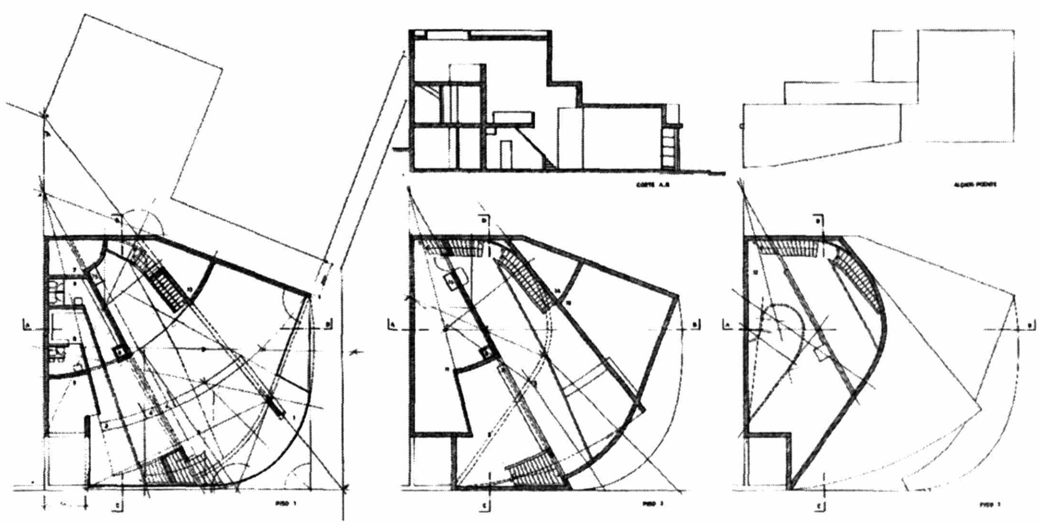


Figure 37 A Siza's project*

The grids that are used in the schematic section do not have dimensions; therefore, they can stretch or shrink whenever needed, for the sake of legibility. Only at final stage of the grammar will the grid have a shape with certain dimensions. According to this schedule, rules have to be applied in a different manner. Some grids exist inside others in a hierarchical way, and a rule was created to control this operation.

RULES

The rules for the completed grammar are comprised of a set of rewriting rules that will match and replace shapes. Rules work inside the grid and they control the deepness of the grid. There are implementation rules for defining the position of the house inside the lot; addition rules introduce the main spaces of the house, (i.e., the living room) from the hall space, for example, the living room. Dissection rules define the subdivision of the space locally. Concatenate rules gather adjacent cells of the same function. Finally details rules that serve to clarify the overall layout. Rules for applied architectural components, such as doors and windows, are embedded in the previous. Therein, a value K controls the application of the rules for the key functions of the house. The K value works with addition and dissection rules. The application of the rules stops when a shade mark is introduced. Then only concatenate and detail rules can be applied, and the final solution is tested against geometric constrains for area and for correct linear dimensions. If the final result does not pass these tests the grammar has to be applied again, from the beginning.

Introduction of implementation rules
Introduction of Addition rules
Introduction of Dissection rules
Introduction of concatenation rules
Finally geometric verification

Implementation rules

The implantation of the house will depend on the configuration of the lot and on the cost of construction. The lot can be subdivided in two: i.e., two relatives might buy a lot and later subdivide it. Other reasons determine whether the house will be a detached or a semi-detached structure. In general, lots have more or less 400 sq meters of area.

The user purchases a lot that corresponds to a fraction of the land. Part of the lot is used to build the street and, later, a sidewalk of inconstant measure.

Depending on the restrictions, other rules can be applied. The implantation of the house in the lot usually corresponds to lot dimension restrictions, determinations for implantation do exist. The general will of the homeowners is to get a detached house, and therefore, the house is put in the middle of the lot. Before this happens, the lot is sometimes occupied by a small construction that corresponds to a temporary and economic shed for the family to live in until each homeowner could get enough money to start the "big" house. Later this small temporary building can be rented out for extra income.

If the lot is not large enough, a semi-detached house becomes the next best option. There are other situations that lead to similar shape solutions, such as the above example of two brothers buying a lot which they will subdivide and build upon. A variation of this example might occur when the two brothers buy a lot which they then divide in equal parts, each of which results in a different story level.

All of these rules reflect different aspects of the implementation of each house in its respective lot, and there are general rules to apply for each situation. In each case, the alignment of the façade is parallel with the road or street. The alignment of the garage depends on the geometric configuration of the lot.

On other hand, the main door is perpendicularly aligned with the gate in the wall facing the street.

In general, houses in this study are two stories high. Sometimes the attic can be transformed into a new dwelling or results from an interior extension of the house. These extensions might serve as dwelling for new offspring.

The grammar starts from the representation of a lot that is the result of a land division. We can find exceptions, but quadrilateral polygons commonly define the boundaries of each lot. The street is defined after this division, and therefore the main orientation for each lot is defined by the street. The house will be designed with the main façade facing the street. For the first rule, the initial shape is made in a transformation from geometric graphic information to a schematic one. Both geographic orientation or topography characteristics are meaningless. The street will rule over design.

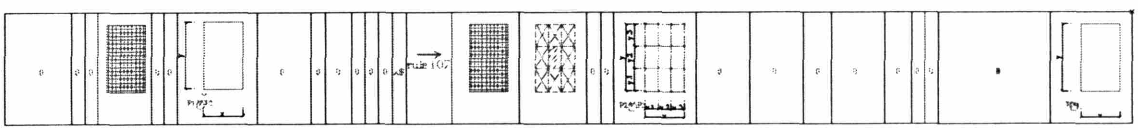


Figure 38 A implementation rule

Rules of addition

The next sequence of the rule application to take place refers to the addition rules. They insert the key functions of the dwellings in a proper order, given by a constant K. The cells of the grid are identified as: direction x=(x1+x2+x3), the same for direction y. In addition, x1 = (x1.1+x1.2+x1.3). This is a succession of values with a maximum number of 4 subdivisions in each stage. This process serves to identify inner cells inside a necessary hierarchy of sub cells in sub grids. Not all elements of the hierarchy are needed. The z values are given with 4 general levels: P0 = ground terrain, P1 = ground floor, P2 = second floor and P3 = attic or roof floor. Each intersection point of the grid is connected with a Cartesian point **P= m, n, o** for any value of m, n and o that belongs to real numbers. From the schematic references this point is in the lower left of a cell point.

The main distribution is made from the hall function. It keeps track of the name of all other applied functions. From the start, a cell identified with the hall function is introduced. From this point on, other functions will be introduced and edited. There are some spots or boundaries where spaces will meet differently, for examples, in the instance of stairs when the level is changed.

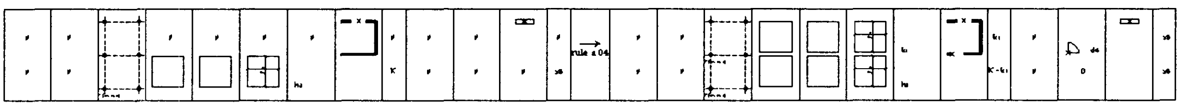


Figure 39 A addition rule

A meaning is parsed into different primitives. The A side does not correspond with the B part.

After the first division, there will be rules to expand functions on each floor. The hall expansion will be perpendicular to the street. Slabs are incorporated in the rules. The following stage will subdivide function spaces. Rules are applied in accordance with previous inputs.

Rules for walls and openings are included in the general rules, and overlapping, inherent in the process, will be controlled by refinement rules. These primitives can be identified if they share two or more points at the same space. Rules will create a wall between different functions. Later, functions that are divided will be gathered. In addition, collected dimensional information will be incorporated into each cell.

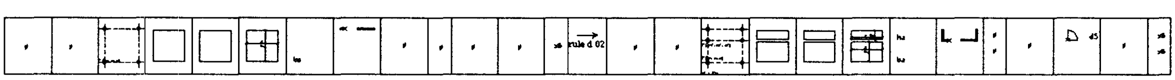


Figure 40 A dissection rule

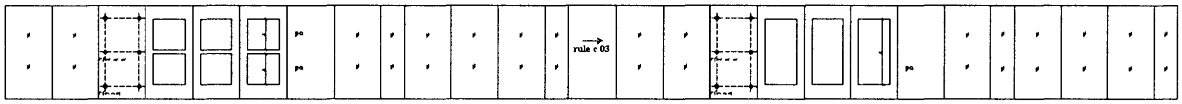


Figure 41 A concatenation rule

The connection of the walls, in general, seems to be problematic. This is a case of external walls, and I want to use set grammar only. This joint belongs to two shapes (s_a, l_a) and (s_{a1}, l_{a1}). If an interception is detected by the sub entities of the shape, it can be substituted by another shape with a pre-defined length. It seems easy to implement such a rule because walls, in this study, are orthogonal. Sub entities are defined with points and intersection points can be detected. It can also define the orientation of the wall to decide on which side other shapes, such as (s_b, l_b) and (s_{b1}, l_{b1}), should be introduced.

Apart from the general rules which encapsulate different components, we have to refine some information. Mostly, these refines are related with walls. At this point the grammar introduces particular rules for walls, doors and windows, but only to refine final shapes.

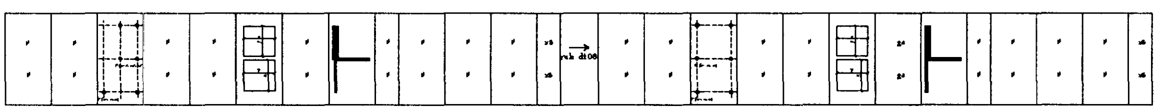


Figure 42 A detail rule

A full description of the rules is in the appendix C and the rule application in the appendix D at the end of this text.

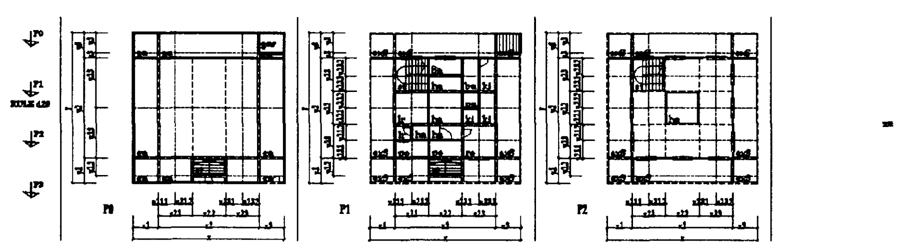


Figure 43 Example of a rule application

INITIAL SHAPE:

The geometric lot is the initial shape; the grammar starts and ends with this shape. This grammar could be the continuation of the grammar mentioned for the allotment. A polygon, usually an irregular quadrilateral shape, was given. Its relation with the street is important; the main elevation of the house always runs in parallel with the street. When the lot is edged by two streets, homeowners take to the one they think more important, which is selected by factors of width or length, and they put the main elevation parallel to the selected street.

The final result is tested against the dimensions of the lot, and the quadrilateral shape of the house will not change despite the irregularity of the lot. The last rule that corresponds to the adaptation of the house within the lot shows only one constraint, which is that the offset of the limits of the lot to any part of the façade of the house has more or less 3 meters in a two parallel vertical plans. Despite of being illegal, these houses execute that rule in every case. There are very few examples where this rule is not applied.

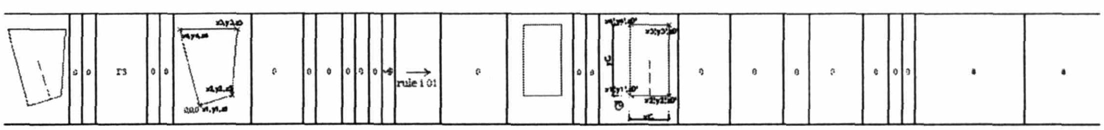


Figure 44

There are no key stages for applying this grammar, and primitives are applied in parallel. There are however some restrictions. Rules should be applied from the bottom to the top of the house. Starting from the ground when everything is done, the application of the grammar should lead to the upper level. This process does not prevent the fact that some rules when applied may introduce shapes on other levels.

To stop function introductions, grey marks are introduced over spaces which are related with functional meaning. The next steps gather same-function spaces and test geometric constraints.

GEOMETRIC EVALUATION

Adequate values or restrictions to apply in the grammar are given as entry data. The output data for evaluation is represented in two and three-dimension notations. At the moment there are only two visual notations, but information is formalized in space. Later in the work, when a computer implementation was created, these two moments of representation can be easily defined with the help of a graphic software environment.

To start the grammar one needs to introduce restrictions.

The restrictions are:

Dimension of the lot, and its relation with the road
Building Costs
Number of levels
Number of rooms
Lot partitions
Number of dwellings

In the end, the output has the following information:

Graphic information is in both the schematic and geometric vocabulary of shapes, the later of which can be used in different system projections, such as the axonometric, linear perspective, or orthogonal. The cost is defined by an estimated value.

Illegal housing
Restrictions for the functions of the house

Units: meters, square meters	T0 Area(x*y) sq meters	T0 Length(x), meters	T0 Width(y), meters	T0 Height, meters	T1 Area(x*y) sq meters	T1 Length(x), meters	T1 Width(y), meters	T1 Height, meters	T2 Area(x*y) sq meters	T2 Length(x), meters	T2 Width(y), meters	T2 Height, meters	T3 Area(x*y) sq meters	T3 Length(x), meters	T3 Width(y), meters	T3 Height, meters	T4 Area(x*y) sq meters	T4 Length(x), meters	T4 Width(y), meters	T4 Height, meters	T5 Area(x*y) sq meters	T5 Length(x), meters	T5 Width(y), meters	T5 Height, meters
	One floor												Two floors											
Hall	+∞	>1.50	>1.50	>2.20	+∞	>1.50	>1.50	>2.20	+∞	>1.50	>1.50	>2.20	+∞	>1.50	>1.50	>2.20	+∞	>1.50	>1.50	>2.20	+∞	>1.50	>1.50	>2.20
Corridor	+∞	>1.10	>1.10	>2.20	+∞	>1.10	>1.10	>2.20	+∞	>1.10	>1.10	>2.20	+∞	>1.10	>1.10	>2.20	+∞	>1.10	>1.10	>2.20	+∞	>1.10	>1.10	>2.20
Living Room	>10	>2.40	>2.40	>2.40	>10	>2.40	>2.40	>2.40	>12	>2.40	>2.40	>2.40	>12	>2.40	>2.40	>2.40	>12	>2.40	>2.40	>2.40	>16	>2.40	>2.40	>2.40
Kitchen	>6	>2.00	>2.20	>2.20	>6	>2.00	>2.20	>2.20	>6	>2.00	>2.20	>2.20	>6	>2.00	>2.20	>2.20	>6	>2.00	>2.20	>2.20	>6	>2.00	>2.20	>2.20
Bath	>4.50	>1.50	>1.50	>2.20	>4.50	>1.50	>1.50	>2.20	>4.50	>1.50	>1.50	>2.20	>6.00			>2.20	>6.00			>2.20	>7,50			>2.20
													>4.50	>1.50	>1.50	>2.20	>4.50	>1.50	>1.50	>2.20	>4.50	>1.50	>1.50	>2.20
													>2.60	>1.15	>1.15	>2.20	>2.60	>1.15	>1.15	>2.20	>2.60	>1.15	>1.15	>2.20
Rooms	-	-	-	-				>2.40				>2.40				>2.40				>2.40				>2.40
1	-	-	-	-	>10.5	>2.40	>2.40		>10.5	>2.40	>2.40		>10.5	>2.40	>2.40		>10.5	>2.40	>2.40		>10.5	>2.40	>2.40	
2	-	-	-	-	-	-	-	-	>9	>2.10	>2.10		>9	>2.10	>2.10		>9	>2.10	>2.10		>9	>2.10	>2.10	
3	-	-	-	-	-	-	-	-	-	-	-	-	>9	>2.10	>2.10		>9	>2.10	>2.10		>9	>2.10	>2.10	
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>6.5	>2.10	>2.10		>9	>2.10	>2.10	
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	>6.5	>2.10	>2.10	
Varanda/porche/marquise	+∞	> 1.80	< 1.80	>2.40	+∞	> 1.80	< 1.80	>2.40	+∞	> 1.80	< 1.80	>2.40	+∞	> 1.80	< 1.80	>2.40	+∞	> 1.80	< 1.80	>2.40	+∞	> 1.80	< 1.80	>2.40
Storage	-	-	-	-	>0.50	>0.60	>0.60	>2.20	>0.50	>0.60	>0.60	>2.20	>0.50	>0.60	>0.60	>2.20	>0.50	>0.60	>0.60	>2.20	>0.50	>0.60	>0.60	>2.20
Closets	-	-	-	-	>0.48	>0.60	>0.60	>2.20	>0.48	>0.60	>0.60	>2.20	>0.48	>0.60	>0.60	>2.20	>0.48	>0.60	>0.60	>2.20	>0.48	>0.60	>0.60	>2.20
Main Stairs	-	-	-	-	-	-	-	-	>5.20	>0.80	>0.80	>4.80	>5.20	>0.80	>0.80	>4.80	>5.20	>0.80	>0.80	>4.80	>5.20	>0.80	>0.80	>4.80
Suplement	6				4				6				8				8				8			
Total net*	>26.50				>35				>48				>60,5				>67				>81,5			
Total gross	35				52				72				91				105				122			
Garage	>9	>3.00	>3.00	>2.20	>9	>3.00	>3.00	>2.20	>9	>3.00	>3.00	>2.20	>9	>3.00	>3.00	>2.20	>9	>3.00	>3.00	>2.20	>9	>3.00	>3.00	>2.20

Observations

Distance between the walls of the lot with windows	< 3.00
Distance between the walls of the lot without windows	>0
Dining Room can be one of the rooms above	

Figure 45 Geometric rules defined by the Building National Code

Names for the functions are as follows and the levels are related with the depth of each function related to the whole:

Functions level 1

Str	Street (entry)
Str(c)	Street (entry for a car)

Functions level 2

Ga	Garden
exS	Exterior space inside a lot defined by two parallel vertical plans: one intercepts the implementation and the other the limits of the lot.
St2	Stair in front of the main door

Functions level 3

Ha	Hall, includes the corridor (sometimes level 4)

Po	Porch
Gar	Garage
Ma	Marquise

Functions level 4

Lr	Living room
Ki	Kitchen (sometimes level 3)
St	Stairs (sometime level 3)
Ro	Room (the value given to K makes distinction between rooms. Roughly there are three types as can be seen in the code building.)
Ba	Bath
Sto	Storage

Functions level 5

Pa	Pantry
Cl	Closet
Va	Veranda, balcony

Although homeowners did not have building permits, these houses were "made by the book". This means the Portuguese building code was used in general, except in those cases mentioned elsewhere which occupied the space, between the symbolic house and the limits of the lot. This legal process of design which the houses loosely followed was fully achieved in 1995 when the state created Aegis areas. Homeowners of these illegal houses can complete legalization if they conclude two steps: 1) the legalization of the quarter and then, 2) if the house respects the general rules approved for the quarter, the legalization of the house will follow. Therefore, the restrictions for the internal space of each house are shown in the next table.

A grammar whose main goal is to analyze actual houses could be used to test new ones against the constraints of the geometry, lot dimensions, and estimated costs. If the result does not fit the user's needs, the grammar will restart again. If this was the case, I believe the geometric results could be improved, along with additional qualifying input, in cases for instance, like technical construction improvements.

Visual notation for the functions is given by a quadrilateral shape and a visible label. When a cell is created, it must be subordinated to the context. The numbering of the cells goes from the left to the right. The rules are applied until the grid has empty cells. Each subdivision cell keeps track of its dimensions, until reaching the concatenation or reduction rules stage wherein sums of separate cells with the same function are named.

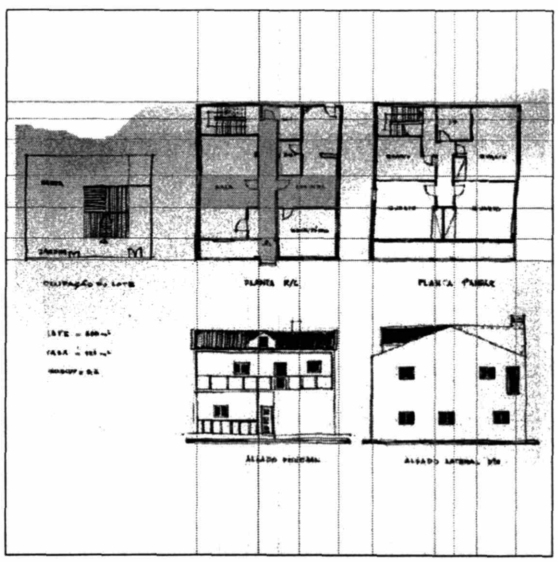


Figure 46 One of the twelve samples of study

The following drawings show four plans of a selected house from the group. While these plans supply only two-dimensional information, the elements of the grammars are described in a full three-dimensional framework. The overall rule applications are in appendix D. In this appendix, there is a fully described list of construction elements in two and three notations.

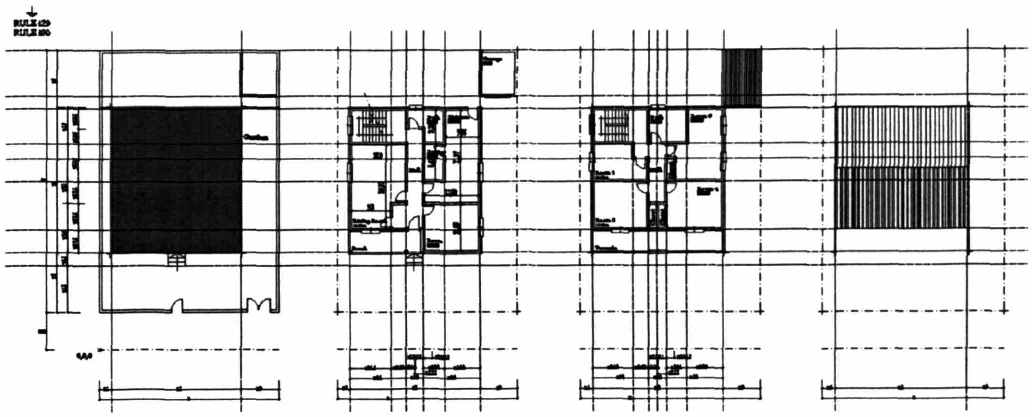


Figure 47 A geometric information of an existent case

CONCLUSIONS

I believe the grammar explained here is the way to analyze this housing typology. We see through the use of this tool how topologic and geometric elements are not so unrelated from common layouts. Homeowners put together different personal paradigms in an ordinary style. The organization of these spaces is simple and grounded in a Greek cross in terms of topologic thinking. Arms of the cross could be stretched or shrunk, depending on lot dimensions and economic resources. Orthogonality is a key rule for these houses.

Economic reasons and taste led to the illegal housing solutions studied here. Most users came from places where houses are articulated with a place, in a vernacular environment. On other hand, orthogonality gives a sense of order and urbanity. The constant orthogonality was intended to help the user integrate into the city. Structures were determined by economic solutions, hot only because of time but also because that is the way masons in the studied area were trained and accustomed to working. In most cases, the drawings which supported these houses were made by draftsmen.

Some of these houses were conceptualized in place by homeowners, walking and talking with the mason and deciding house organization on the spot. As is mentioned in the work of Jorge Spencer that quote the works of J. Coulton and S. Kostof, Greek architects made projects described by words. Everything was in the mind of the architect and everything was understood by the mason.

The grammar is now ready to be introduced in a computer implementation and allow prospective work in the future. The author can foresee three stages: in the first stage, the framework is introduced in computer implementation and the user plays the grammar according to restrictions controlled by the computer. In the second stage the user plays with the grammar from a collection of alternatives given by the computer, based on a heuristic search algorithm. Finally, the last stage would be to reformulate the framework of the grammar in order to allow parsing construction shapes into primitive shapes in opposition to parsing primitive shapes of the construction components.

SUMMARY

This chapter argues that a formal set grammar description is closest to the process of conceptualization for the illegal houses in question. Spatial organization for these houses originated from hall spaces, and other spaces were decided accordingly. Geometric dimensions of these "dots" were dependent mostly on economic factors. Dots are defined by the author as the set of functional and symbolic spaces that are introduced in the space with a selected hierarchy. The combination of such dots and a structural grid made the final shape of the houses.

6 CONCLUSIONS

Shape Grammars abridge the essence of any shape transformation, in ways equivalent to Noam Chomsky's transformational-generative grammar for verbal languages. The expression 'Standard Shape Grammar' designates the essence of shape grammar as defined by George Stiny and James Gips (1972). Recent works of George Stiny and Terry Knight strengthened this concept in formalistic terms. Standard Shape Grammar uses both graphic and analytic components of a shape in order to emphasize shapes languages, along with the addition of shape perception. The author's work here states, as has been said elsewhere, that different results will occur when carrying out tasks with shapes in either analytic or its graphic modes. Furthermore, as analytical and graphic languages are different, translations between them are not always possible.

Shape grammar formalism is used primarily for work with representative shapes and to complete architectural shape representations. In the latter case, architectural shape is described by a set of different representation types which are translated into formalism by different algebras. In the proposed grammar, the procedure allows for a parsing of different qualities of meanings and enables users to work with separate rules which still do not fulfill the formal concepts of Shape Grammars. The author argues that such an analysis was not needed in this particular situation.

This is a study of shapes that attempt to encapsulate the dreams of homeowners. Shape grammars are used to describe architectural phenomenon in increasingly more accurate ways, from simple grammar, parallel grammar, to communicative parallel grammar (Knight, 2004). These various grammars increase our power to deal with the complexity of the architectural shape in the computational field. With a defined grammar, we have infinite solutions within a solution space. Whether the occurring architectural spaces are more or less confined, the limitless space of shape grammars enables a user to apply new rules as needed through standard shape grammar functions.

With further systematic exploration, with the help of computer implementations and using a complete standard shape grammar, rules could transgress language by creating and utilizing emergent shapes. Chomsky's work on natural languages raises this possibility and while its potential was not explored here, it should be considered in later architecturally specific shape work.

Herein, shape grammars have helped to accurately describe the dream houses of the homeowners of a group of illegal houses in Lisbon. As seen in this work, shapes can encapsulate the meaning of a home for the homeowner. Shape grammars also introduce some intelligibility to this apparent chaos. Although, the author cannot guarantee of the correctness of this grammar for the entire universe of the subject with 100% certainty, his work has created a very serious approximation of what exists in the field from the collected sample. These examples were collected from a previous work from Portuguese literature, which helps to certify the randomness of the sample. In addition, using the shape grammar concept with the formalism of the set grammar has helped achieve his thesis goals by parsing the components of the architectural shape.

However, one big issue that traverses his work relates to the type of representation that architects actually understand. Since shapes can have different qualities, architects may use them in different ways for conceptual purposes. While one quality is no better than the other, yet, we may have different preferences. Therefore, it is important to do computation after understanding exactly what designer wants.

The author's work herein has created a symbolic grammar to help to represent the dream house, based on house analysis morphology, and original homeowner conceptualizations. This formal grammar can in the future offer good solutions to build different designs that fulfill the concept of the shape grammars. After all, this type of housing has a very common layout solution.

Due to its computational implications and based on the work of others already mentioned, the author has utilized a computer tool to introduce as many concepts as it was possible. Appendix H reports on a first contact made through a very simple shape grammar that uses two rules.

In this particular context of the work, it was also speculated to link two computer implementations, grounded in two different formal concepts that could work together into one: the SGtools and a set of heuristic rules. The first provides intelligibility and generative power; the second intends to help to find, inside the space of a grammar, a good solution for a designer.

To conclude, in the background of his thoughts, as also a teacher, there is a will of helping architects to start using computation and computers for all purposes of architectural design. The author really does not believe computation can be a kind of fashion neither the use of computers. Since Building Information Management (BIM) systems arrived firstly with

Archicad in the 90s, architectural representation only lacks a ground where architects can work: alone with computer or/and communicating with others. Geoffrey Broadbent (1973) said that architects were afraid of using computer for the same reasons that draftsmen were. As a lecturer of disciplines related with shapes and their formal representation, the author has helped draftsmen to overcome this problem now he would like to help architects. In addition, the scale is no more a problem as he mentioned before in the chapter 3. Computer representations are a good system to produce, test, and design and consequently avoid unnecessary final construction and yet allowing taking good decisions

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ILLUSTRATION CREDITS

Figure 2. Instituto Nacional de Estatística (INE), Auditoria Ambiental (AA) Gabinete de Estudos e Planeamento (GEP) do Ministério das Obras Públicas, Transportes e Habitação.

Figure 3. Figure three in the work of Margarida Sousa Lobo (1975).

Figure 5. Colleted from Câmara Municipal de Cascais; Second image: page 78 (PDM, 1991); Third picture: Seixal, in Fernão Ferro: um plano de reconversão Urbanistica, Luís Bruno Soares & al., in Sociedade e Território, 1, pages 51.

Figure 9. In the article Urbanização Clandestina e Politica Urbana. of Luís Bruno Soares, of Sociedade e Território, 1, page 25.

Figure 10. Aerial Photography, March 2000 AML, Geometral.

Figure 13. In the work of (ferreira, 1985).

Figure 14. In Arquitectura Popular Portuguesa, 1988, AAP.

Figure 15. In the work of (Pierluigi Nicolin 1986) pages 90.

Figure 25, AAP, Arquitectura Popular Portuguesa, 1980, Lisboa

Figures 33 and 35. Aerial Photography, March 2000 AML, Geometral.

APPENDIXES

APPENDIX A

EXAMPLES

These examples were retrieved from this work:

Estudo Sociológico da Habitação Clandestina na Área Metropolitana de Lisboa

Perfil Social e Estratégias do "Clandestino"

Edição: Centro de Estudos de Sociologia, ISCTE

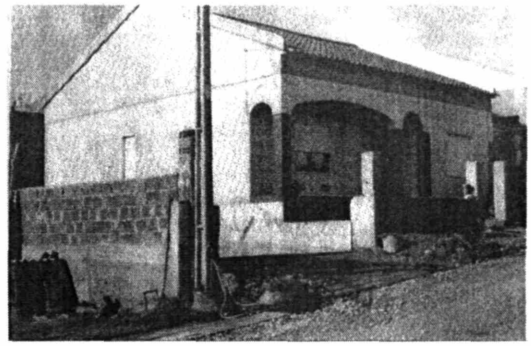
Authors:

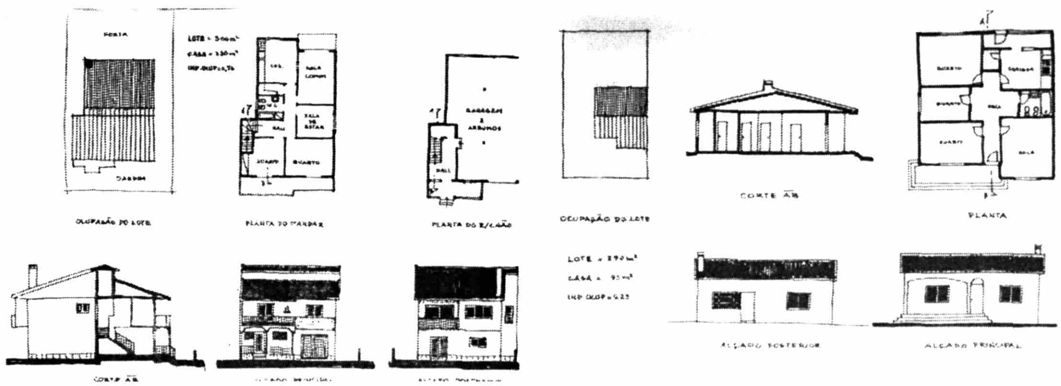
António Fonseca Ferreira, Isabel Pimentel Guerra, Nelson Matias e Robert Strussi.

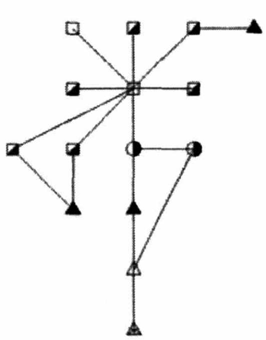
1985

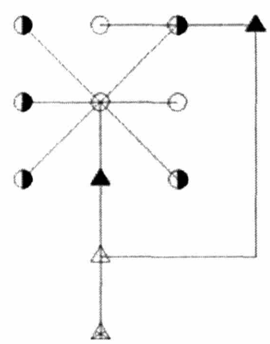
It was analyzed the functional behavior of the houses.

CASES 1 AND 2









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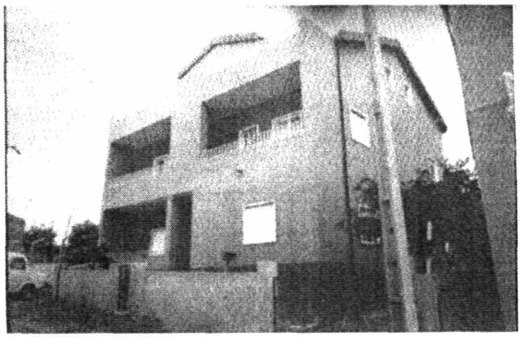

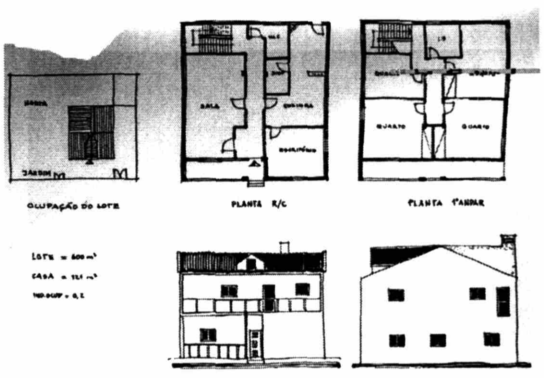

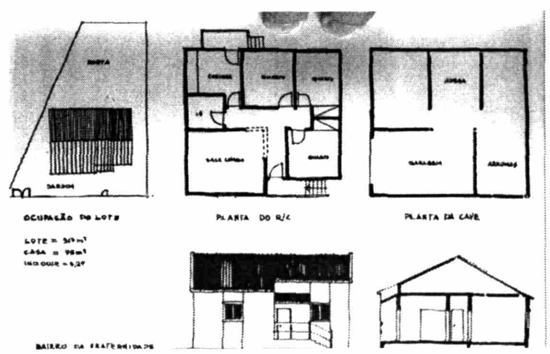

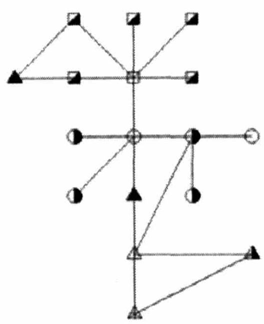

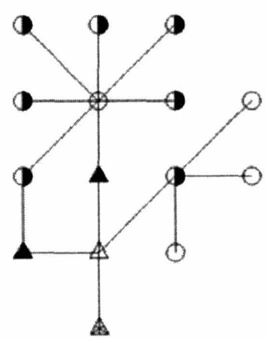

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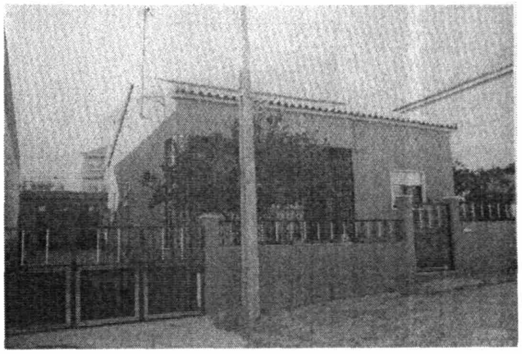

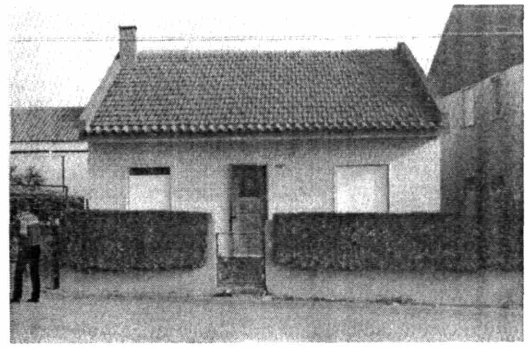

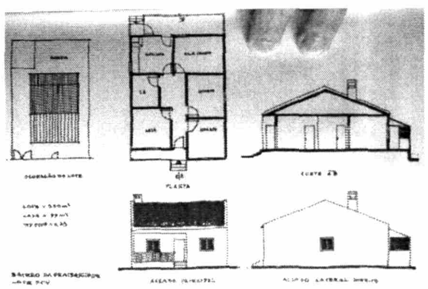

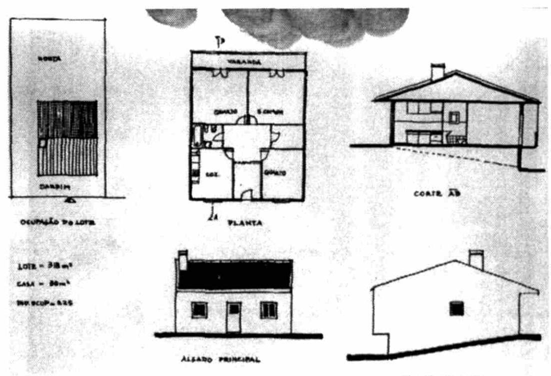

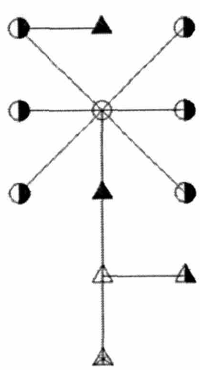

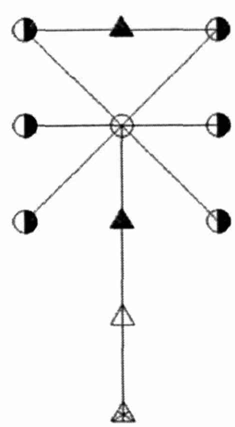

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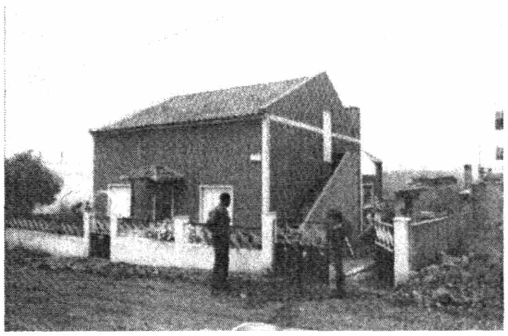

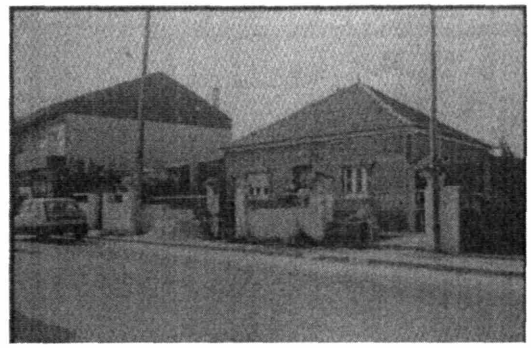

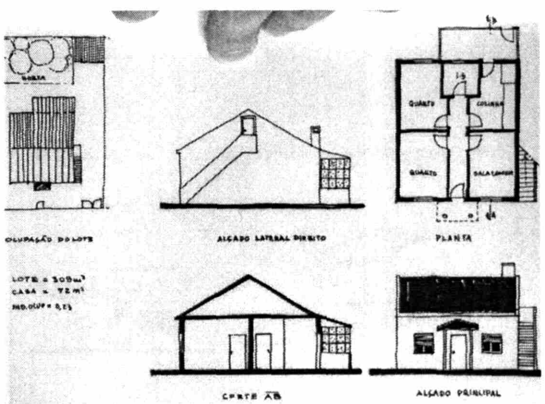

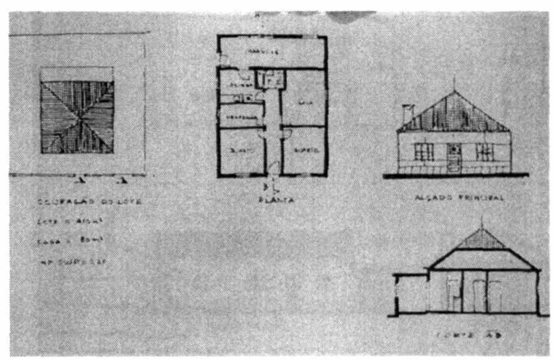

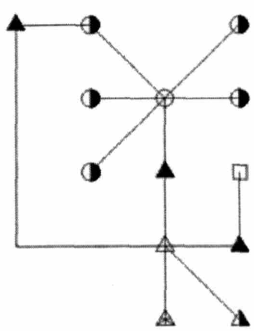

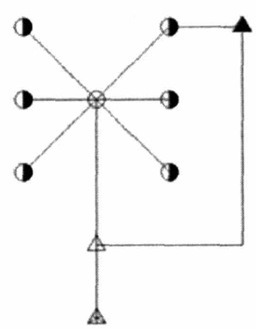

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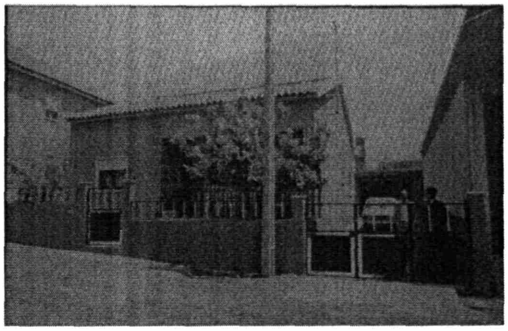

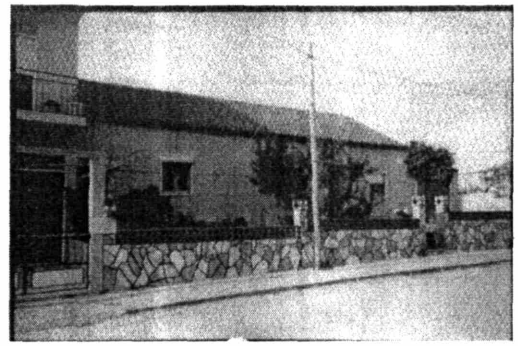

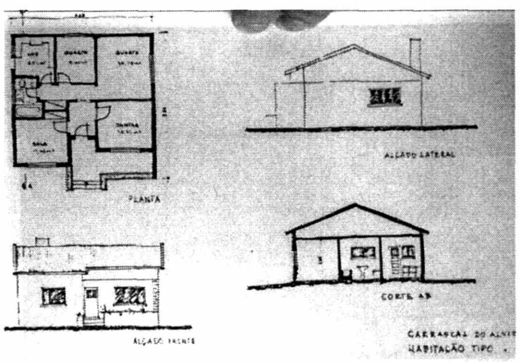

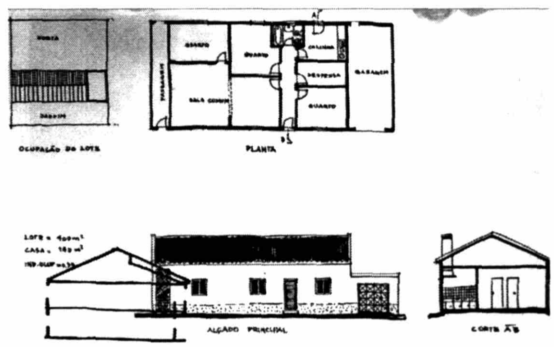

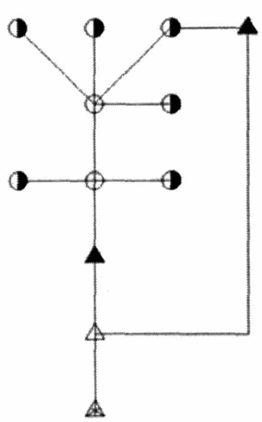

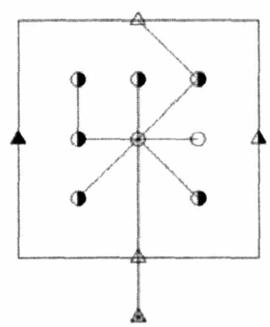

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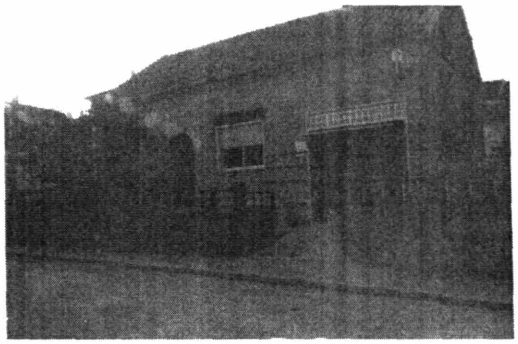
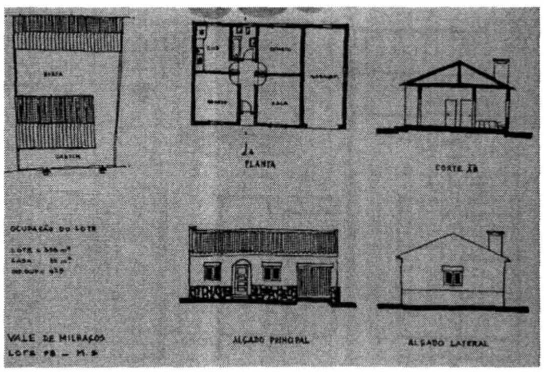
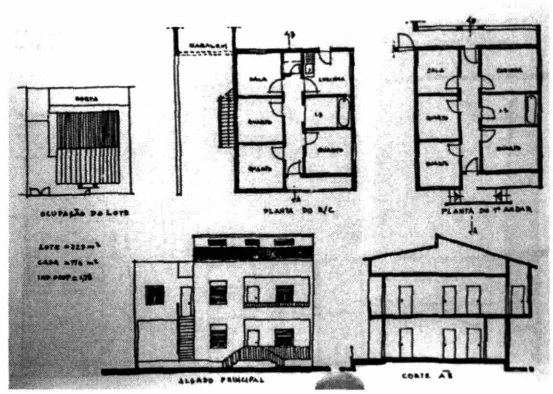
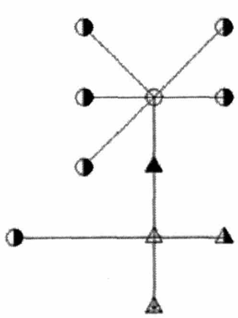
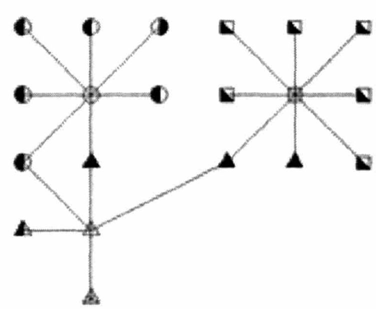








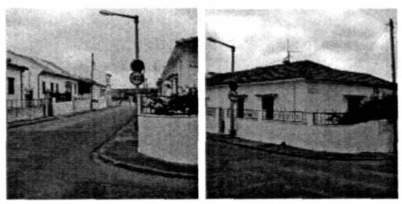


APPENDIX B

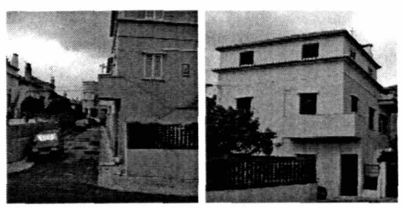
IMAGES OF HOUSES OF REFERENCE FOR HOMEONERS, STATE EXAMPLES

Before 1974

Caselas, Lisbon

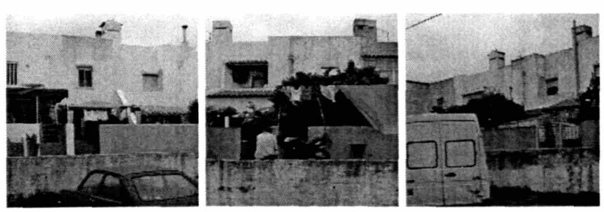


Serafina, Lisbon



Alvito, Lisbon

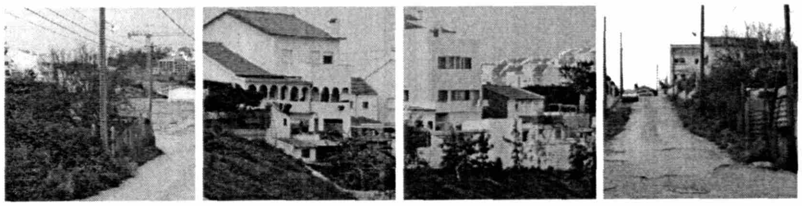
After 1974



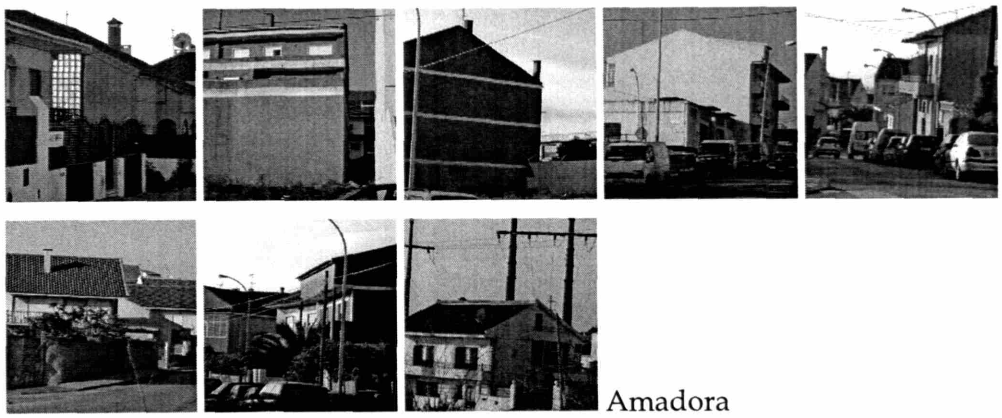
Cruz de Pau, Seixal

Corroios, Seixal

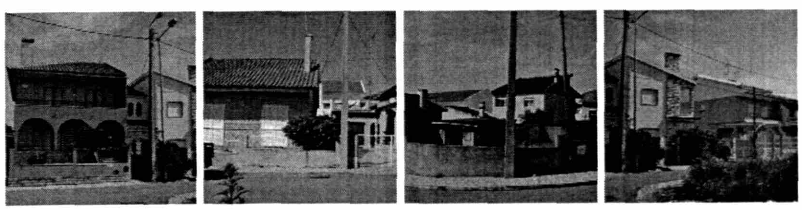
CLANDESTINE HOUSES



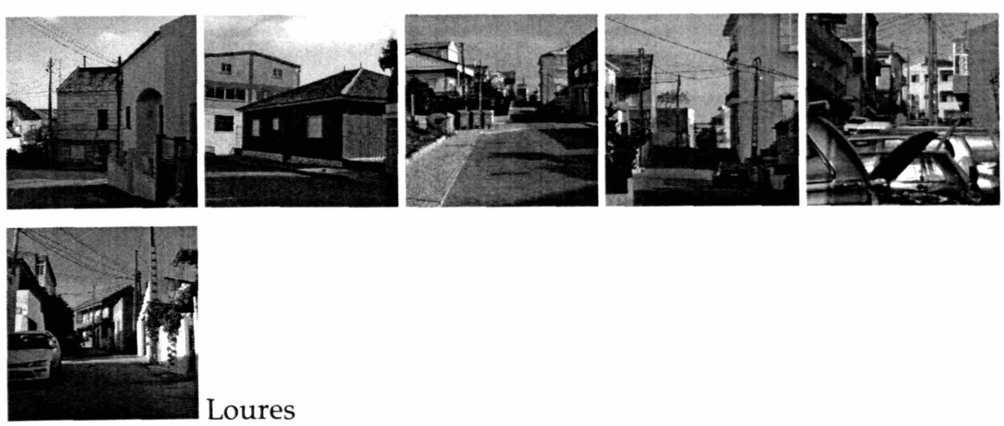
Almada



Amadora



Cascais

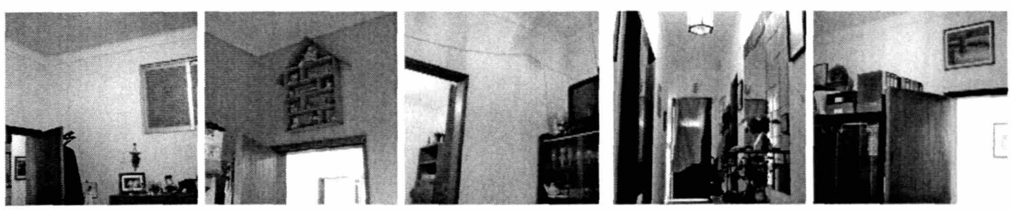


Loures

Seixal

Loures

Interior of a house at Loures Quinta das Queimadas, Second Floor



Interior of a house Loures, Quinta das Queimadas, First Floor.

Exterior of a house Loures, Quinta das Queimadas, Exterior

APPENDIX C

This appendix has the description of the rules of the grammar.

FUNCTIONS AND LEVEL OF DEEPNESS

Functions level 1

1 str street (personal entrance)

2 str(c) street (car entrance)

Functions level 2

3 ga garden

4 exS Exterior space inside the lot

Functions level 3

5 ha hall, includes the corridor (sometymes level 4)

6 po porch

7 gar garage

8 ma marquise

Functions level 4

9 lr living room

10 ki kitchen (sometimes level 3)

11 st stairs (sometime level 3)

12 ro room

13 ba bath

14 sto storage

Functions level 5

15 pa pantry

16 cl closet

17 va varanda, balcony

Entry data

Number of the rooms: defines the type of the house.

Number of the floors: different floors can be the extension of the house or different dwellings.

Partition of the lot: it can be dividing into a half or added into other. Although in this case, the house is built regarding only one. Sometimes, the additional lot is sold.

Time for building: because of economic reasons, some lots were occupied first with a small house in the botton of the lot.

Numbers of dwellings: many reasons made this possible, more than one dwelling by a plot.

Output data after introduced in a computer implementation

1. Different plans for each level (notation in 2D)
2. Different elevations (notation in 2D)
3. Isometry (notation in 3D)
4. Perspective (notation in 3D) Viewpoint at personal entrance

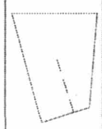
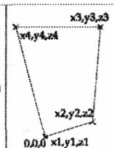
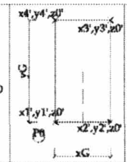
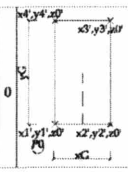
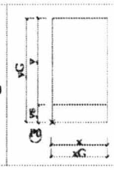
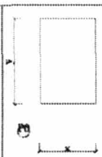
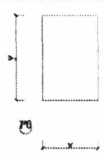
[Each representation has a proper notation (symbols)]

Glossary

l = level of floors
n = local variable, $n \in N$
fn = identification of the functions $n \in N$
k = variable that keeps track of the inserted functions

P0, level of the ground of each lot
P1, ground floor of the house
P2, first floor of the house
P3, level of the attic

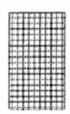
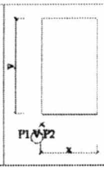
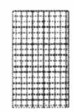
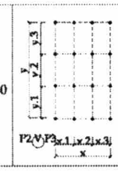
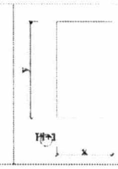
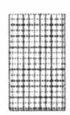
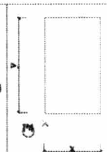
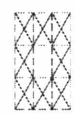
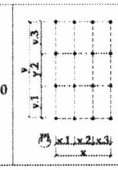
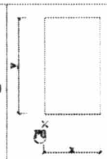
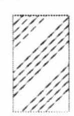
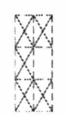
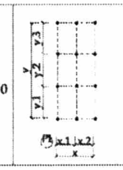
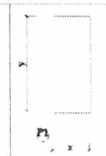
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
	0	0	PS	0	0		0	0	0	0	0	0	x$	→ rule i 01	0		0	0		0	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 02	0		0	0		0	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	0	→ rule i 03	0		0	0		0	0	0	0	0	0	0	#	#

IMPLEMENTATION RULES

	Rule i04	Rule i05	Rule i06
PARAMETRIC SHAPE SCALE 1/A	0	0	0
SPACE BELOW	0	0	0
SPACE ABOVE	0	0	0
SELECTED SPACE			
PAVEMENT MODULE	0	0	0
CEILING MODULE	0	0	0
DIMENSIONS			
FUNCTIONS	0	0	0
WALLS	0	0	0
INPUT DATA	0	0	0
STRUCTURE	0	0	0
DOORS	0	0	0
WINDOWS	0	0	0
COST	0	x$	x$
RULE	→ rule i 04	→ rule i 05	→ rule i 06
SPACE ABOVE	0		
SELECTED SPACE			
PAVEMENT MODULE	0	0	0
CEILING MODULE	0	0	0
DIMENSIONS			
FUNCTIONS	0	0	0
WALLS	0		
INPUT DATA	0	0	0
STRUCTURE	0	0	0
DOORS	0		
WINDOWS	0	0	0
COST	0	0	0
PARAMETRIC SHAPE SCALE 1/A	#	#	#
DIMENSIONS SPACE ABOVE OR BELOW	#		

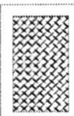
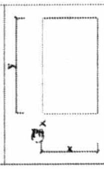
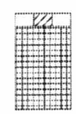
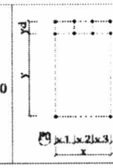
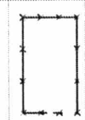
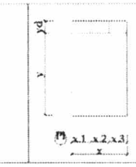
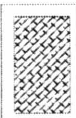
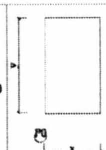
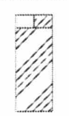
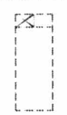
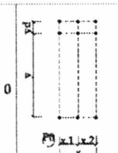
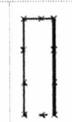
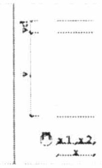
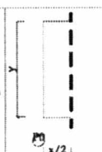
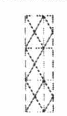
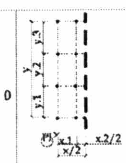
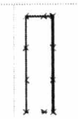
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 07			0	0		0	0	0	0	0	0	0	#	
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 08	0		0	0		0	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 09			0	0		0		0	0	[illegible]	0	0	#	

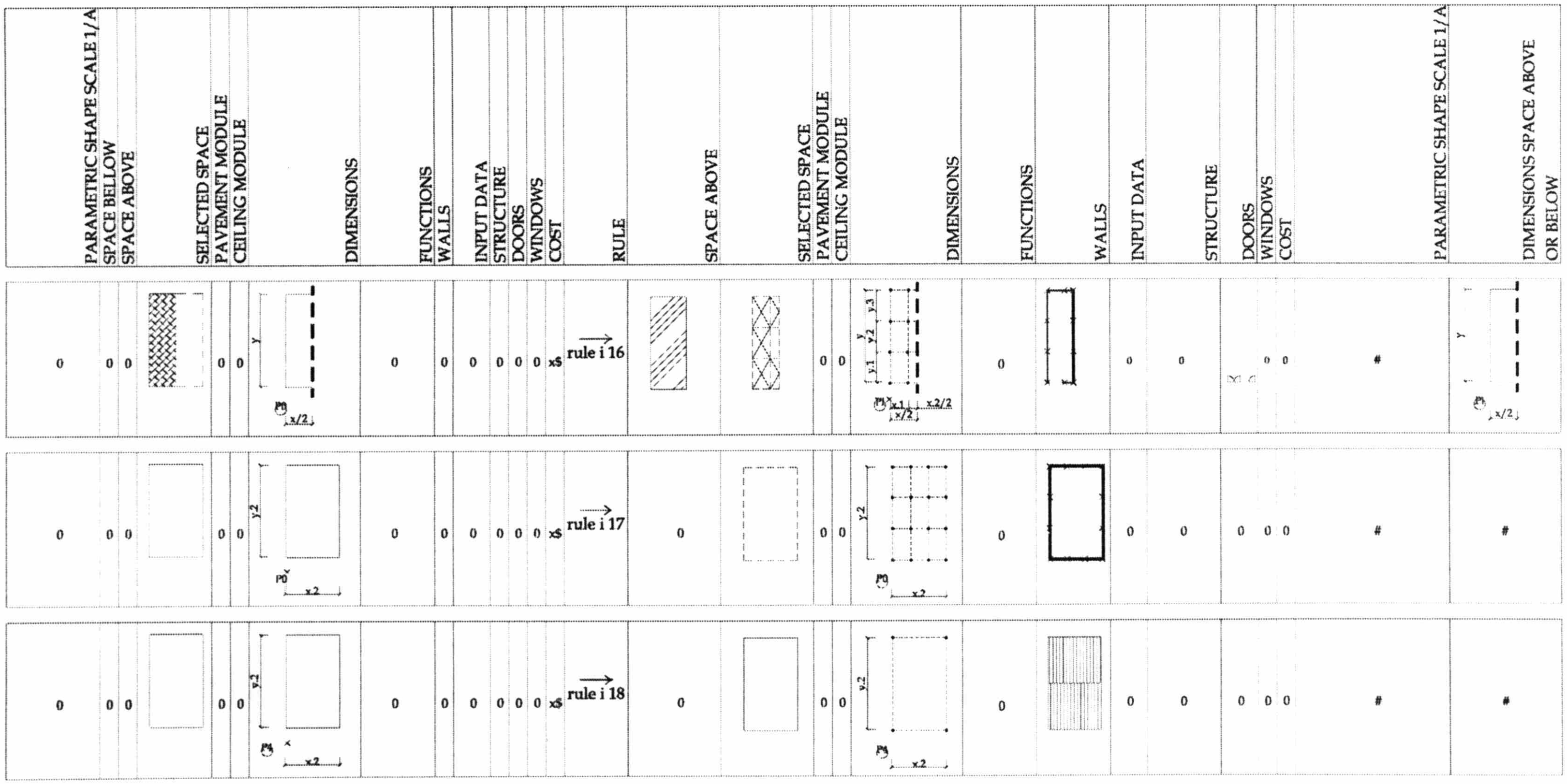
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 10			0	0		0		0	0		0	0	#	
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 11			0	0		0	0	0	0		0	0	#	
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 12	0		0	0		0	0	0	0		0	0	#	#

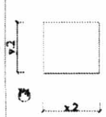
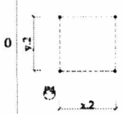
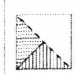
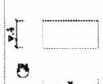
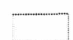
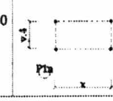
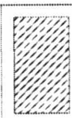
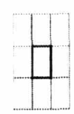
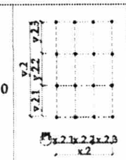
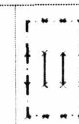
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 13			0	0		0		0	0		0	0	#	
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 14			0	0		0		0	0		0	0	#	
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 15			0	0		0		0	0		0	0	#	

IMPLEMENTATION RULES



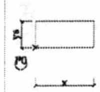
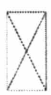
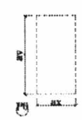
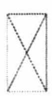
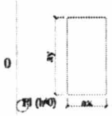
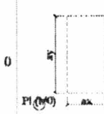
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	x$	rule i 19	0		0	0		0		0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	x$	rule i 20	0		0	0		0		0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	x$	rule i 21	0		0	0		ha		0	0	[illegible]	[illegible]	0	#	#

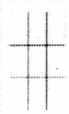
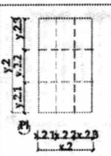
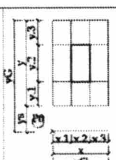
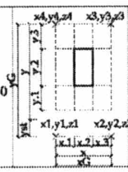
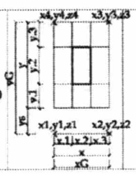
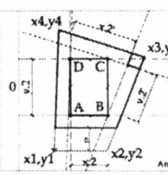
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0	y2 x2	0	0	0	0	0	0	x$	rule i 22	0		0	0	y2 y21 y22 y23 x21 x22 x23 x2	ha		0	0	0		0	#	#
0	0	0		0	0	y2 x2	0	0	0	0	0	0	x$	rule i 23	0		0	0	y2 y21 y22 y23 x21 x22/2 x2/2	ha		0	0			0	#	#
0	0	0		0	0	yd x2	0	0	0	0	0	0	x$	rule i 24			0	0	yd x21 x22 x23 x2	ha	0	0	0	0	0	0	#	yd x2

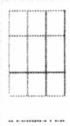
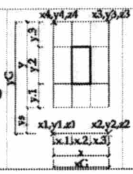
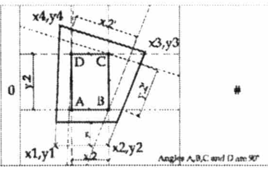
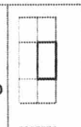
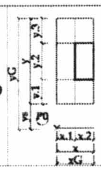
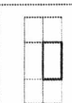
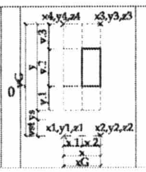
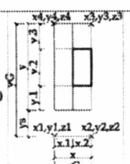
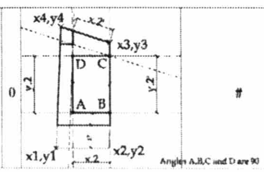
IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	x$	→ rule i 25	0		0	0		sidewalk	0	0	0	0	0	0	#	#
0	0	0		0	0		0		0	0	0	0	x$	→ rule i 26	0		0	0		ga	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	0	→ rule i 27	0		0	0		exS	0	0	0	0	0	0	#	#

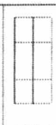
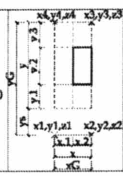
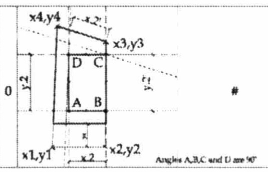
IMPLEMENTATION RULES

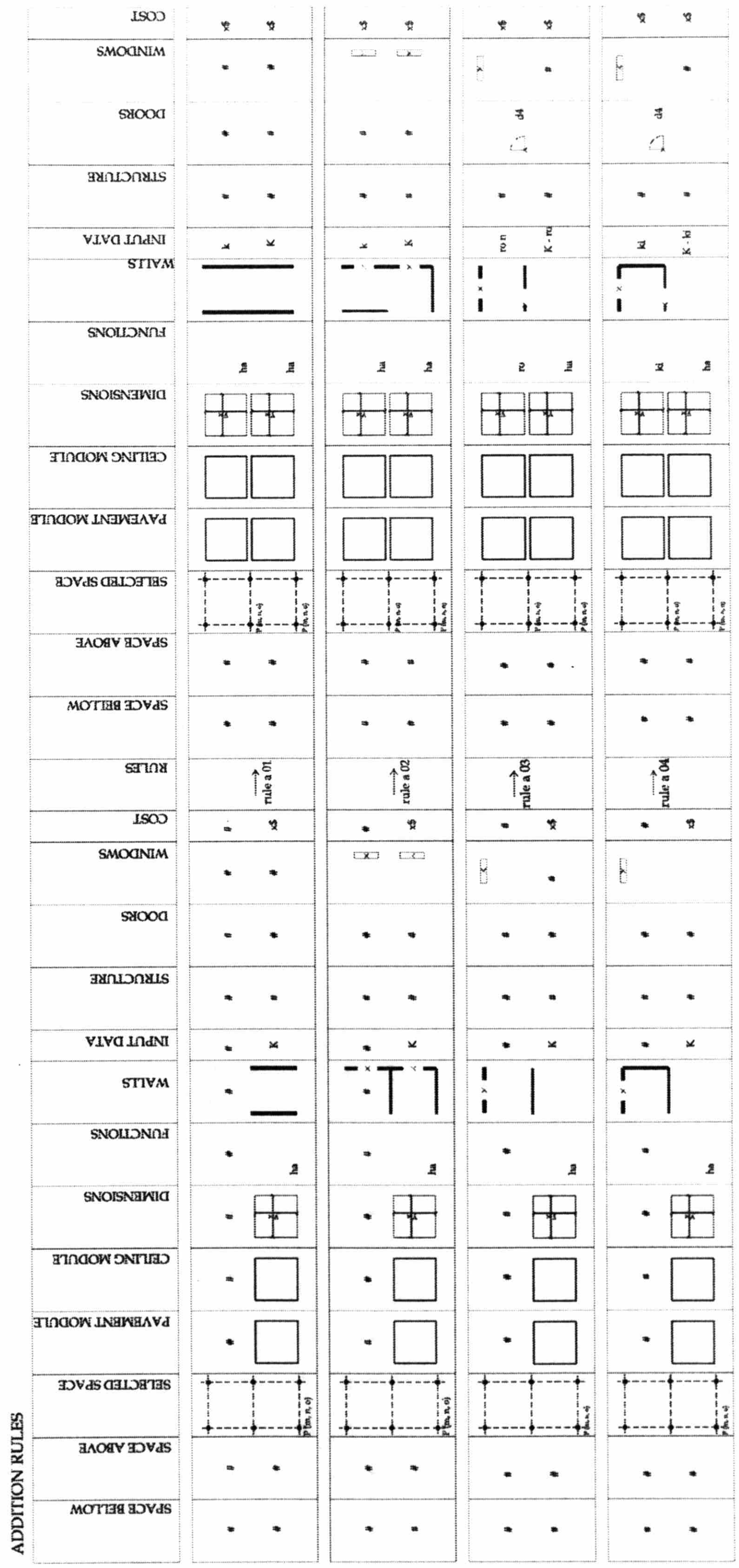
PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	0	→ rule i 28	0		0	0		#	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	0	→ rule i 29	0		0	0		0	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	0	→ rule i 30	0	0	0	0	0	0	0	0	0	0	0	0		#

IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	0	rule i 31	0	0	0	0	0	0	0	0	0	0	0	0		#
0	0	0		0	0		0	0	0	0	0	0	0	rule i 32	0		0	0		0	0	0	0	0	0	0	#	#
0	0	0		0	0		0	0	0	0	0	0	0	rule i 33	0	0	0	0	0	0	0	0	0	0	0	0		#

IMPLEMENTATION RULES

PARAMETRIC SHAPE SCALE 1/A	SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	RULE	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST	PARAMETRIC SHAPE SCALE 1/A	DIMENSIONS SPACE ABOVE OR BELOW
0	0	0		0	0		0	0	0	0	0	0	0	→ rule i 34	0	0	0	0	0	0	0	0	0	0	0	0		#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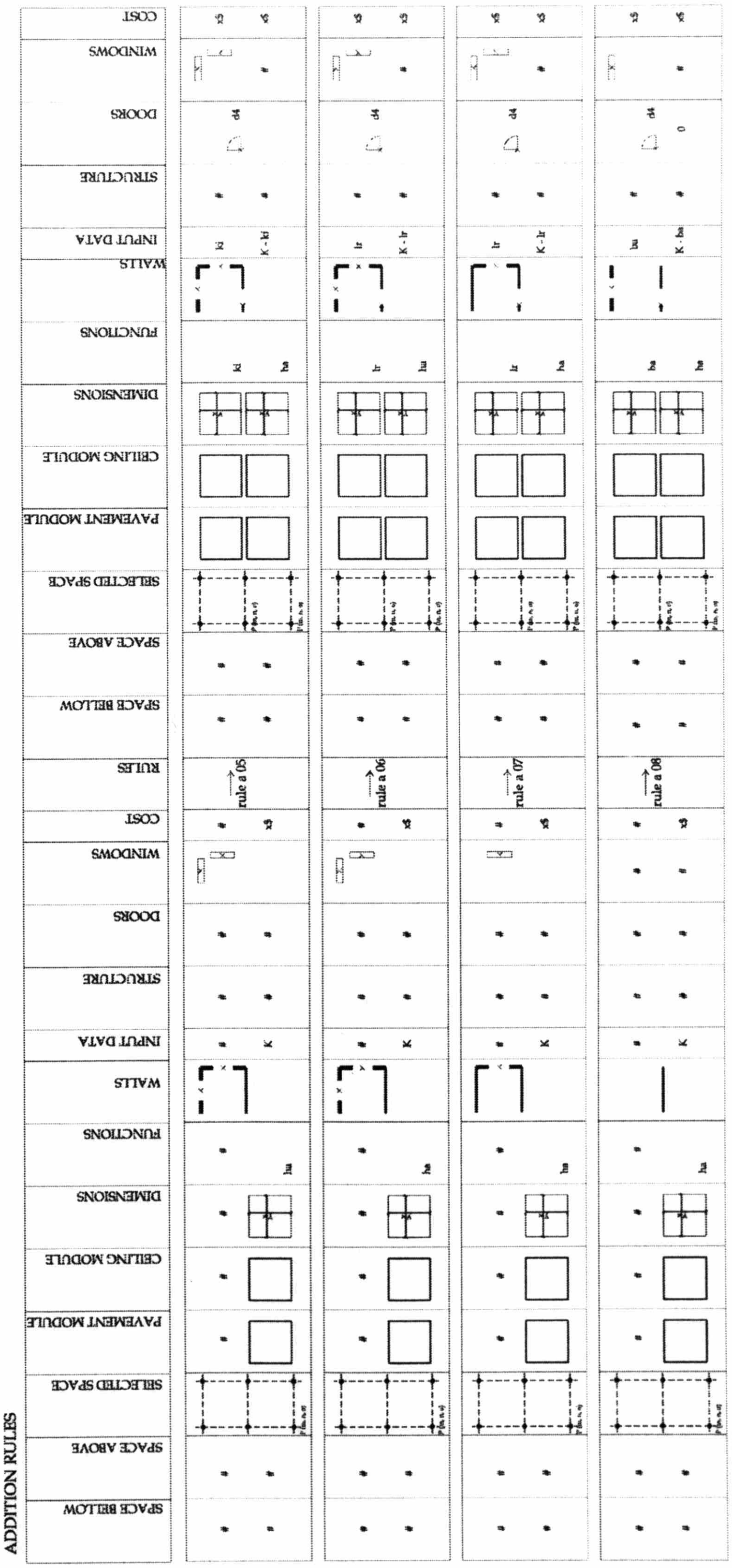
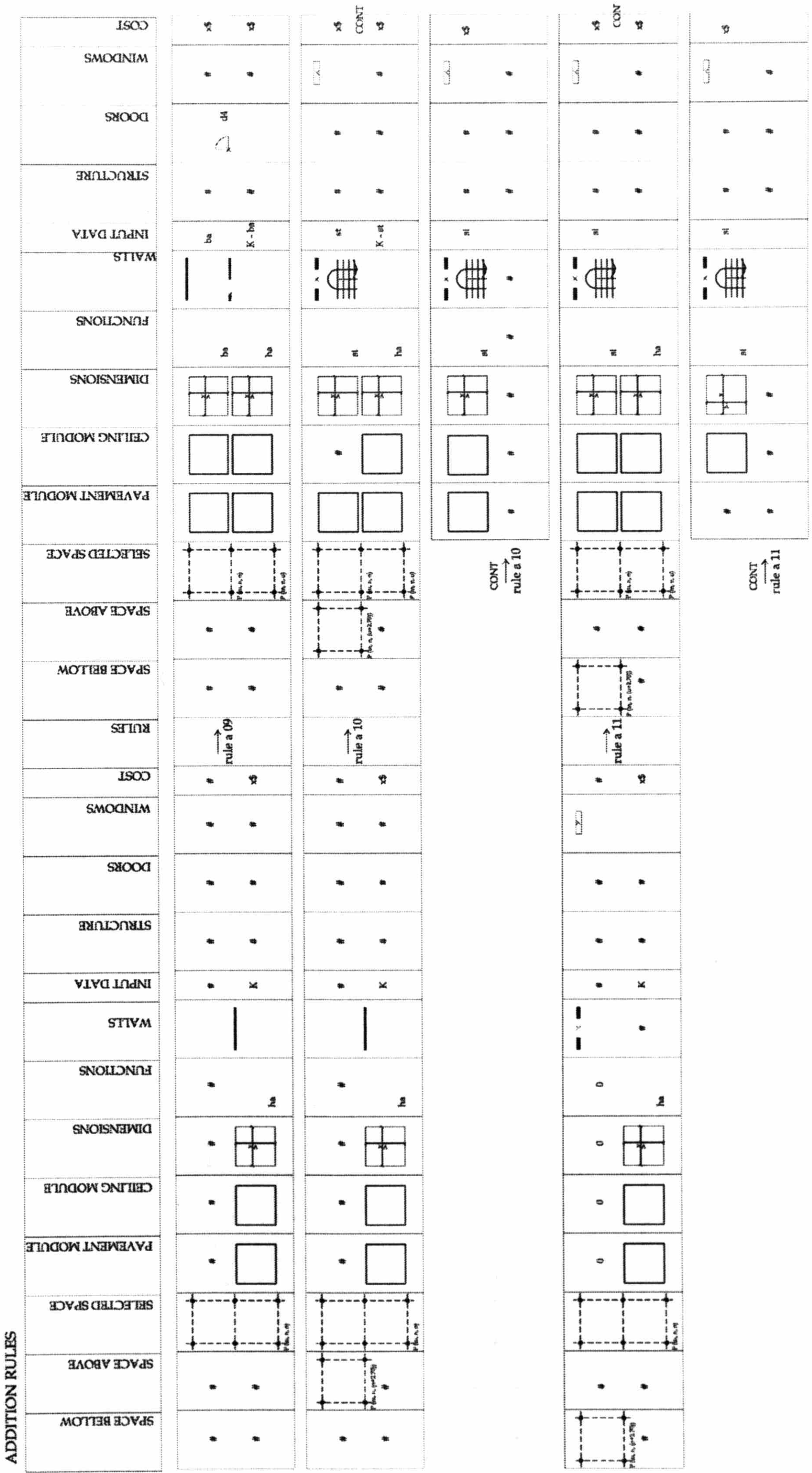
SPACE BELOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULES
rule a 01
rule a 02
rule a 03
rule a 04

ADDITION RULES

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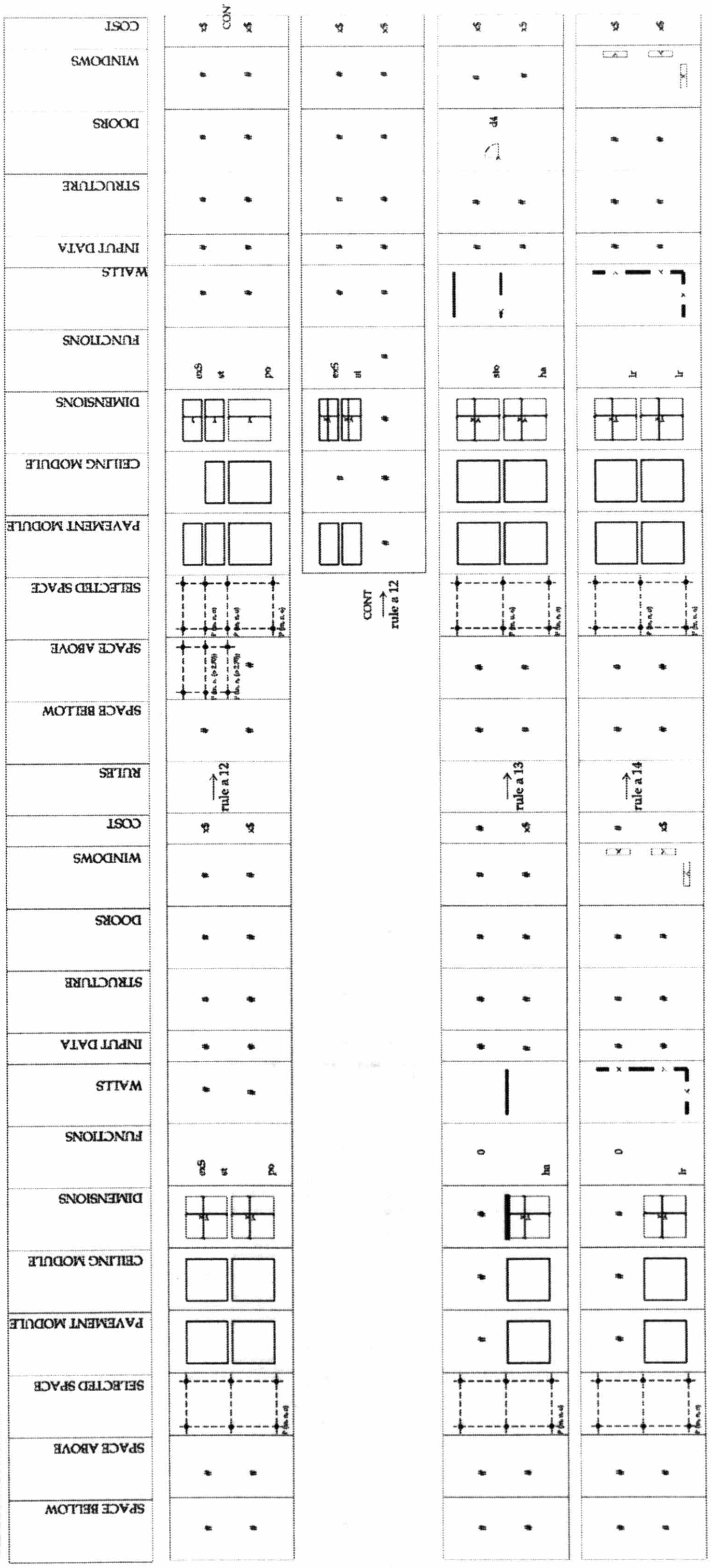
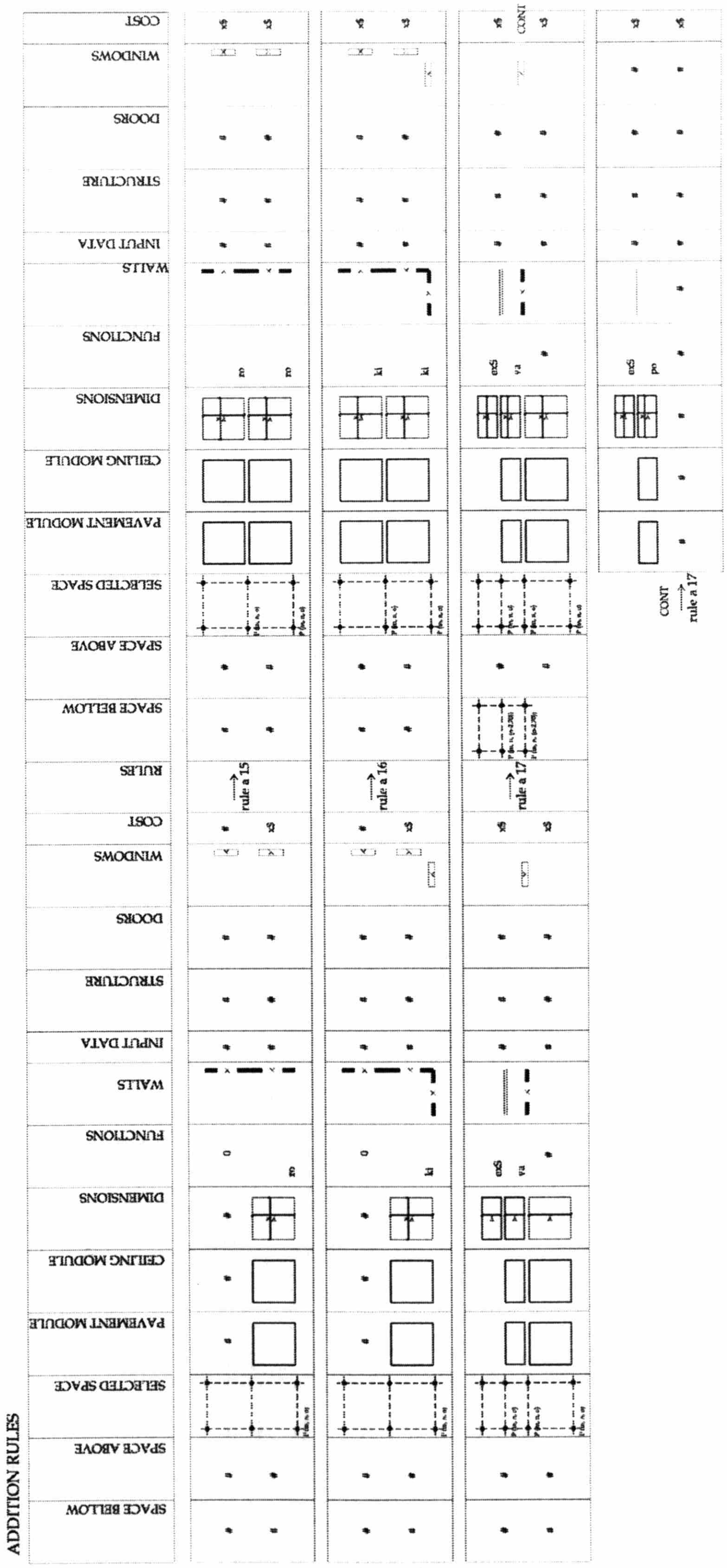
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULES
rule a 09
rule a 10
rule a 11
CONT
rule a 10
CONT
rule a 11

ADDITION RULES

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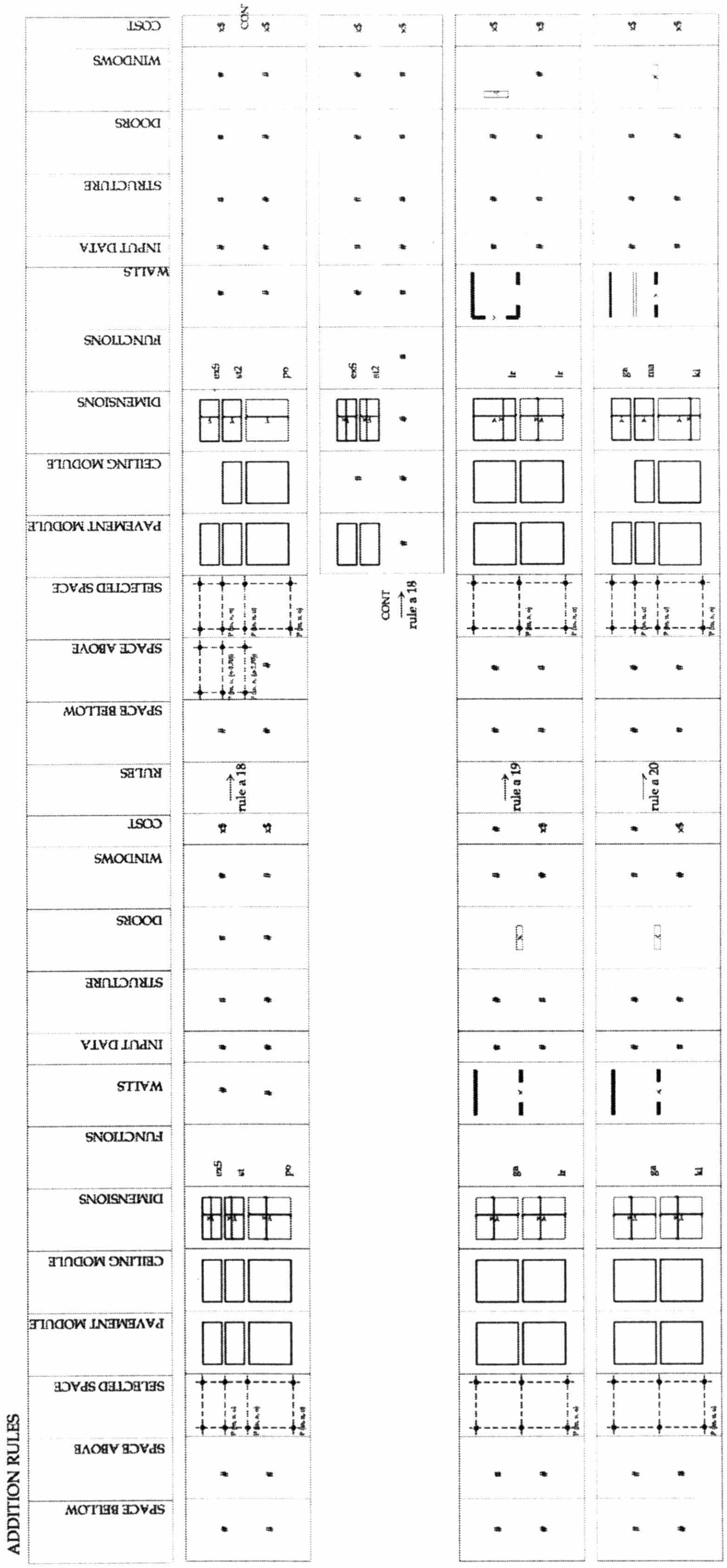
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULES
rule a 15
rule a 16
rule a 17
CONT
rule a 17
CONT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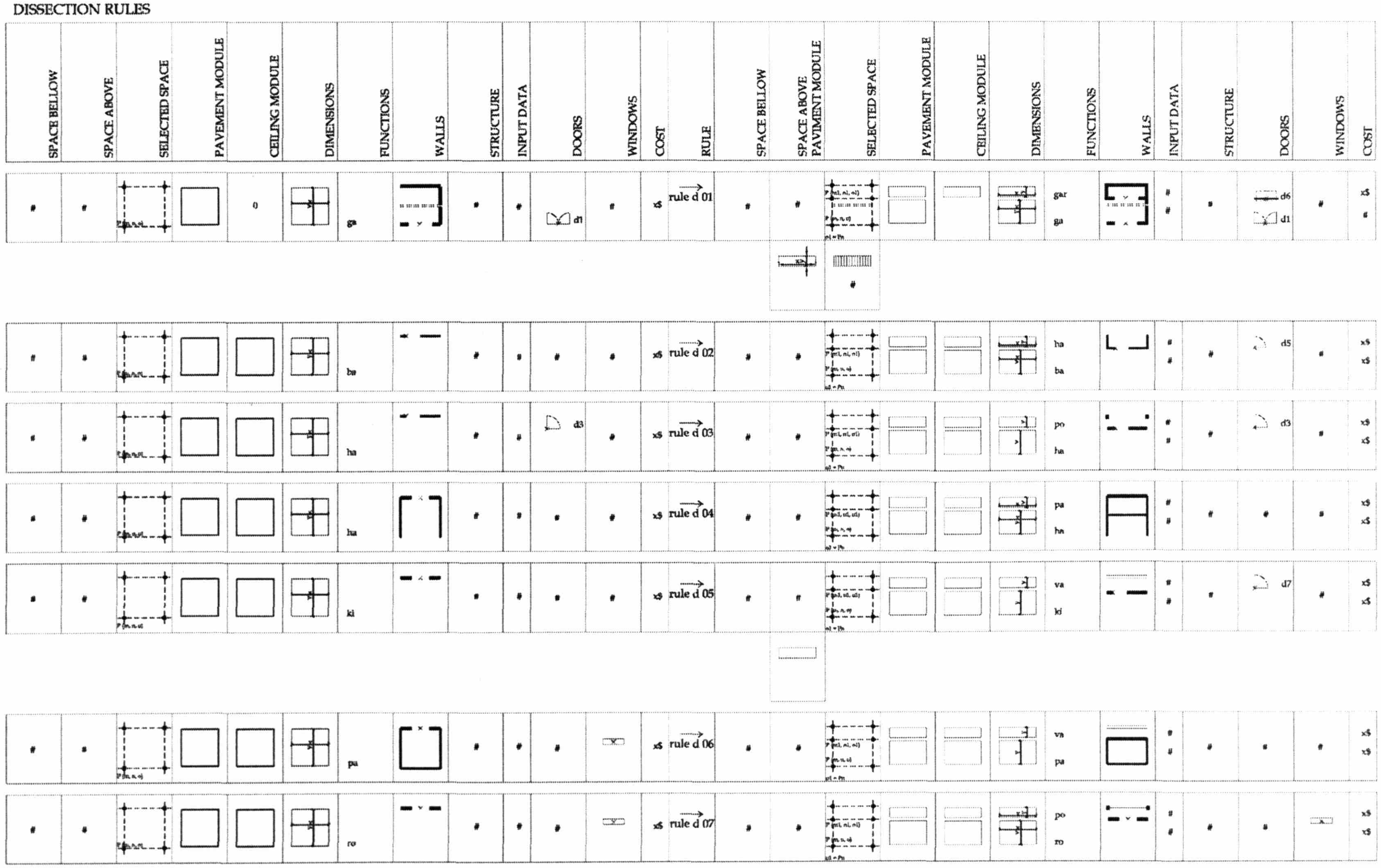
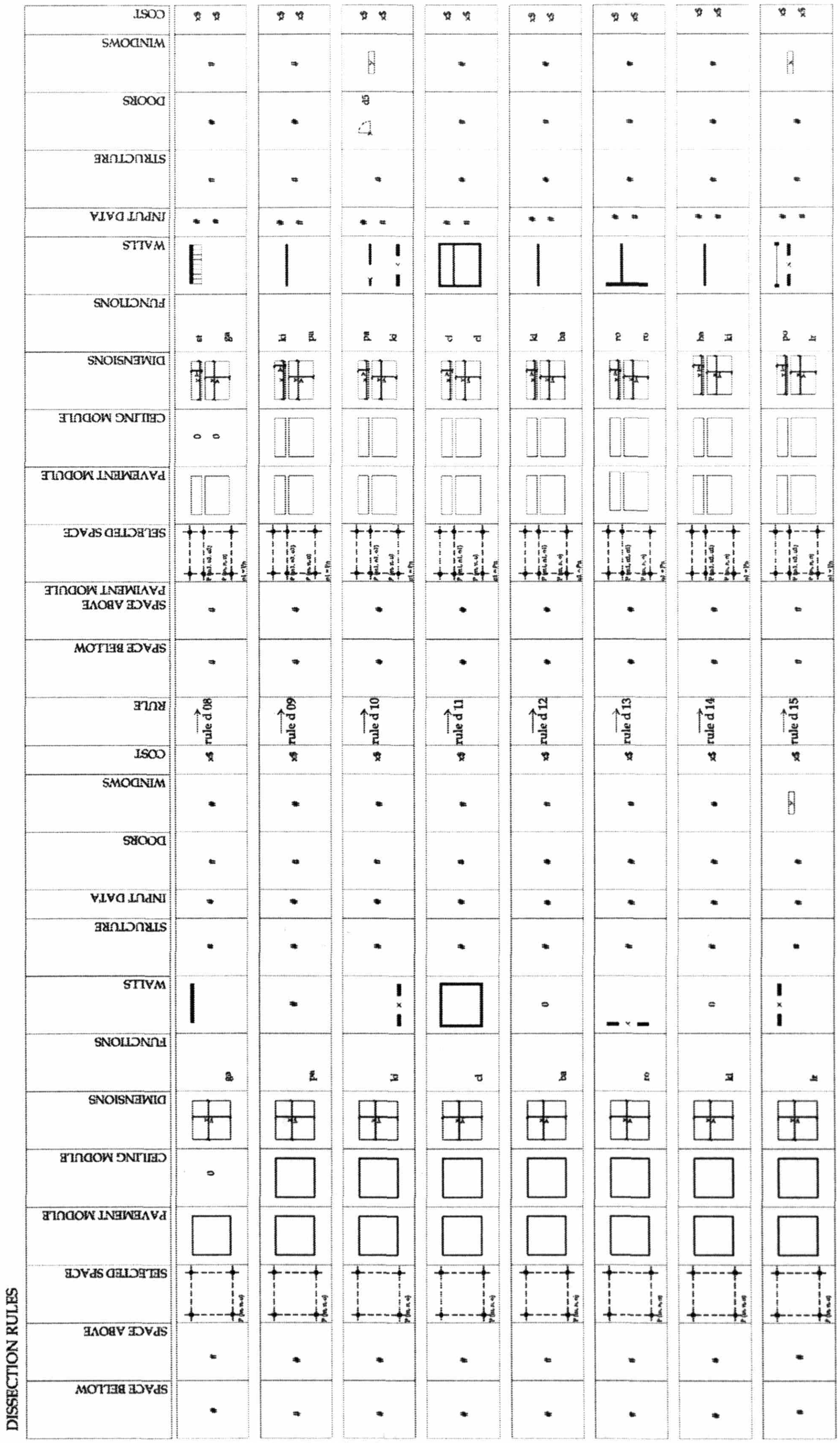
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULES
rule a 18
rule a 19
rule a 20
CONT

DISSECTION RULES




DISSECTION RULES
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SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
STRUCTURE
INPUT DATA
DOORS
WINDOWS
COST
RULE
SPACE BELLOW
SPACE ABOVE
PAVIMENT MODULE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
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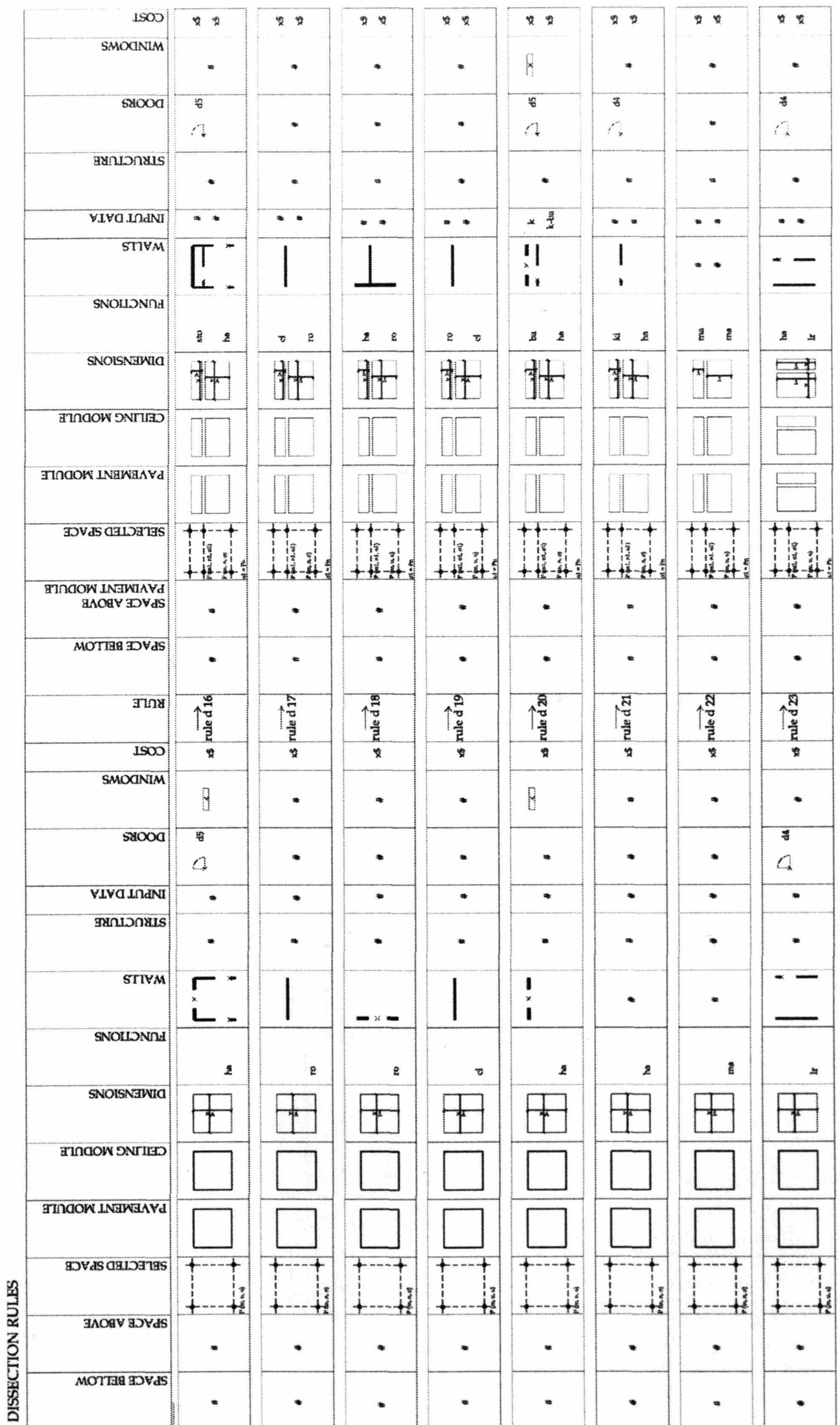
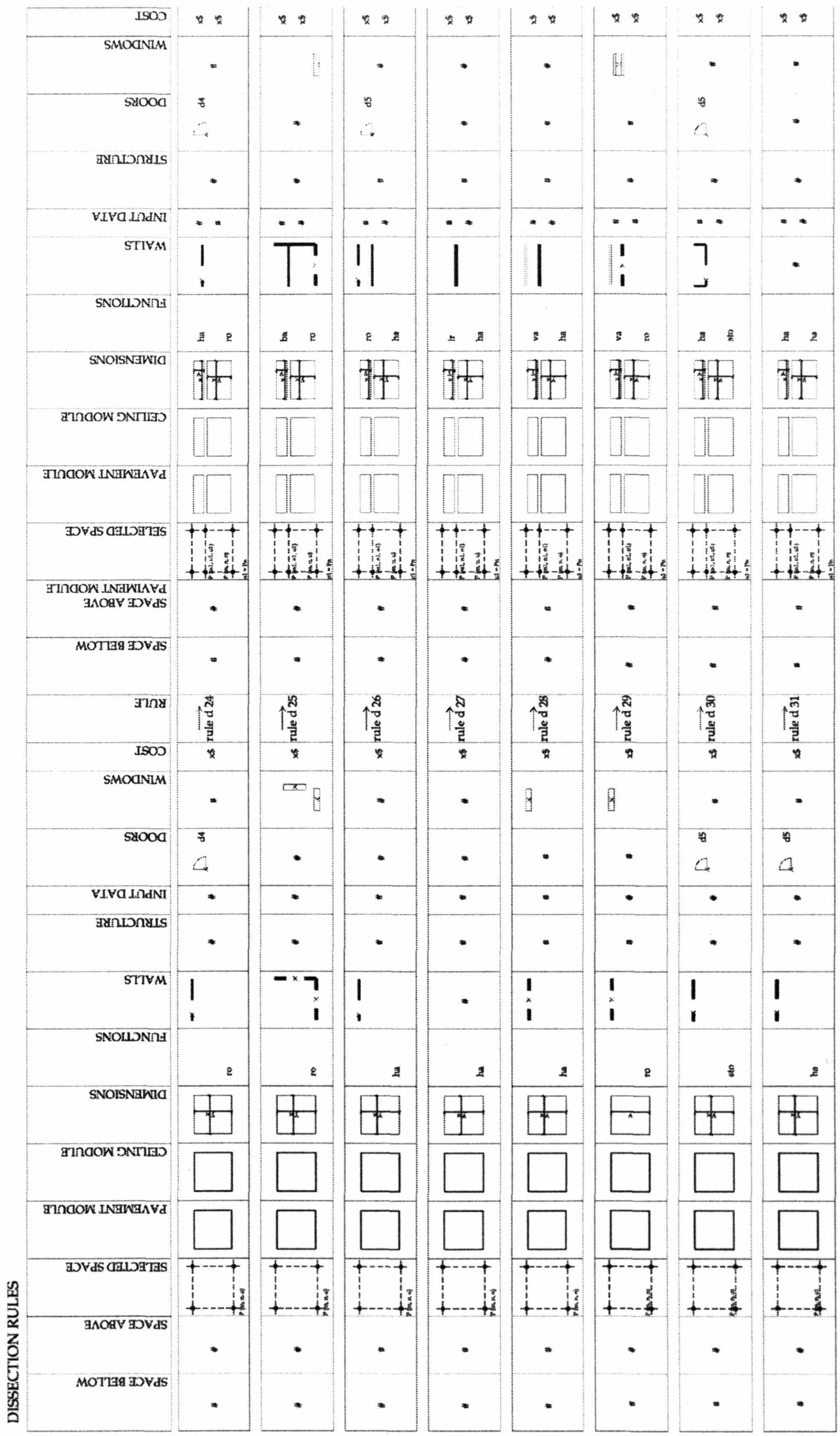
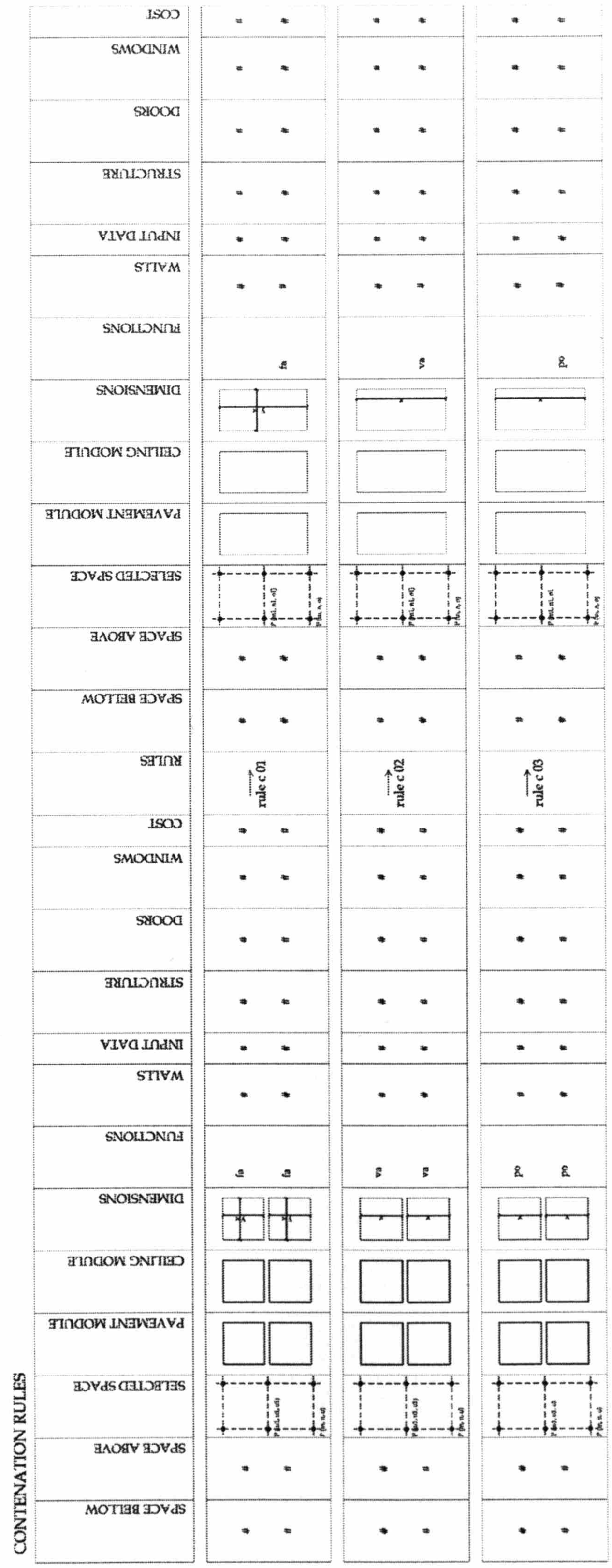
rule d 09
rule d 10
rule d 11
rule d 12
rule d 13
rule d 14
rule d 15

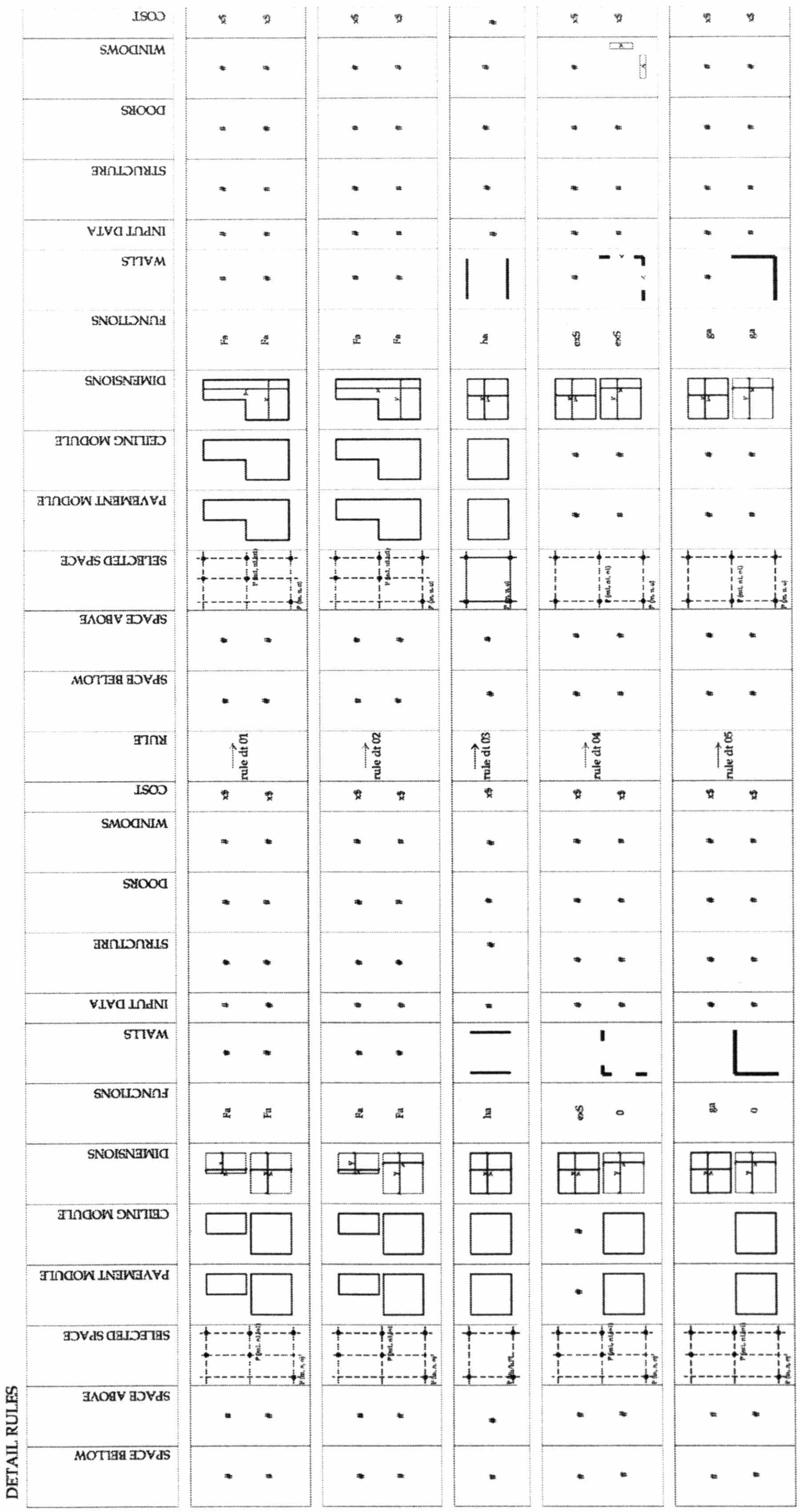

DISSECTION RULES
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
STRUCTURE
INPUT DATA
DOORS
WINDOWS
COST
RULE
SPACE BELLOW
SPACE ABOVE PAVIMENT MODULE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
rule d 16
rule d 17
rule d 18
rule d 19
rule d 20
rule d 21
rule d 22
rule d 23


DISSECTION RULES
SPACE BELOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
STRUCTURE
INPUT DATA
DOORS
WINDOWS
COST
RULE
SPACE BELOW
SPACE ABOVE PAVIMENT MODULE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
rule d 24
rule d 25
rule d 26
rule d 27
rule d 28
rule d 29
rule d 30
rule d 31

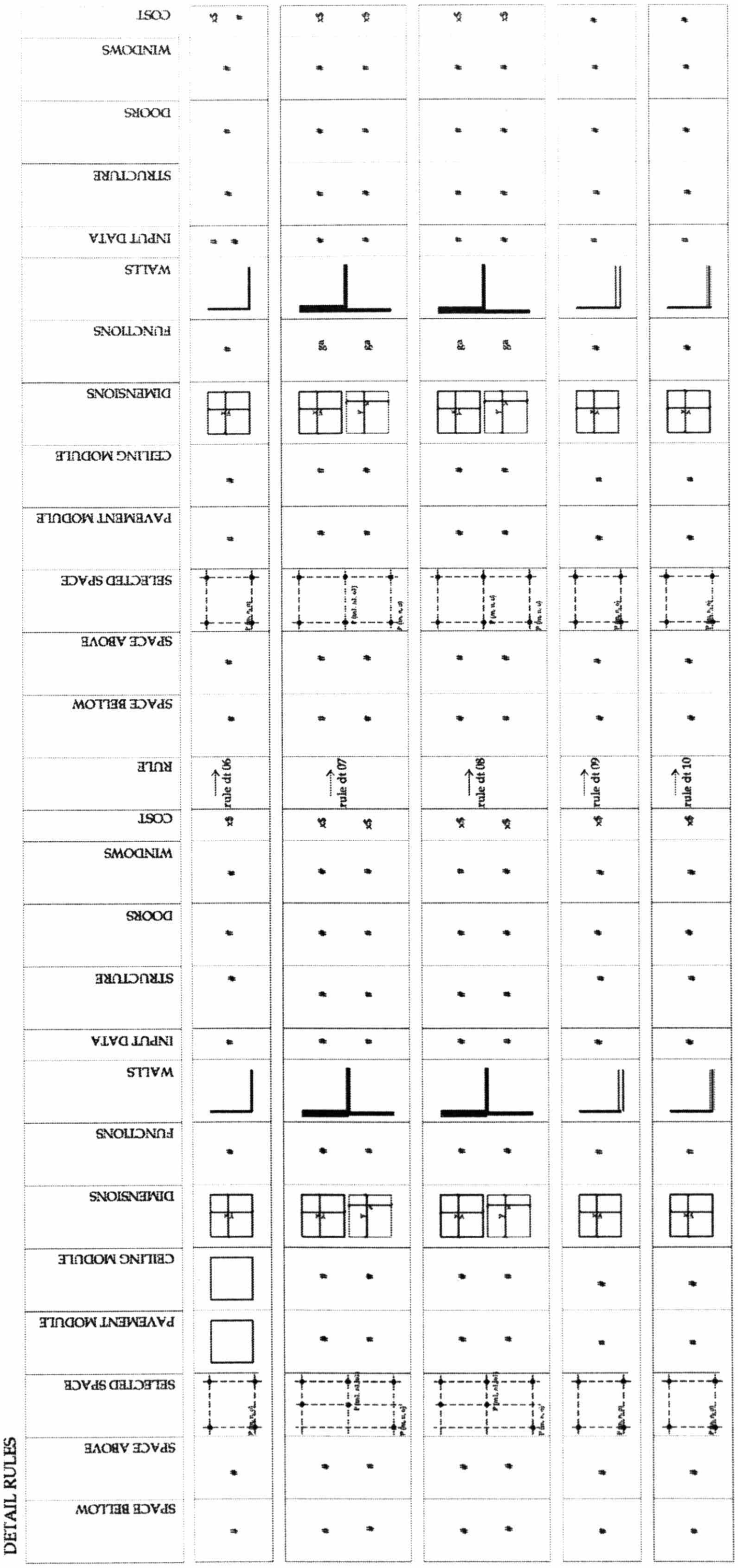
DISSECTION RULES

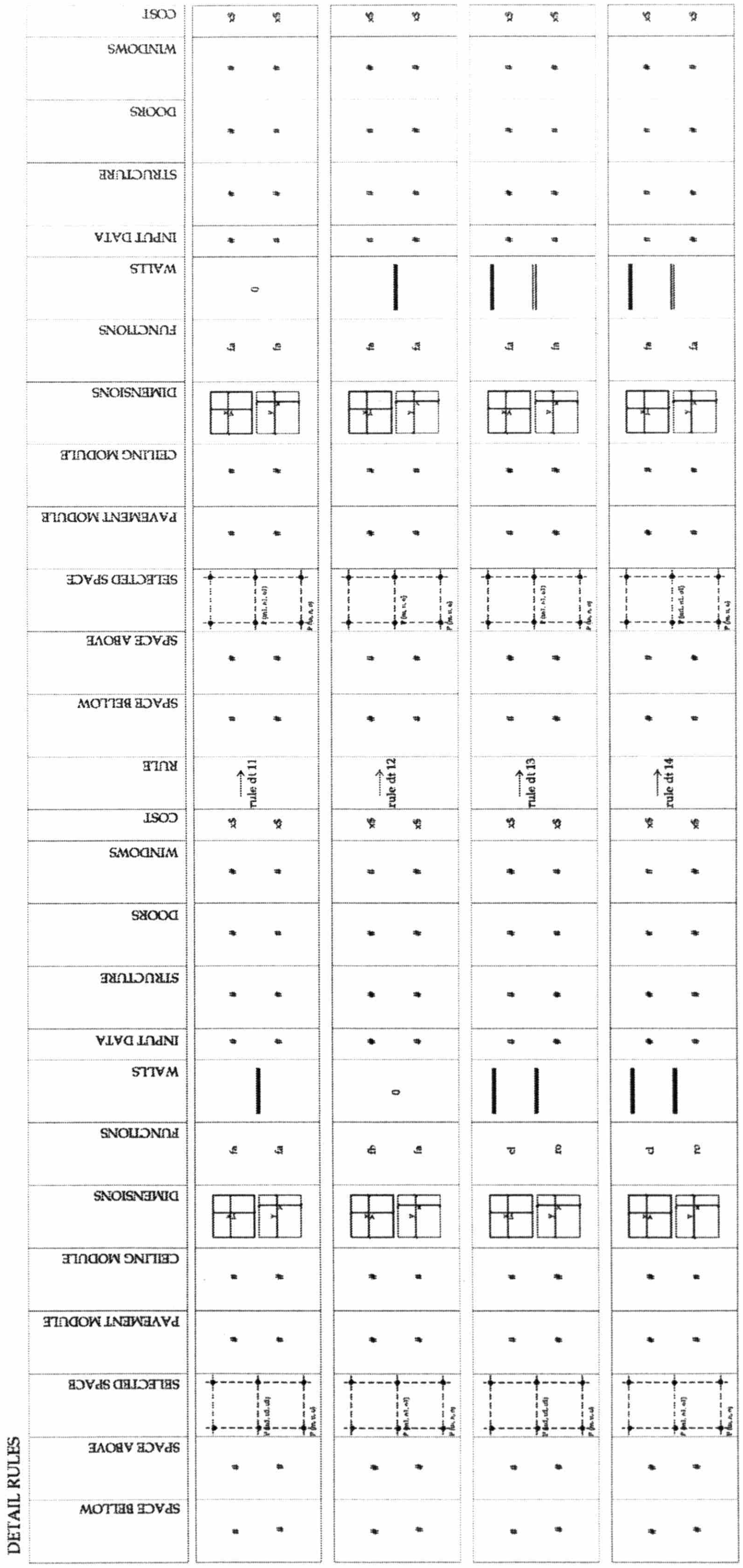
SPACE BELLOW	SPACE ABOVE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	STRUCTURE	INPUT DATA	DOORS	WINDOWS	COST	RULE	SPACE BELLOW	SPACE ABOVE PAVIMENT MODULE	SELECTED SPACE	PAVEMENT MODULE	CEILING MODULE	DIMENSIONS	FUNCTIONS	WALLS	INPUT DATA	STRUCTURE	DOORS	WINDOWS	COST
#	#					ha		#	#	d5	#	x5	rule d 32	#	#					d ha		# #	#	#	#	x5 x5
#	#					lr		#	#	#		x5	rule d 33	#	#					vn lr		# #	#	#		x5 x5

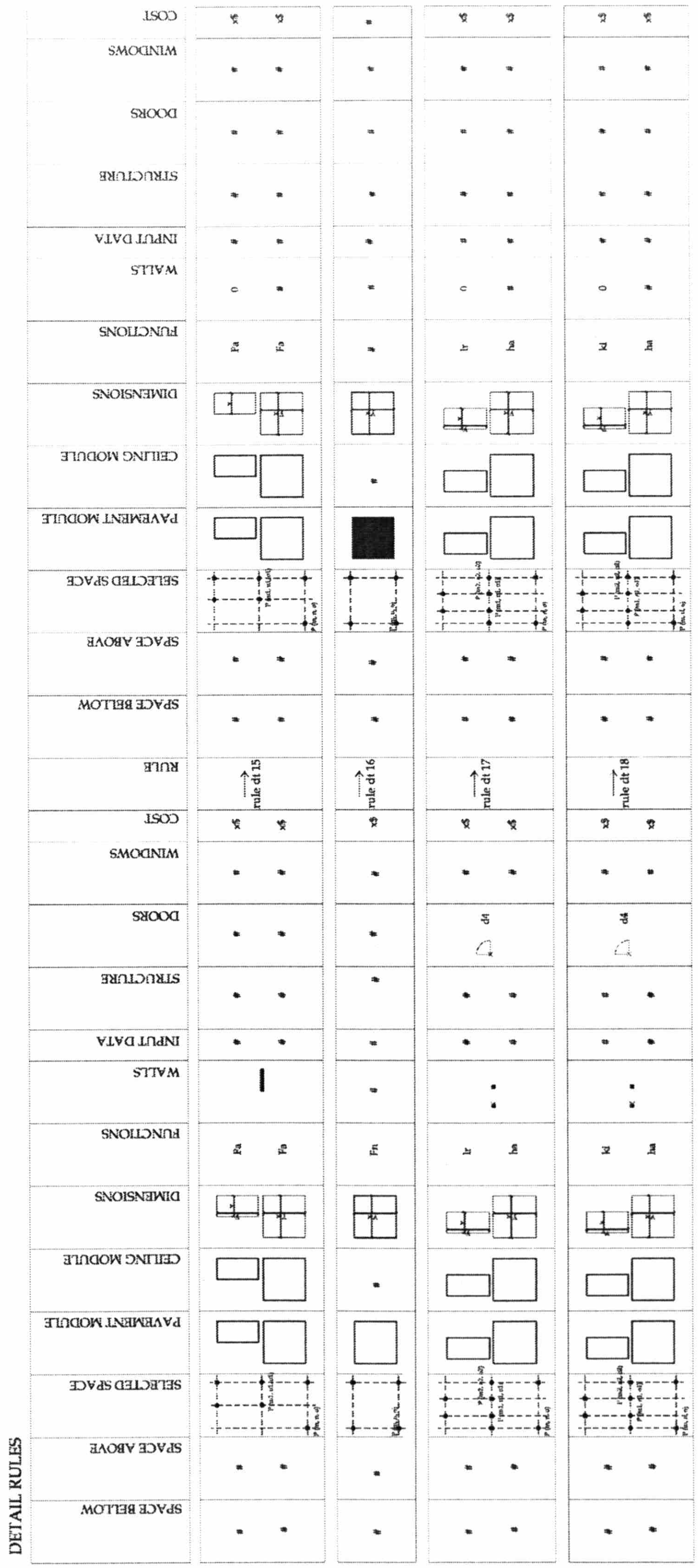

CONTENATION RULES
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULES
rule c 01
rule c 02
rule c 03
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST


DETAIL RULES
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULE
rule dt 01
rule dt 02
rule dt 03
rule dt 04
rule dt 05
Fa
ha
exS
ga
0
x$

DETAIL RULES




DETAIL RULES
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULE
rule dt 11
rule dt 12
rule dt 13
rule dt 14


DETAIL RULES
SPACE BELLOW
SPACE ABOVE
SELECTED SPACE
PAVEMENT MODULE
CEILING MODULE
DIMENSIONS
FUNCTIONS
WALLS
INPUT DATA
STRUCTURE
DOORS
WINDOWS
COST
RULE
rule dt 15
rule dt 16
rule dt 17
rule dt 18
Fa
Fo
Fn
lr
ha
kl
d4

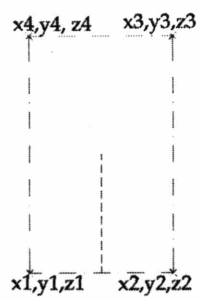
APPENDIX D

This appendix has a description of a rule application for one case of the group of houses: house number 3.

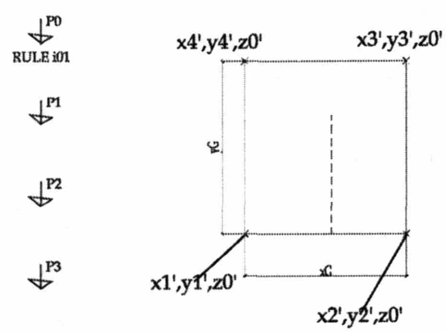
HOUSE 3

RULE APPLICATION

RULES GROUND PLAN FIRST FLOOR PLAN SECOND FLOOR PLAN ROOF PLAN



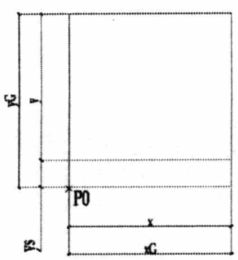
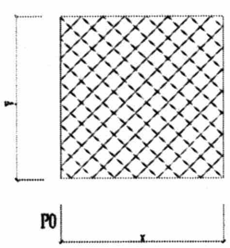
INITIAL SHAPE - LOT (Quadrilateral polygon)



0 0 0

HOUSE 3

RULE APPLICATION

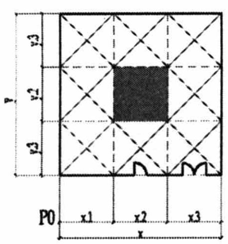
RULES	GROUND PLAN	FIRST FLOOR PLAN	SECOND FLOOR PLAN	ROOF PLAN
P0 RULE i02 P1 P2 P3		0	0	0
P0 RULE i03 P1 P2 P3		0	0	0

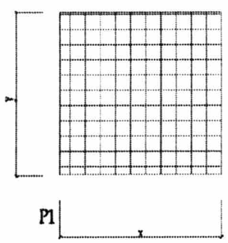
HOUSE 3

RULE APPLICATION

RULES | GROUND PLAN | FIRST FLOOR PLAN | SECOND FLOOR PLAN | ROOF PLAN

P0
RULE i05
P1
RULE i03
P2
P3





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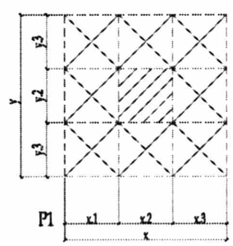
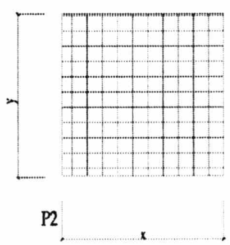
0

P0
P1
RULE i07
P2
RULE i03
P3

=





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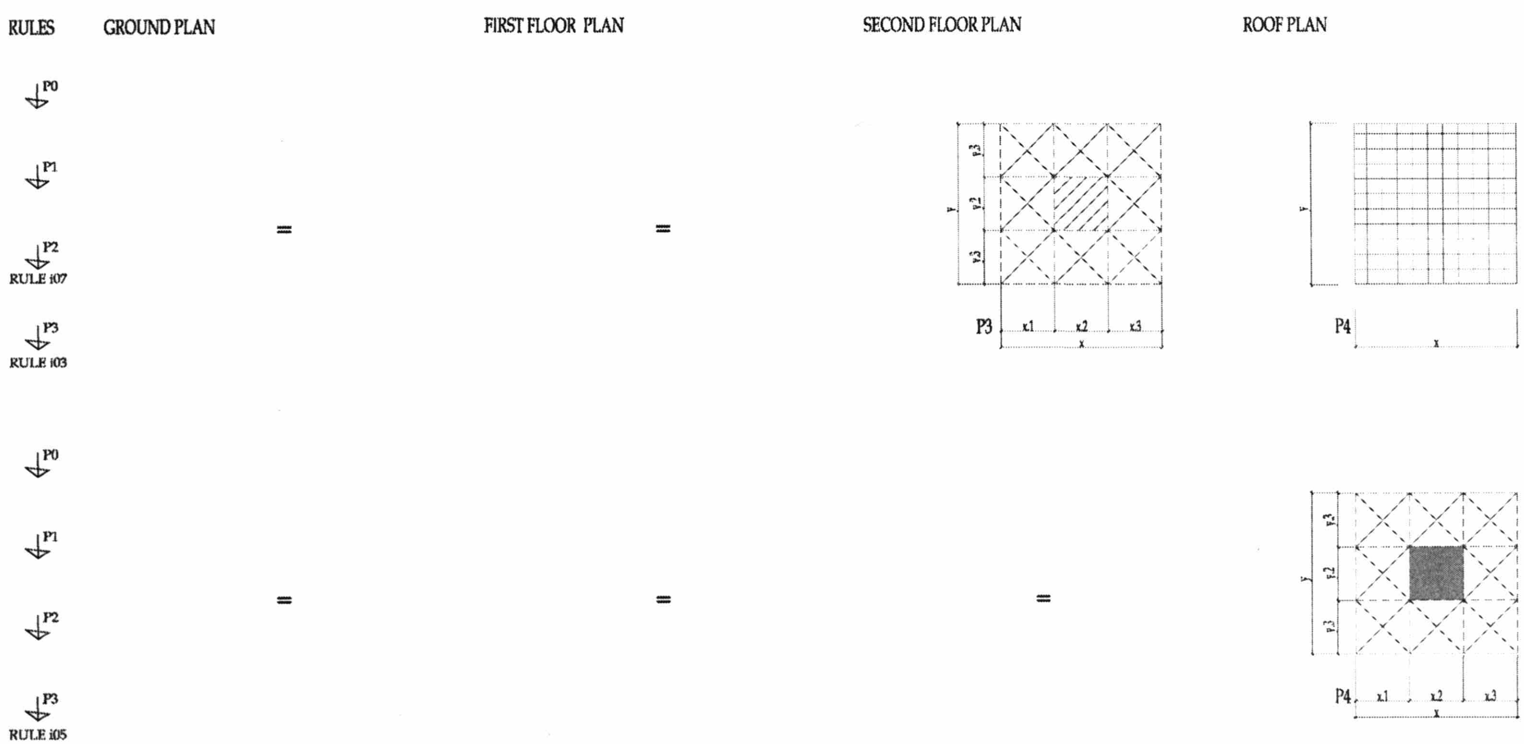
HOUSE 3

RULE APPLICATION

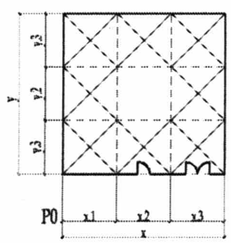


HOUSE 3

RULE APPLICATION

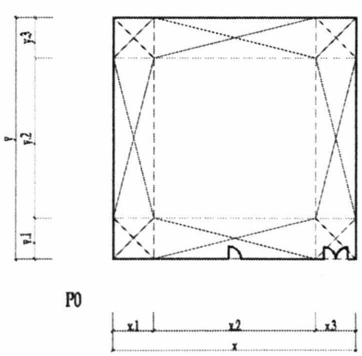
RULES | GROUND PLAN | FIRST FLOOR PLAN | SECOND FLOOR PLAN | ROOF PLAN

P0
RULE i17
P1
P2
P3



= = =

P0
RULE i27 x4
P1
P2
P3



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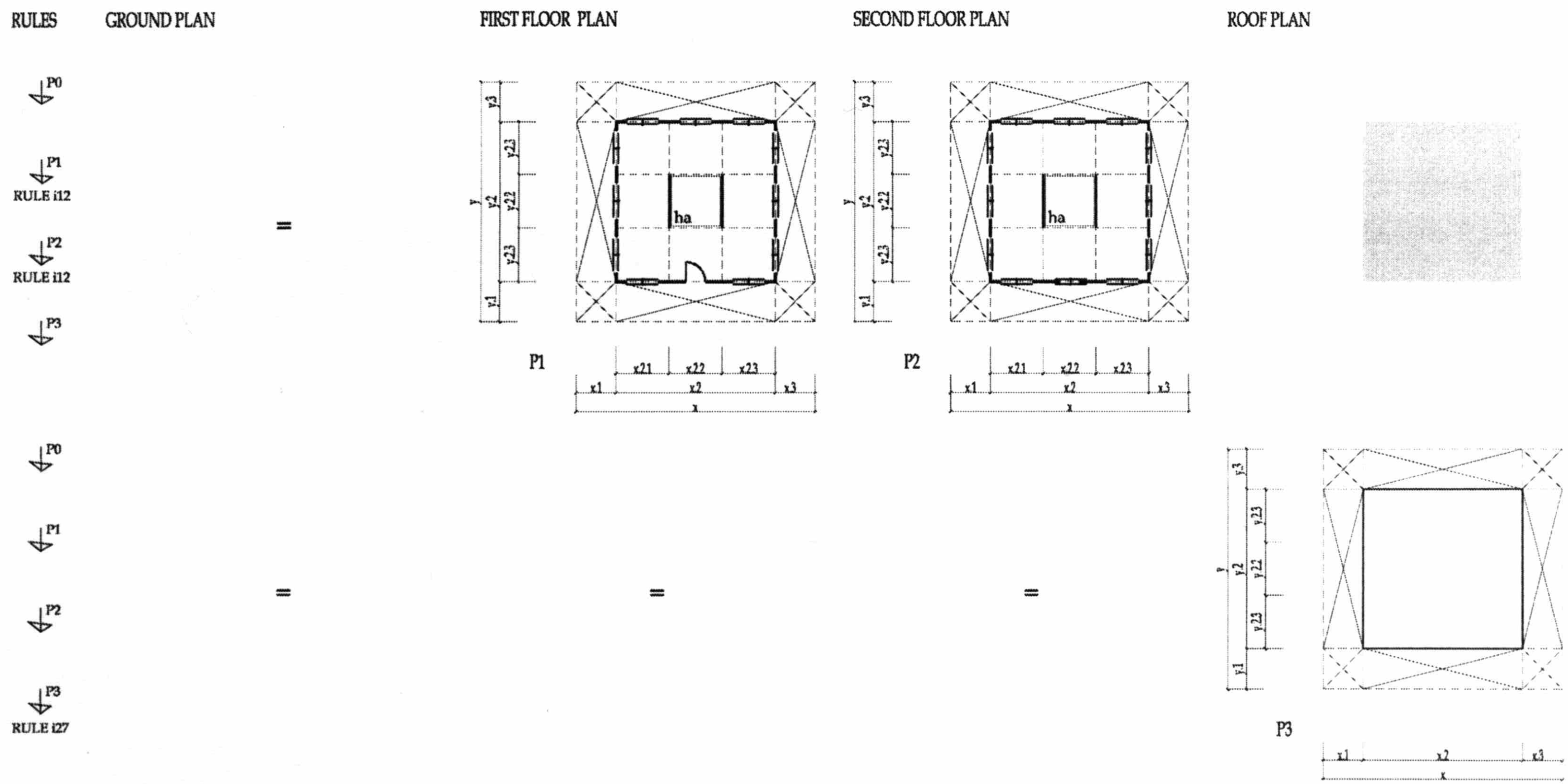
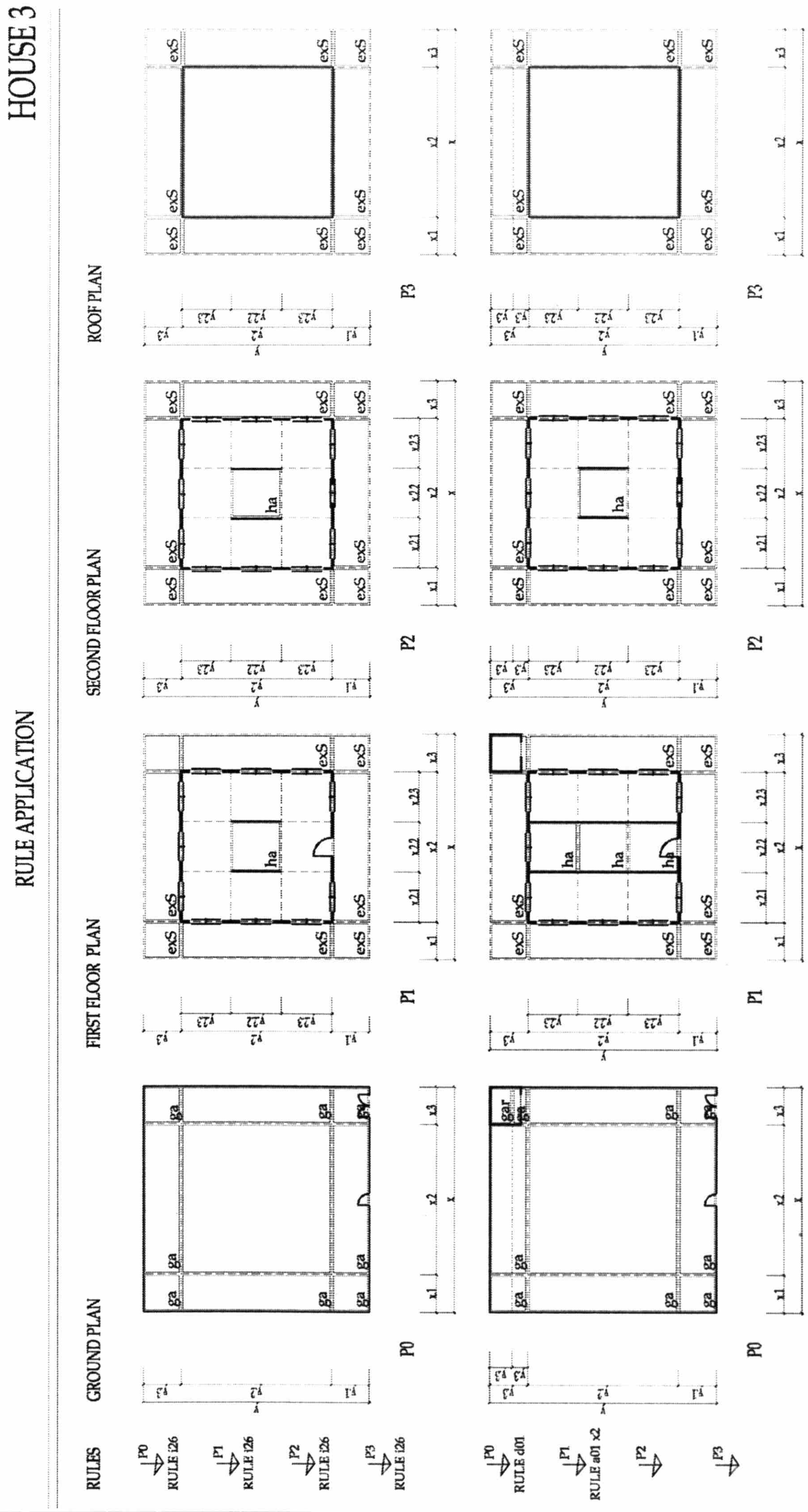
HOUSE 3

RULE APPLICATION

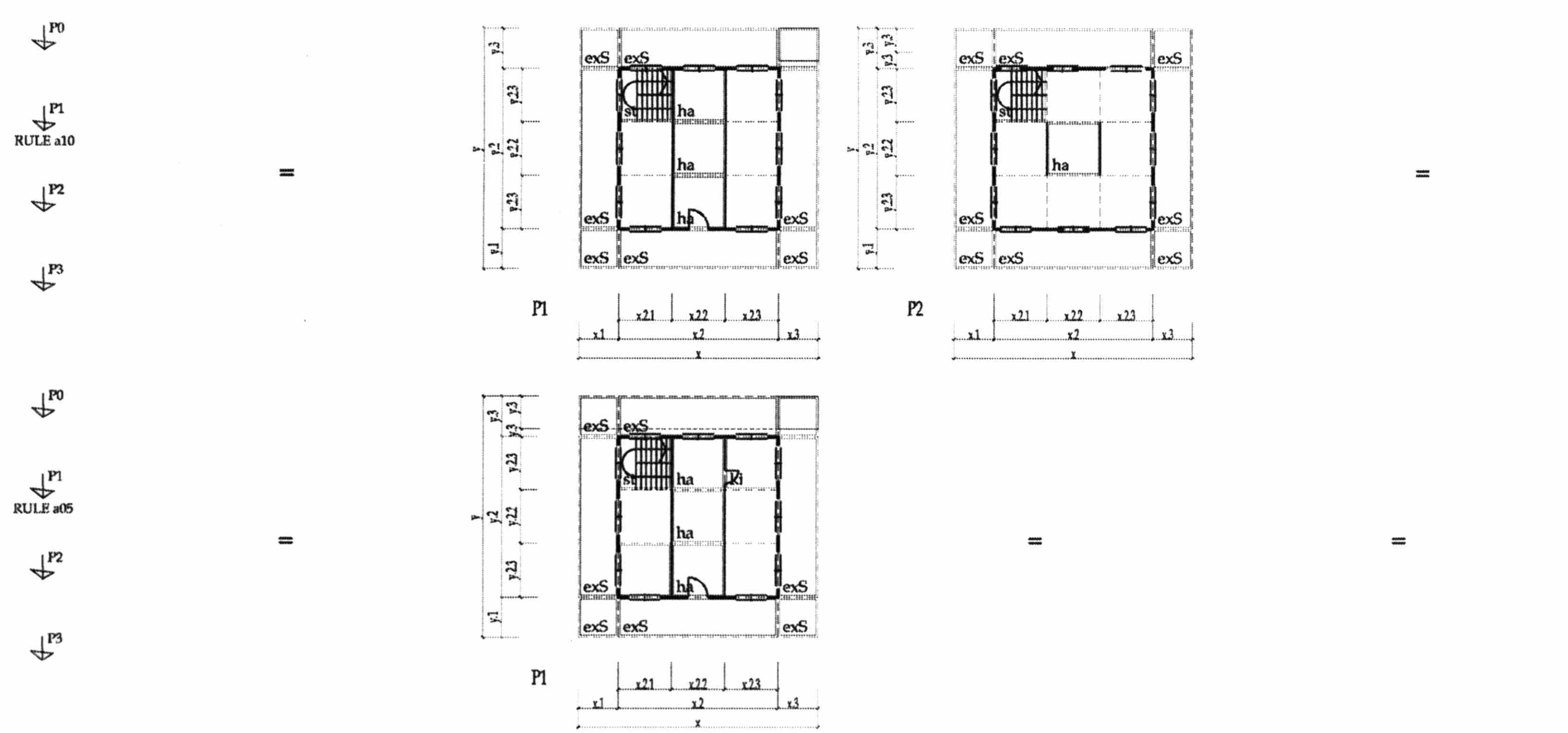



HOUSE 3
RULE APPLICATION
RULES
GROUND PLAN
FIRST FLOOR PLAN
SECOND FLOOR PLAN
ROOF PLAN
P0
P1
P2
P3
RULE i26
RULE d01
RULE a01 x2
ga
gar
ha
exS
x1
x2
x3
x21
x22
x23
y1
y2
y3
y21
y22
y23

HOUSE 3

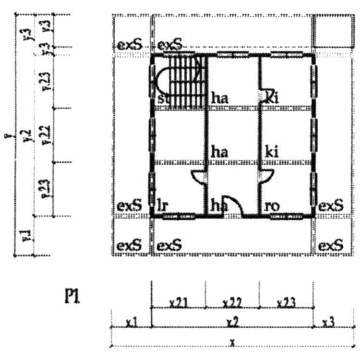
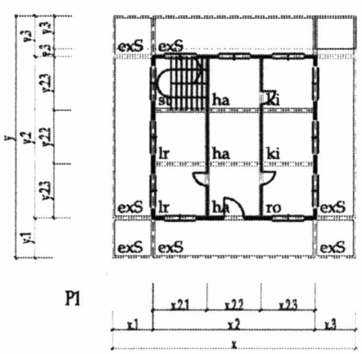
RULE APPLICATION

RULES GROUND PLAN FIRST FLOOR PLAN SECOND FLOOR PLAN ROOF PLAN



HOUSE 3

RULE APPLICATION

RULES	GROUND PLAN	FIRST FLOOR PLAN	SECOND FLOOR PLAN	ROOF PLAN
P0 P1 RULE a16 P2 P3	=	 P1	=	=
P0 P1 RULE a14 P2 P3	=	 P1	=	=

HOUSE 3

RULE APPLICATION

RULES | GROUND PLAN | FIRST FLOOR PLAN | SECOND FLOOR PLAN | ROOF PLAN

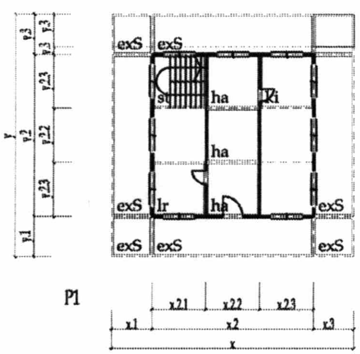
P0

P1
RULE a07

P2

P3

=



P1

=

=

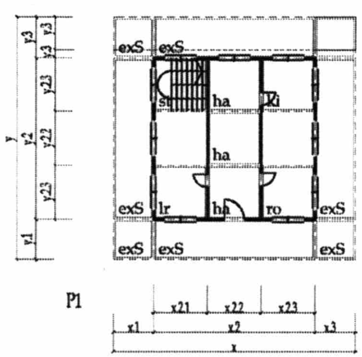
P0

P1
RULE a03

P2

P3

=



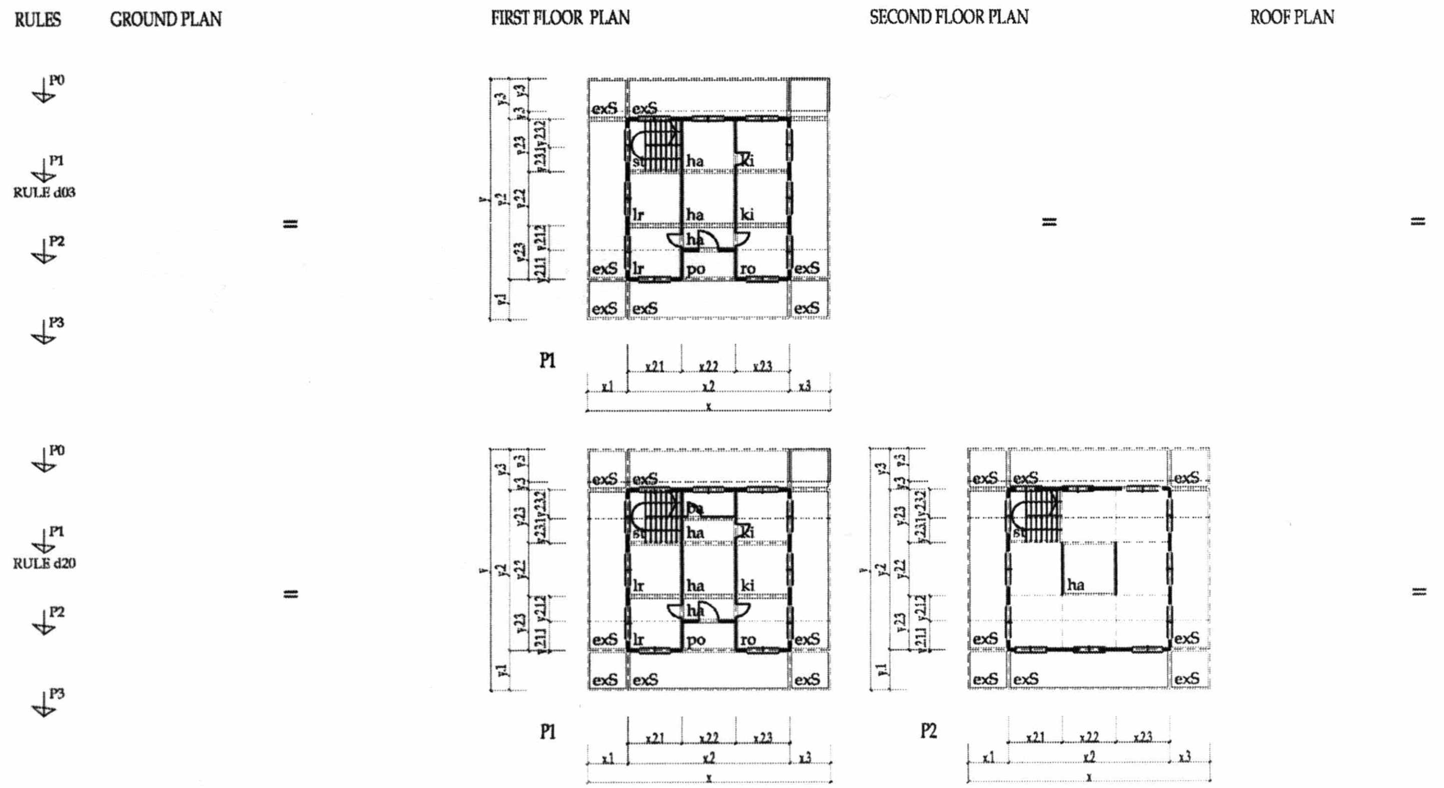
P1

=

=

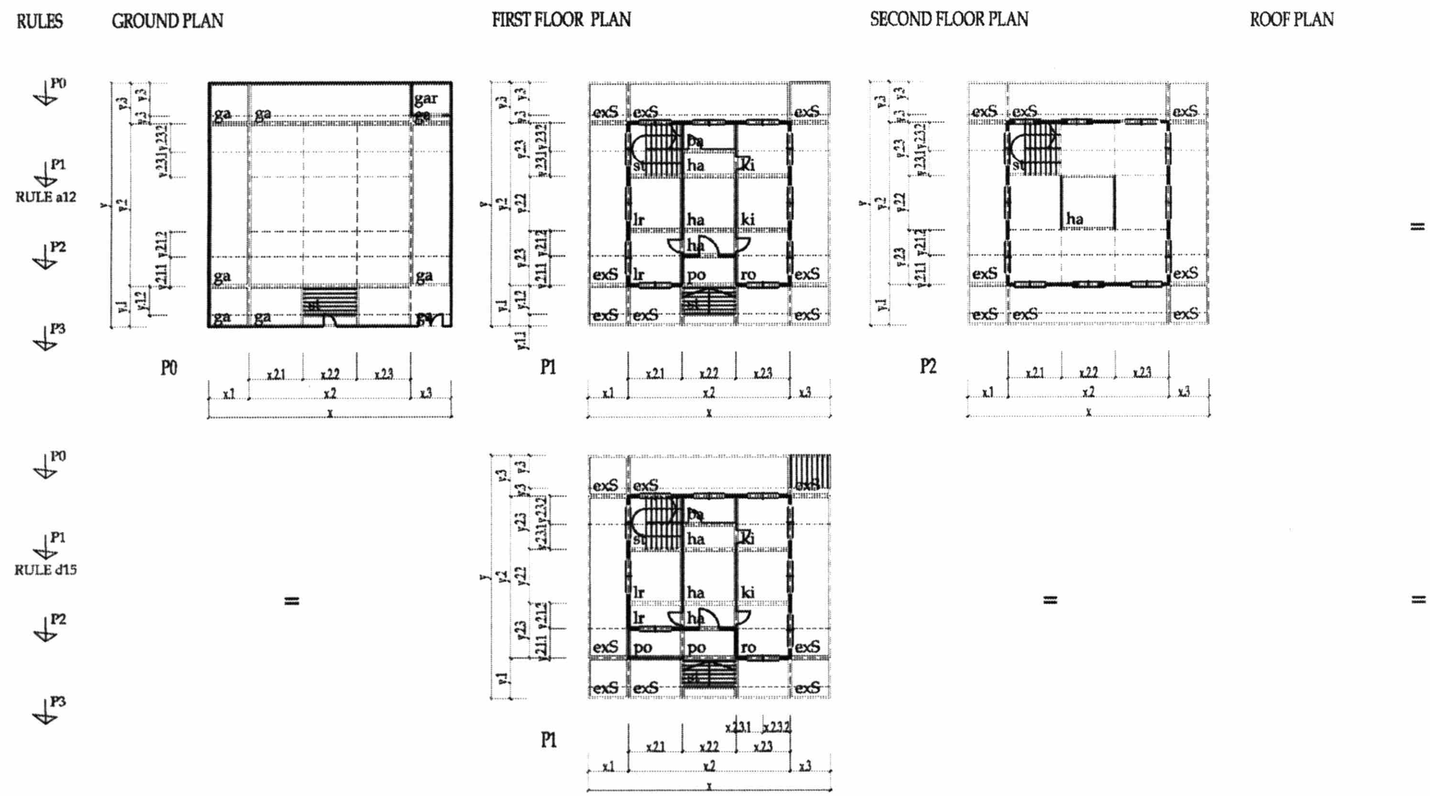
HOUSE 3

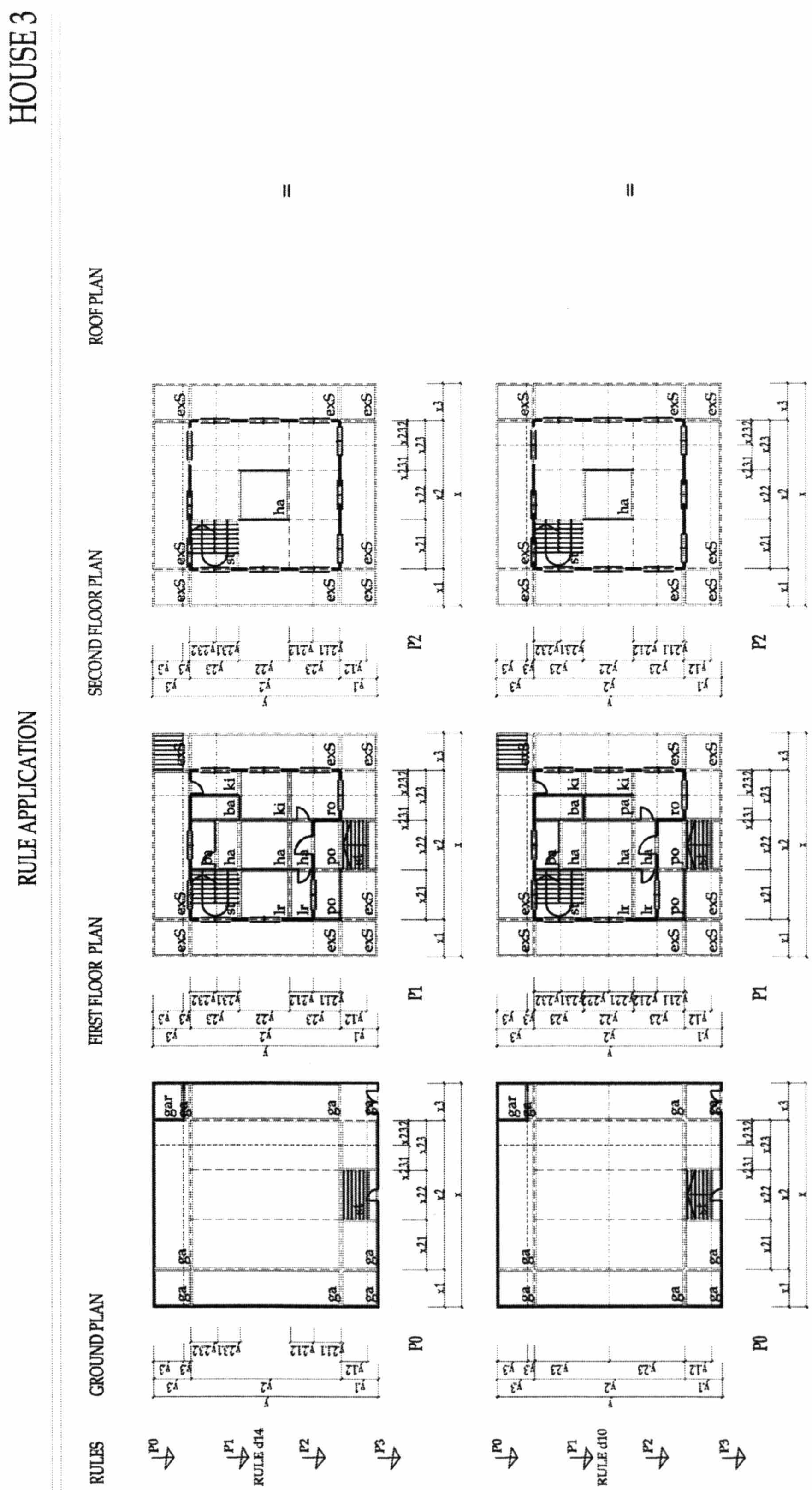
RULE APPLICATION



HOUSE 3

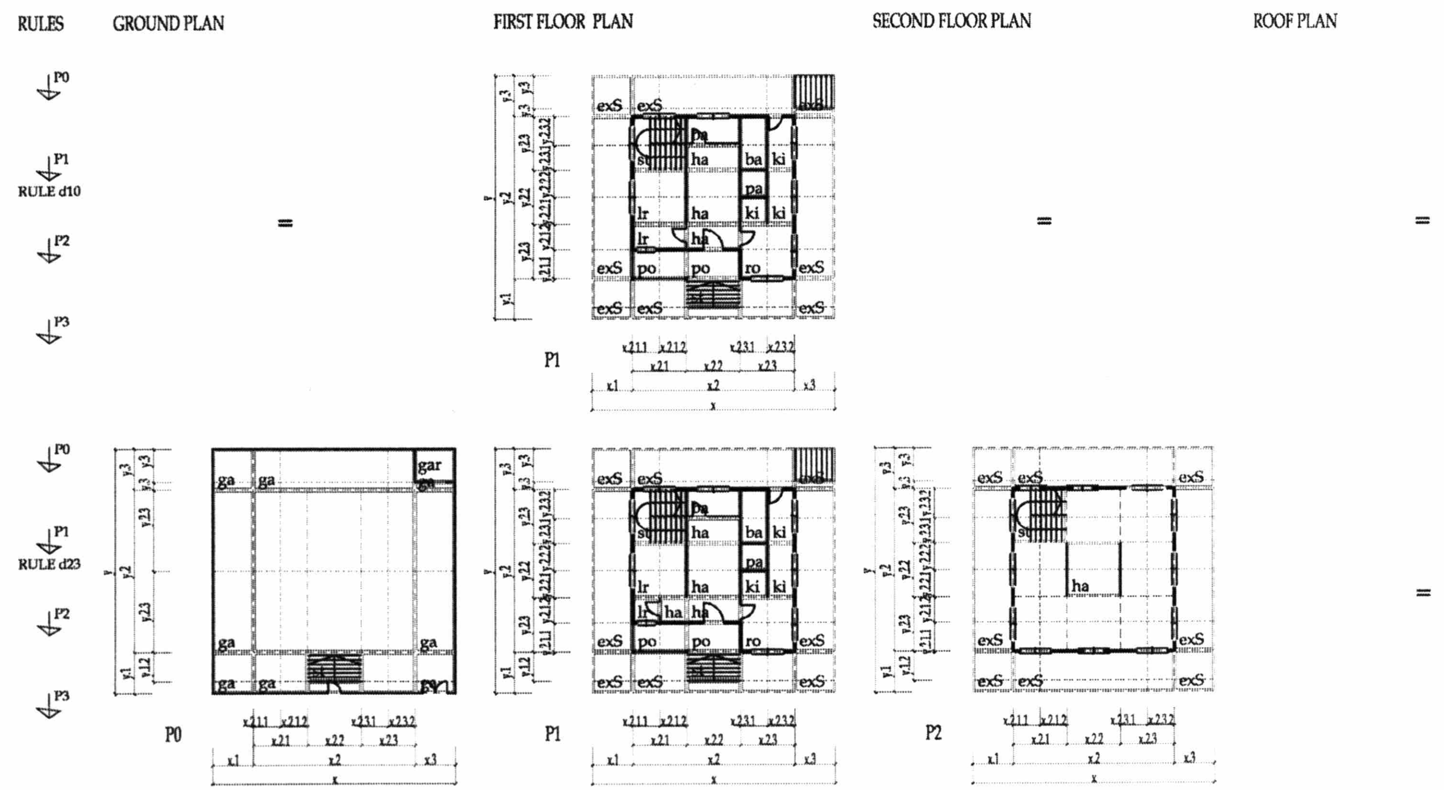
RULE APPLICATION




HOUSE 3
RULE APPLICATION
RULES
GROUND PLAN
FIRST FLOOR PLAN
SECOND FLOOR PLAN
ROOF PLAN
P0
P1
P2
P3
RULE d14
RULE d10

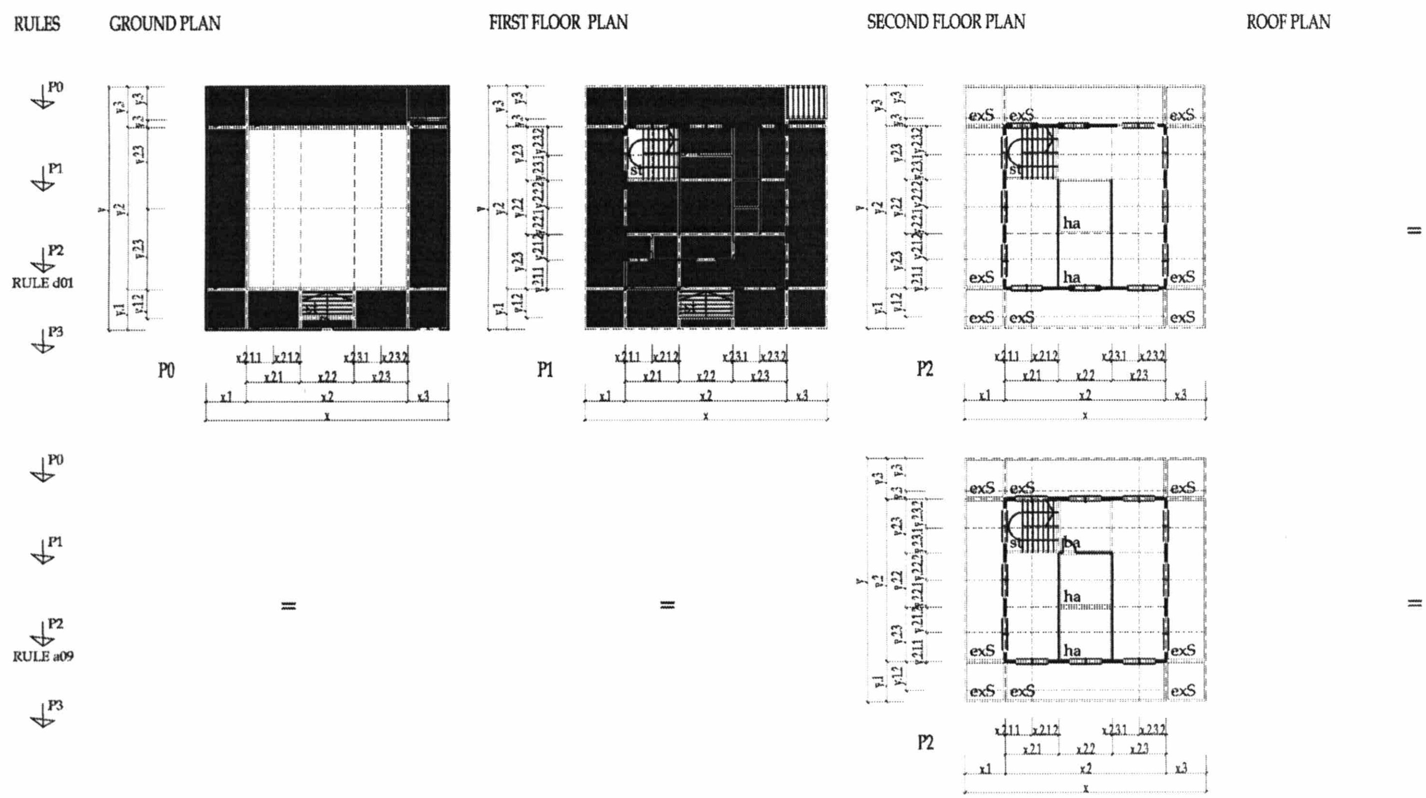
HOUSE 3

RULE APPLICATION



HOUSE 3

RULE APPLICATION



HOUSE 3

RULE APPLICATION

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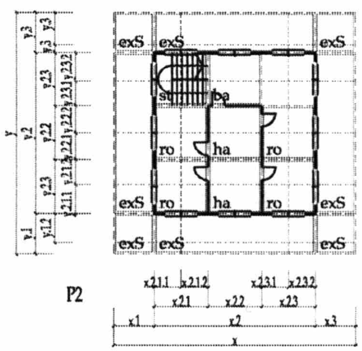
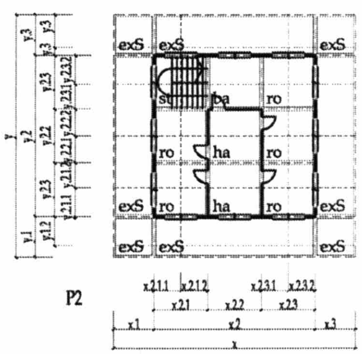
P0 P1 P2 RULE a03 x6 P3		=		=		=	
P0 P1 P2 RULE a15 P3		=		=		=	

HOUSE 3

RULE APPLICATION

RULES | GROUND PLAN | FIRST FLOOR PLAN | SECOND FLOOR PLAN | ROOF PLAN

P0

P1

P2
RULE d29 x2

P3

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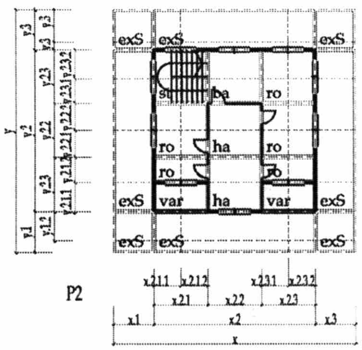

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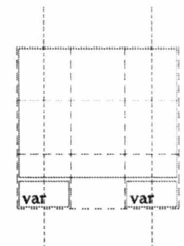

P0

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RULE d28

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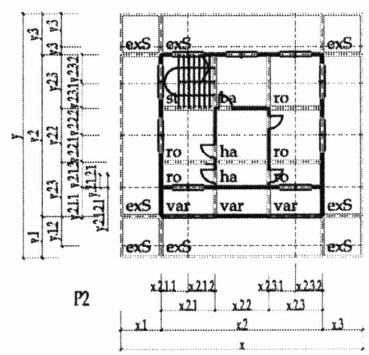

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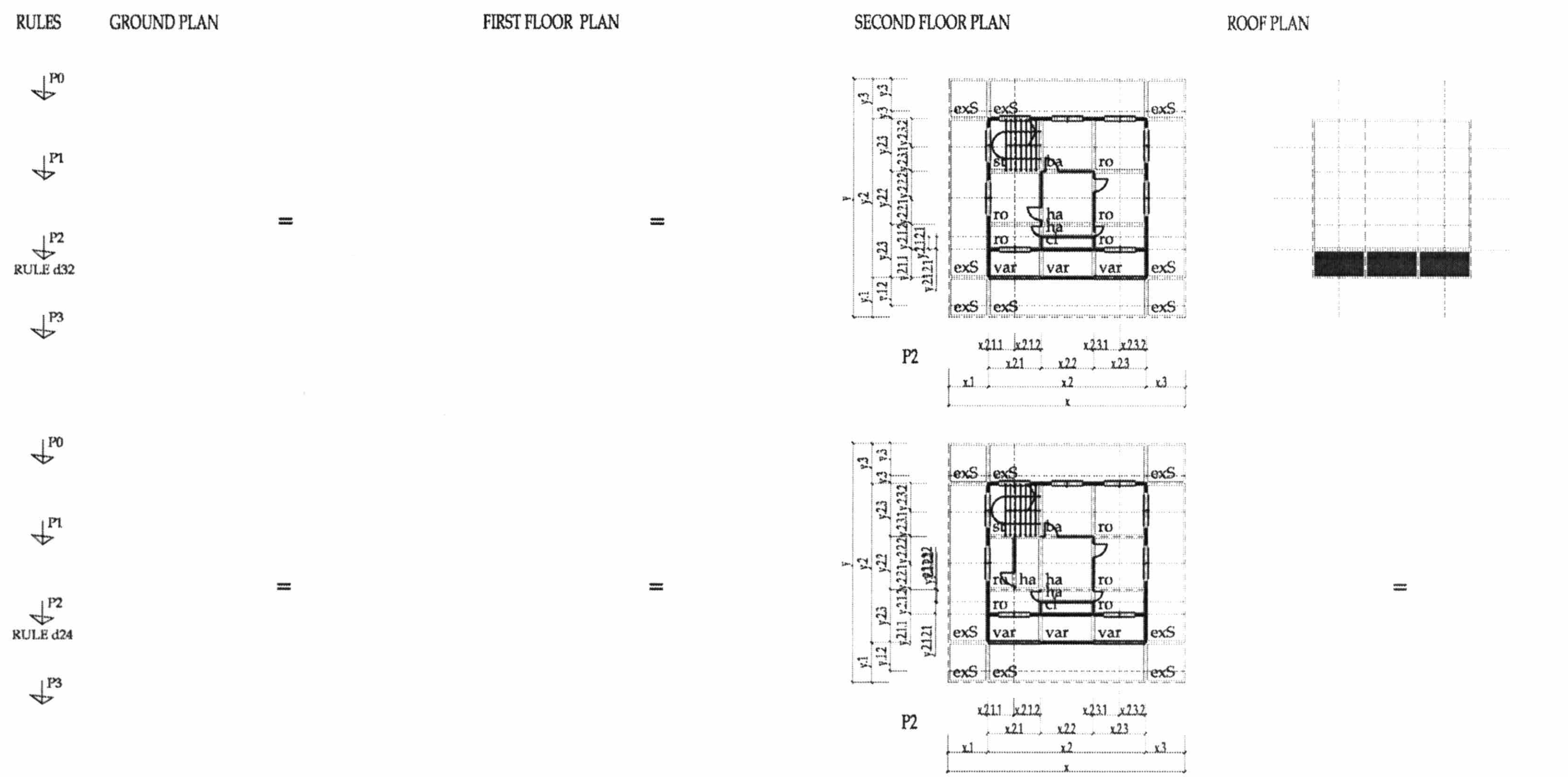
HOUSE 3

RULE APPLICATION



HOUSE 3

RULE APPLICATION

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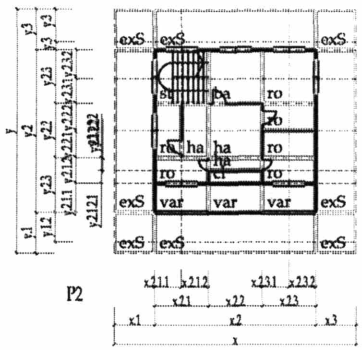
P1							
P2 RULE d13		=		=	 P2	=	
P3							
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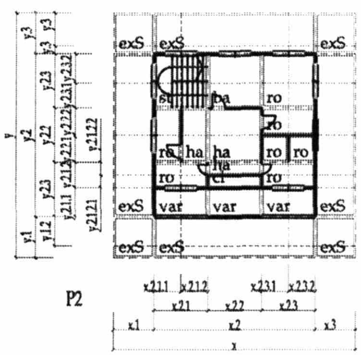
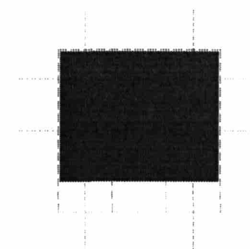
P1							
P2 RULE d13		=		=	 P2		
P3							

HOUSE 3

RULE APPLICATION

RULES	GROUND PLAN		FIRST FLOOR PLAN		SECOND FLOOR PLAN		ROOF PLAN
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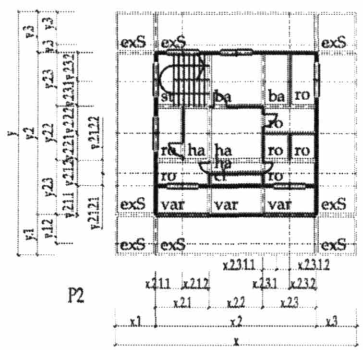
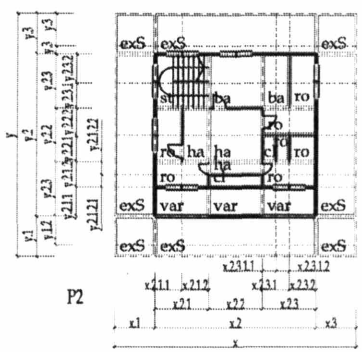
P1							
P2 RULE d18		=		=	 P2	=	
P3							
P0							
P1							
P2 RULE d17		=		=	 P2	=	
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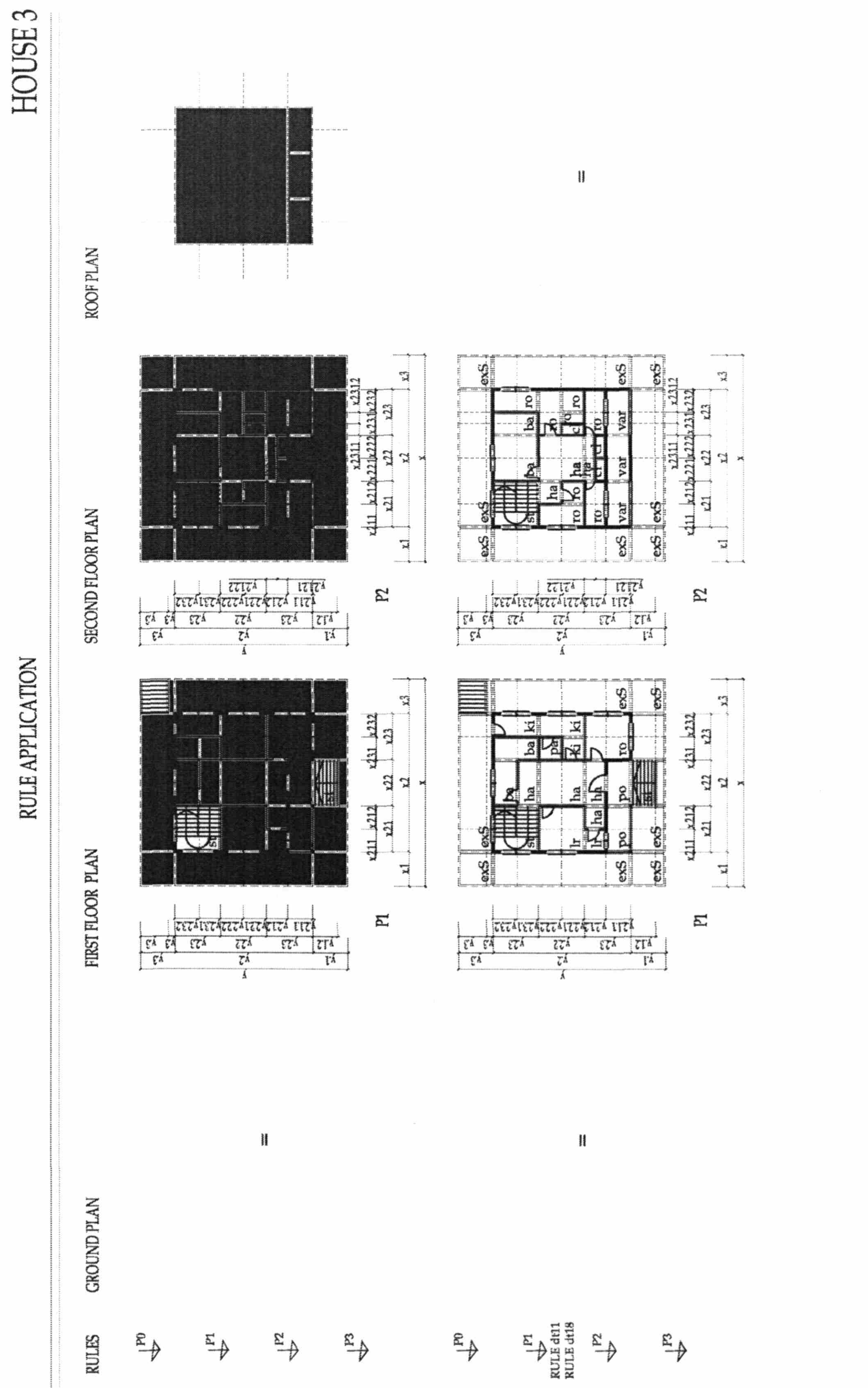
HOUSE 3
RULE APPLICATION
RULES
GROUND PLAN
FIRST FLOOR PLAN
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P0
P1
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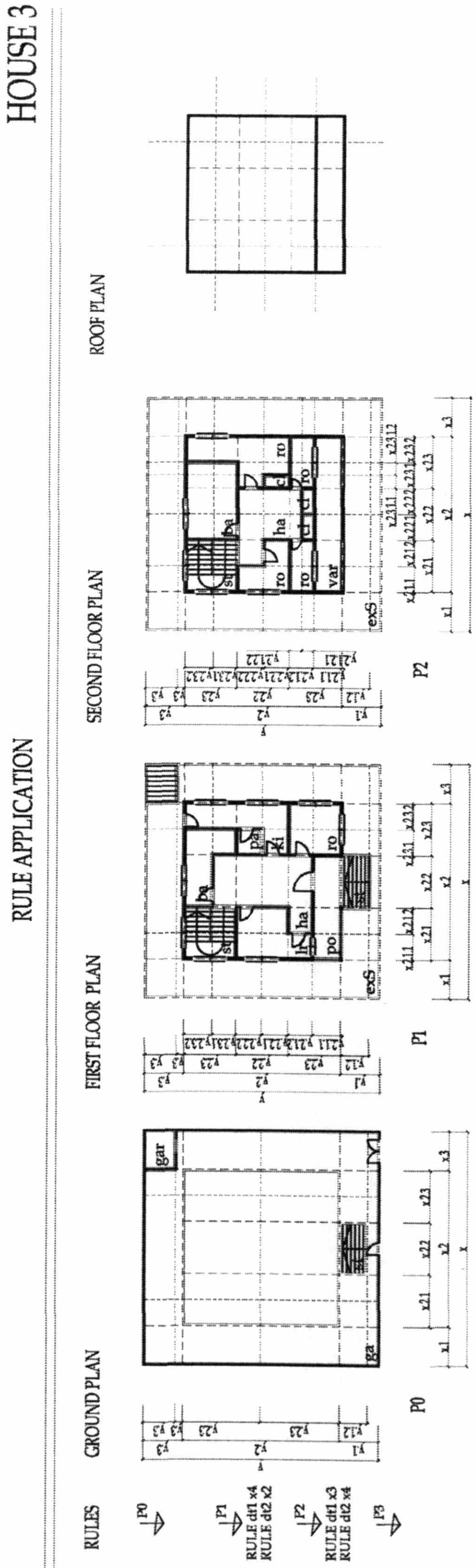
P3
RULE dt11
RULE dt18


HOUSE 3
RULE APPLICATION
RULES
GROUND PLAN
FIRST FLOOR PLAN
SECOND FLOOR PLAN
ROOF PLAN
P0
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RULE df1 x4
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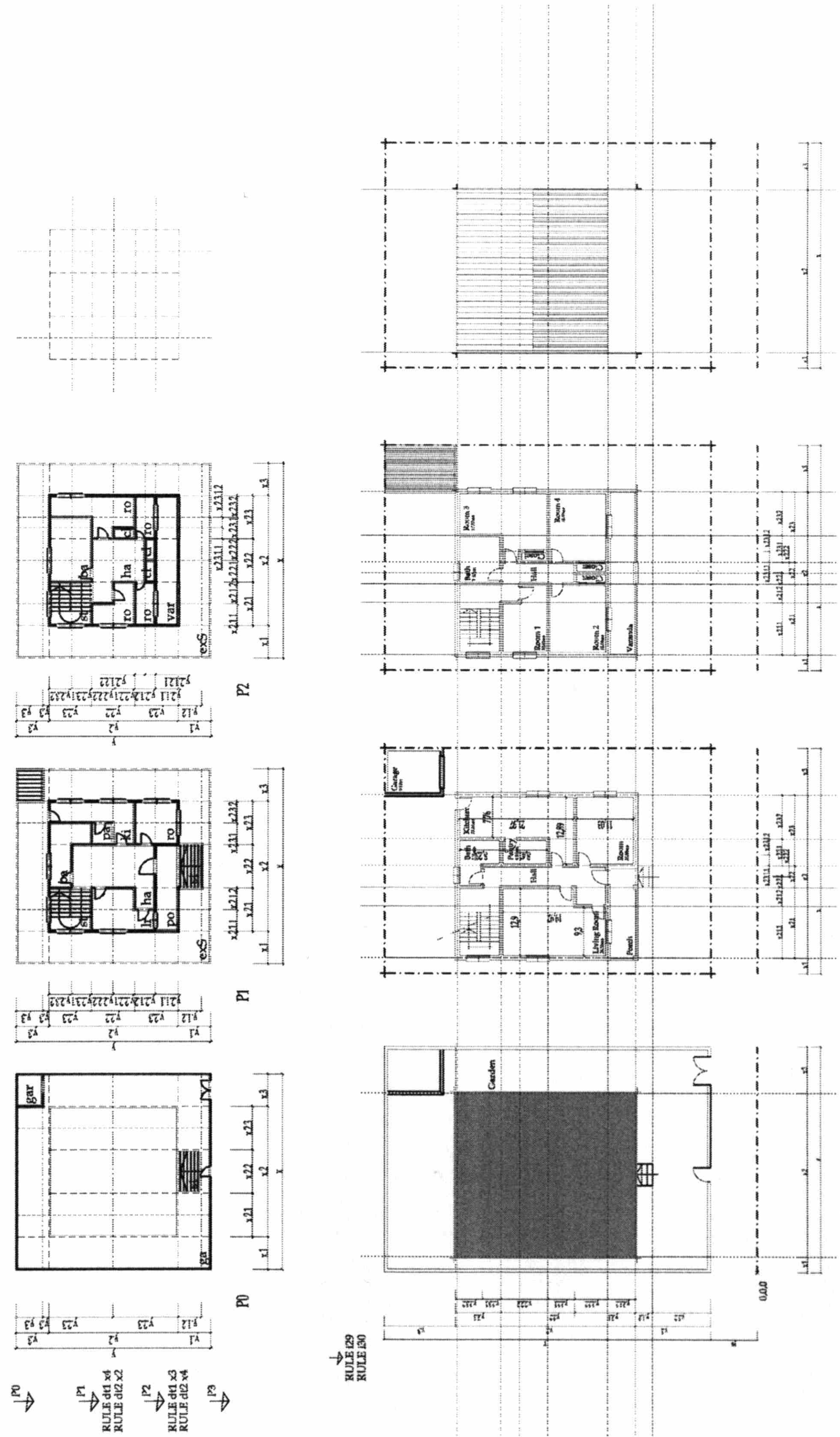
RULE df2 x4
P3



APPENDIX E

CAN A COMPUTER IMPLEMENTATION BASED ON SET GRAMMAR ALLOW EMERGENT SHAPES?

Luís Romão,

School of Architecture and Planning, Massachusetts Institute of Technology, USA, and Faculdade de Arquitectura, UTL, Portugal

lromao@mit.edu

Abstract. In a previous paper, (Romão 2005) it was shown that a designer could create his own rules and combine them for application in a deterministic way using a computational device based on Set Grammars called SGtools. Using this device, the designer can assess the results in a visual manner and then change the rules without any knowledge of a programming language. This work examines whether SGtools can deal with emergence by coupling the representational abilities of Set Grammars with the search power of hybrid algorithm inspired on Genetic and Taboo search algorithms. The use of this search algorithm enhances the ability of the designer to explore solutions in practical time thereby enabling him/her to find unexpected, emergent solutions.

Keywords: Shape Grammars, Generative Design; Prediction and Evaluation.

INTRODUCTION

Two strategies have been used in visual art: grabbing shapes as objects or formulating objects from shapes. Francisco d'Ollanda (1955) mentioned these strategies through the words of Michelangelo Buonarotti, when he argued for differences between the Flemish painters and the Italian ones. According to Ollanda, Michelangelo said that Flemish painters drew things back and forth to compose a painting, using landscapes, saints, and other symbolic "objects", which Italian painters did not. The relevance of this quotation is that its implicitly identifies two processes of representing art through shapes that can be used for transposing processes and representation to computation. The statement of Kurt Badt, quoted by Rudolf Arnheim (1996), about how impressionist and pos-impressionists saw shapes can help to illustrate this argument. As he pointed out, both strategies apply for creativity but not in the same way:

The Symbolists derived their representation of the world from individual objects; they built it around single figures, composed it of objects, in Latin: res. Their intention was that of realists, regardless of the meaning they attributed to the objects. The Impressionists proceeded from impressions of the whole, from a connexion of things, into which these things had grown and which they had created by their natural growth. ... In their conception of the world and in the intention of their art, which had the task of showing that conception, the Impressionists were naturalists (using the word nature in its original sense of nasci: being born, wanting to become, growing.) This means that there was in fact a profound difference between the two artistic tendencies. But there is no difference of rank or value between the two conceptions of reality. They are two equally good aspects of the same thing. For this reality of the world exists, in man's conception, as connexion but also as segregation because the two can be thought of and represented only in mutual relation.

The first part of this statement shows some relevance for our argument: symbolists represent the world from a collection of objects. In opposition, others represent reality as a whole framed by connections. For different reasons, artists decide to use one of the approaches, or both. Therefore, the idea of designing with shapes as symbols with hierarchical relations is not new, and it is worth to explore in computation.

BACKGROUND

In recent literature, several authors have claimed for a shift of paradigm in design and computation (Mitchell, 1990; and Emdanat, 1999). The procedure of transposing representation and process in computation could follow the bottom up approach used by Rodney Brooks (2005) in the cog robot project. He says: *It turns out to be easier to build real robots than to simulate complex interactions with the world, including perception and motor control. Leaving those things out would deprive us of key insights into the nature of human intelligence.* In this approach, methods of interaction are evaluated and tested in order to fulfill a distant goal. The concept of starting a design process from almost nothing is common in design practice. After the initial conceptual sketches, a huge collection of regulations and technical issues is considered in the project development. A question then arises, how can one conceive a tool that supports this incremental development of the design process? How can one assure that this tool is flexible enough to allow the exploration of different formal universes without jeopardizing productivity?

Terry Knight (2003) stated that Shape Grammars (SG) are characterized to support intelligibility, and evolutionary computation systems supports productivity. Some examples of combination of SG and Genetic Algorithms (GA) or Simulated Annealing (SA) have been experimented inspired by those claims, however, the expectation of a final and a clear production result is lower for designs that are beyond the engineering design context. The methods of research have been used to evaluate building performance, or predict energy conservation (Caldas and Rocha, 2001) or design structural analyses components (Shea and Cagan, 1999). This type of simulation and some articulated process and representation are nicely done. The characteristics of these areas have certain well-defined values that can be represented by algorithm operations. However there are other aspects of design more difficult to quantify. It is necessary to answer to some minimal requirements: to promote a good computer representation of shapes and associated elements, to promote a process framework to manipulate that representation and to promote a resourceful control to act on information. In addition, John Gero (1999) introduced the concept of constructive memory to answer the need of explaining some of the phenomena that occurs in designing and design thinking. He identifies a gap between "reinterpretation" and "unexpected discovery". He also argues that emergence can happen by a reinterpretation of existent shapes. In fact, natural metaphor process seems to miss human memory representation. Meanwhile, it was introduced a combination of GA and TS (Hansa, 2003). This mixed was justified because TS process narrows too much the field of search in opposition with the other. Nevertheless, one may wonder that by introducing a metaphor of memory could approach design process because instead of having a single, although huge, blur line (or space) of search, it could happen instead of different lines (or spaces) of search.

As Samir Emdanat (1999) stated that coupling generative systems and a meta-heuristic research method provided: a compact representation of the design space that can be subjected to systematic explorations to discover feasible design topologies, and an exploration that can be efficiently directed to feasible segments of the design space from which designs that can exhibit highest utility are selected. Other methods and combinations of them have been used in design with shape grammar; the paradigmatic example is of the Christine Shea and John Cagan (1999) work. It was used the simulated annealing process for structural analyses. Other example is combining GA and SG (Rosenman 1996). Outside architectural design, GA have also been tried by mixing metaphors of memory or cultural transmission, which improved GA performance (Spector 1996) in author opinions.

Therefore, SG were selected because they proved to be a solid background in terms of computer representation and analyses, and GA were selected as a computer process of search have proved to be a consistent method of search where productivity is applied. The memory metaphor was added because it seems that is part of a human process of thinking and it might improve the method of search.

SGtools is a local tool that performs under set grammar guidance, a method that can control representation, but the question is if it can be combined with method search strategies. The user defines a grammar by visual means and rules that can be stored and retrieved. A shape in a vocabulary defines a grammar from a group of rules based on the isometric properties of a rectangle, for 2D purposes or of an oblong, for 3D ones. One can play with different grammars in combination that are applied at the same search space. Designs are evaluated visually by one person or more in a group. One can substitute a shape by other shape after being defined a spatial relation with rectangle or oblong shapes. Equivalence shapes can be any shape. This tool seems adequate to represent shapes and to keep in memory information about shapes, and to work together with a set of algorithms to represent processes.

SHAPE GRAMMAR PARAMETERS

Generative grammars are made of finite descriptions that explain an infinite set of designs in a known language (Stiny 1980). This formalism is specified by a vocabulary of shapes described as symbols and a group of transformations to generate new arrangements of shapes. As a design production system, it can generate known designs and new ones in the same style. That is the main strength of the generative systems that provide a concise and computable representation of design space. In its basic formal definition, it can be described as: G = [U, L, T, I]. Where U states for a vocabulary of non-terminal shapes, L states for terminal shapes, T states for a set of transformations and I for an initial shape. This production system works with a set of rewrite rules type A→B, when A is found in C the rule is applied under given transformations.

Only Euclidian and affinity transformations are allowed. Rules of addition and subtraction are applied to shapes described in a zero-dimension. Concepts of shape equivalence and color grammar can operate over shapes through rules. The SGtools uses parts of this framework device described earlier.

RESEARCH OPTIMIZATION METHODS

There are not optimal solutions on research methods and the same can be said for designs. Algorithms that support creative design should help to produce surprising designs: randomness is needed. Playing with chance has to be combined with a goal-oriented search. It has to be an effective way of exploring on a searching space. Therefore, what seems to be interesting is a division of labor between a human designer who is equipped to deal with ill-defined problems, and a machine that can formulate a great range of possible designs.

GENETICS ALGORITHMS

GA have been used for a quite some time in the area of design: a metaphor that simulates some aspects of evolution of nature, by modeling its behavior on a formal machine. These concepts and procedures are being largely applied to architecture descriptions and processes (Testa and al., 2001). John Gero (1999) summarizes the advantages of this method: it can produce unexpected results due to the random search; it can produce complexity, which is important if designer needs it; fitness can change over evolutionary time, which is very important during a design process; and fitness can be humanly evaluated, which supports an effective goal-oriented process. The blind search allows unexpected shapes that can become interesting by human visual evaluation.

TABOO SEARCH

It is also introduced another stochastic method of research that roots from the 70s, which Fred Glover (1996) presented for the first time in 1996. Many others had contributed for its formalization. The use of memory is the main key of this method. It keeps track of local information and simultaneously of the whole process, which Glover calls the dynamic neighborhood search techniques. A general definition can be: a solution of x moves to a solution $x1$ after n moves, if $x1$ is in the group of $N^*(x)$, and not in the group of the taboo list. Taboo lists can have different qualities.

FRAMEWORK REPRESENTATION

Processes that are applied here are inspired on those described earlier. A mix of both processes is introduced along with SG to produce design results. The question is; what are the tangible strategies to apply to represent a good approach to human design process. In terms of functionality, it means that a designer can work with any shape under SGtools framework, but he needs to use a programming language to alter the process search strategies, but not variable values. The presented example is very simple.

PROCESS OF SG ENCODING

This example is made for a two-dimensional scenario. The vocabulary is a rectangle of any dimension that is called in SGtools by frame, plus any other shape from the vocabulary of AutoCAD software. This second shape can later be changed through a method of shape equivalence inspired on the concept of Knight (1981). All Euclidian transformations are applied to a rectangle regarding its isometric properties. In this example, rules are four to limit this exploration. There are rules for shapes and operators for the search process that are dependent and listed into genotypes. For set grammars, it was defined a very common group of spatial relations. There are no terminal rules. In formal terms, this is a grammar composed by these parts: S_g = (U, L, T, I). Where, *U* stands for any possible AutoCAD shape. *L* stands for a labeled rectangle shape, and *I* for an initial shape. In figure 1, rules are shown and it is possible equivalent shapes.

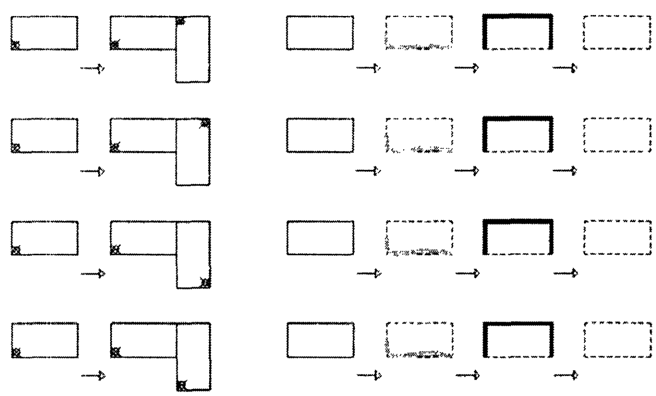


Figure 1Rules definition and possible shape equivalence

PROCESS OF GA ENCODING

A genotype contains information to be manipulated by crossover and mutation operators, while a phenotype is used for selection purposes. For this experiment, parameters are described as follows. Chromosome is represented by a binary format. It is composed of an identification of a shape, an associated SG rule and a number of rule applications. For example a chromosome |111 00 11| has respectively a shape that belongs to a grammar rule and its position in the space, a grammar rule with an associated shape, and three rule applications.

Fitness is given by human visual evaluation. A user should select from a range of possible shape rules, which one should prevail over others. For this example, it was implemented a fitness function with two possible options: selection of horizontal or of vertical lines. One may say that horizontal lines should prevail over the others. Other possible selection decision was a selection by the type of shape grammar rules. These criteria are applied randomly over existent population.

Crossover will work by binary representation and two points crossing. For example: |111 00 01| and |100 01 10 | may be the parents of |111 00 10| and |100 01 01| chromosomes. The correspondence in this case: |111 00 01| means a shape and its position of a range of eight possibilities. The second part represents a shape grammar rule that is associated with the shape. The last part represents the number of rules application that ranges from 0 to 3. The process of pairing selection and mutation are random. In this case only half of the whole population can do crossover processes, where $P_c = 0.5$.

Mutation will occur by flipping one gene value. For example, |010 00 11| may go to |010 01 11|, which means that the selected shape is changed by a shape of the other rule, but the position in space will be the same. This process is applied to a small percentage of population, $P_m < 0.001$.

Parameters can be changed for selection and the ways they are applied. In this case, it was applied roulette-wheel selection method. For example, the number of vertical/horizontal lines and rule type can be altered by human evaluation. For the first case, it was applied 80/20 percentages. For the second, the chosen rule is removed by 10% of the total rule population and by 30% for the others rules. These values can be altered during the search. Population size and results are controlled by the user. At any time can be introduced a number of possible elements of a population.

The selection process also includes a pre-defined function that does not admit duplication of a same shape at the same space. A new population is created and kept into a new layer. Only current population is seen, other populations are frozen, but they can be retrieved and new populations can derive from them.

A new population derives from an old one by means of a selection. The user can track different generations and can retrieve them. From an old selected population can derivate a new line of search. There are no limitations to the number of population proposed and evaluated, neither to the lines of direction of search. For example, in figure 2 it is shown different lines of direction that the search can take. Not only a line direction can change, but also it is possible to create a new direction from an old population. It is similar with the process of retrieving an old drawing previously dropped into a litter basket.

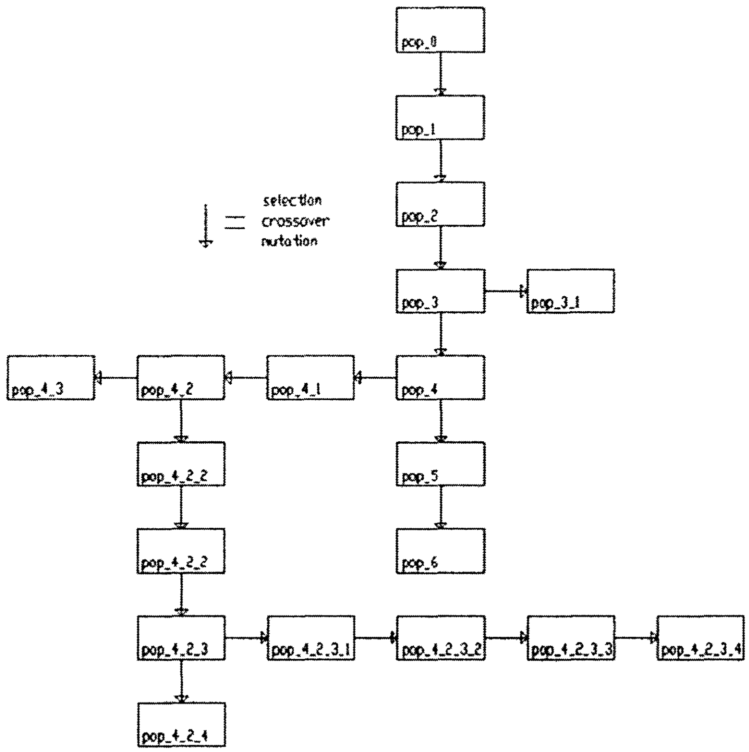


Figure 2 Populations can be stored and retrieved.

CONCLUSIONS AND FURTHER WORK

One of the goals of this paper was to inquire if a computer implementation could combine metaphors of genetic algorithm process and shape grammars representation to obtain interesting goal-oriented design approach. It was seen that is needed further exploration to prove validity, not only with this simple grammar, but with also introducing grammars that are more complex. Memory metaphor seems relevant because older populations could be reevaluated to provide new reformulated ones.

The goal for emergence results a limited because it can play an important role for design. It is gotten by human visual evaluation over populations. There is not computer emergence though. Populations that embody options are in the universe of the grammar but they are difficult to reach by a systematic evaluation. There is also the possibility from existent design shapes being formulated into new rules, which augment enormously possible search spaces. During the process of search, the user can create new rules shaped by other rules and shapes. For example, rule_1 is A→tA, and rule_2 is B→tB both are part of a rule_3 C→t_1C, where C contains A and B shapes and t_1 is different of previous t(s) values but they work all together in a parallel format.

There was other goal: creating a tool that could "grow" along with the comprehension of the user in terms of design and mainly in terms of tools. This approach is not new (Testa and al., 2001). The process of interrelation between computer and designer, using this application or a different one, could be a good strategy to stronger relations between designers and computers. It was introduced both spatial and visual features to promote and do control offspring better. The populations illustrated in figure 3 could be used to support a detached house for example. There are no constrains of areas spaces or topologic relations between them.

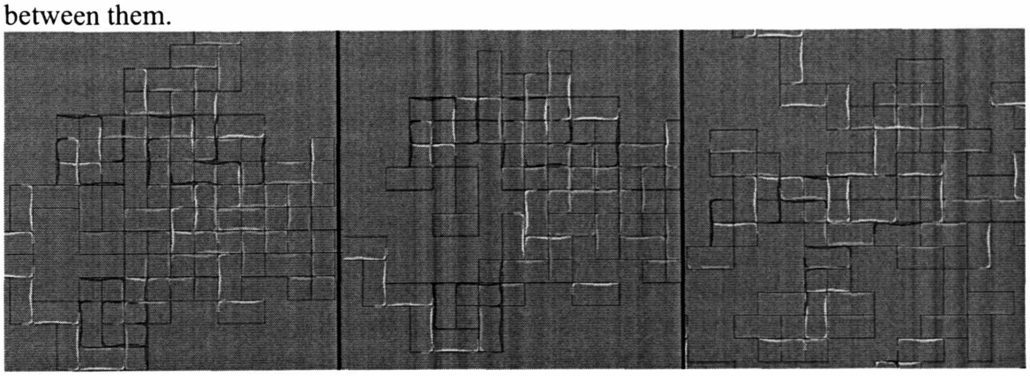


Figure 3 Populations 2, 3 and 9.

Real tests should be made against real design programs, in terms of early stages of design. It was not presented any completed design result yet. The same grammar and the same search process could lead to different design results depending on the designer. Even a same designer could reach different solutions in different times. This process only focuses the morphology aspects of design and aspects of emergence will be explored only in terms of designer evaluation. Nevertheless, more work must be done to generalize this framework and improve user interfaces.

An important aspect should be noted. There is not only one linear path of search, even blurred and large, but many. These directions were tracked and the end of the process is decided by the user. He goes as far as he can handle. It seems odd or randomly but it was argued that the introduction of the memory metaphor narrows the space of search. During the process of search, shapes can be changed and tested. By changing shapes, previous population may need to be evaluated.

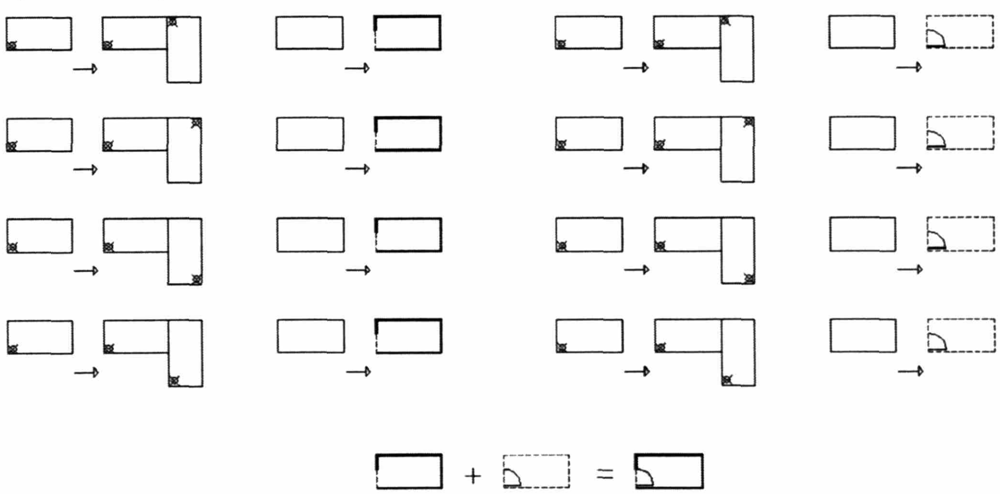


Figure 4 Different rules of different grammars can interact; the holistic relation is given by the user

To conclude, a genetic approach was applied, mixed with concepts that are outside the genetic definition. This will alter results profoundly. It is thought that certain phenomena are artificial regarding those dependent of the goals or purposes of the designer. Results are different for each designer, in opposition to natural laws that are controlled by natural phenomena, which tend to a same result.

ACKNOWLEDGES

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APPENDIX F

AN EXAMPLE OF A COMPUTATIONAL TOOL TO USE A STANDARD SHAPE GRAMMAR IN COMPUTATION

(Working paper)

School of Architecture and Planning, Massachusetts Institute of Technology and Faculdade de Arquitectura, Technical University of Lisbon

Luis Romão

ABSTRACT

I would like to explain to students how Shape Grammars (SG) being a formal device could work in a computer implementation. Like any other formal device, it should allow working with shapes in a computer environment based on George Stiny definition. Many other formal devices relate shapes with computation, for example, spatial grammar, set grammar, expert systems, annealing shape, fractals and others. I can show them some examples of it. I had already created some computer implementations to exemplify those, as SGtools and others. These implementations work with shapes, as they were symbols. As reference of a SG implementation, I only have the work of Mark Tapia and the papers he wrote. I have already enough trouble saying that designers may use shapes "loaded" with meaning, but

also that they may use shapes as we see them "striped" of any meaning unless the meaning they have as shapes, even more, that by parsing shapes we can get new shapes. Moreover, when I say that visual perception and computation should blend into one process the discourse becomes even more difficult.

BACKGROUND

I have had two motivations for doing this work. One was to present to students of the last years of architectural program, what has been researched in the area of architecture and computation, in a brand new discipline that pretends to discuss the subject. The other was to test an approach to reformulate the grammar of the illegal housing from a set grammar to a standard shape grammar.

The foundation of this implementation is grounded in the formalism of shape grammars as George Stiny and James Glips defined it (Stiny and Gips, 1972).

Despite of the implementation of shape grammars in computer have be having some technical difficulties it is been made some examples for educational goals, (Chase, 1989; Krishnamurti, 1981; Krishnamurti, Giraud, 1986; Tapia, 1999). Therefore, I have tried to create an example that could be a supporting tool for teaching: easy to show and to be used by the students. I took the example of Mark Tapia as a main reference.

IMPLEMENTATION

To be more convenient, clear, and accessible to students I have decided to create a small implementation in the AutoCAD graphic environment using the AutoLisp language. I can show it in class and students can use it for testing. I hope this become an example to students do their own grammars.

The works of Mark Tapia and the formal devices of George Stiny sustained this assignment. It was selected a small vocabulary of shapes and an easy rules to apply. The user can comparing it with the set grammar examples in order to understand the issues of a symbolic strategy and a shape one in terms of shape description. There is no recursion here because I believe it was not important at this stage. The implementation, as it is, could be expanded later to accept recursion and automation to this grammar.

Starting from the general idea of what a shape grammar is: G=(N, T, R, I), which N stands for non-terminal vocabulary, T for terminal vocabulary, R for a set of rewriting rules, and I for initial shape, it is given an example of a rule.

$$(tA) \rightarrow (tB) \qquad (1)$$

In addition, the rules are the following:

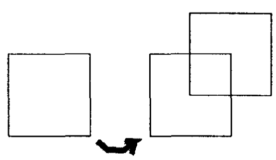


Figure 4 Rule 1 (non-terminal)

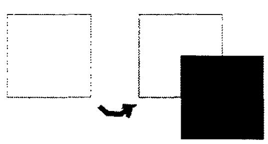


Figure 5 Rule 2 (terminal)

Translations and scale are transformations that will be used. The process to apply rules is:

$$C(n\text{-}1)\text{-}(tA)+(tB)=Cn \qquad (2)$$

The rule is applied to any shape that we see in C without restrictions. Restrictions are given by the rules. It is embedded a shape of the rule over shapes of C and they are collected to apply the rule. This grammar uses Boolean operations of sum and part relation. The rule is only applied to shapes that can be seen and are explicit represented. They cannot be "phantoms". If by mistake the user selects two points of a diagonal to identify a square in C, and they do not belong to a diagonal of an existent square the rule is not applied.

The process can be described as *shapes algebras*. Two collinear lines which overlap in any part or which have an endpoint in common may combine via reduction rules for + (sum), to form new lines (Chase, 1989). Shapes are finite arrangements of basic geometric elements. I considered here points, lines, and limited areas as basic elements. We describe algebras of lines and shapes composed of lines, and planes bounded by lines. It may be decomposed into its parts, which consist of other lines embedded within it. There are an infinite number of lines, which may be part of an existent line. This is not as Stiny proposal but later this would be altered. We use *part relation* ≤, for example, *l1* ≤ *l2* means that line *l1* is embedded in or part of line *l2*. The recursive nature of the grammar is not shown here.

Lines on the shape C are decomposed only to allow the application of the rule. The embedding relations are limited to this constrain. Therefore, this application as it is could support other types of shape rules. The figure 3 and 4 shows the possible shapes and therefore the limitation of this implementation that does not follow Stiny maximal lines concept.

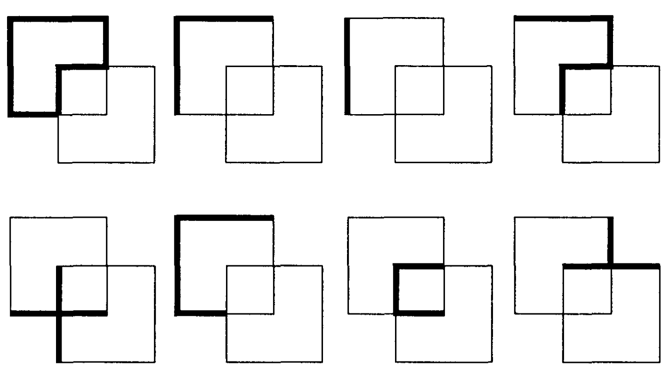


Figure 6 These are some of the shapes that can be identified in C

However, it is not possible with these, and many others.

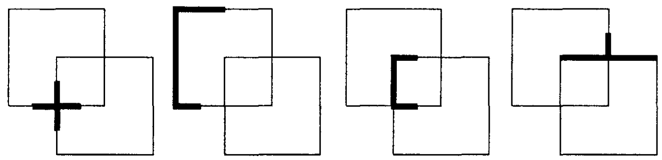


Figure 7 These are parts of shapes or shapes that cannot be identified in C

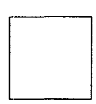
In practical terms it is needed an AutoCAD graphic application of any version. This application has three commands. From the scratch we need to insert an initial shape in a new drawing, which has be a square and apply one of the two rules.

is: It is used in a new drawing to introduce the initial shape for the first time
ishape: It is used to reintroduce the initial shape more then once
ss: It is used to apply the rule 1.
ss2: It is used to apply the rule 2.

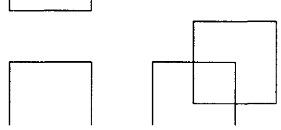
The inputs of the user are; introducing two points that defines a diagonal of a selected square. Then it must to be chosen one of the four possible sides to apply the rule by clicking a point in the graphic area, and in the end, accepting the rule application saying "yes". We may say "no" to reformulate shape.

In order to use this implantation it is needed to load this macro into AutoCAD.

(LOAD "[drive/directory]/sg_sq_rule.lsp")



The initial Shape



The Rule A→ B

Because of the symmetry of the square, there are four possibilities to apply the rule. The user must choose one by pointing a direction in the graphic area.

Given transformations of translation and scale, a square is imposed over a part of the drawing. It is used an embedding operation and if it matches the rule will be applied. If it was not a square above A shape, the implementation will stop.

CONCLUSIONS

An important change that urges to do is the implementation of maximal lines. However, it is possible to use this application to answer the main goal of this implementation that was to explain to students, how is the SG formalism applied to computation and how shapes could be described differently inside a symbolic machine. By altering some functions to this formal description, it could be easy to add other rules, recursion possibilities, and automation. Further work could be done using different algebras in the process.

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Chase S. C., (1989). Shapes and shape grammars: from mathematical theory to computer Implementation, *Environment and Planning B: Planning and Design*, 16:215-242

Krishnamurti R., (1980). The arithmetic of shapes, *Environment and Planning B: Planning and Design* 7:463-484

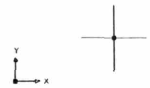
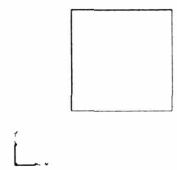
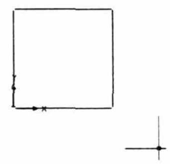
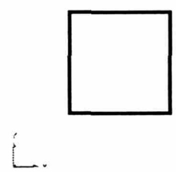
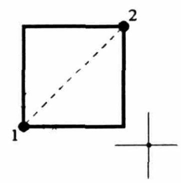
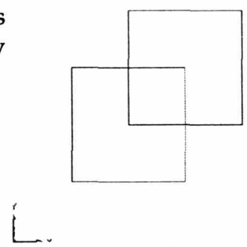
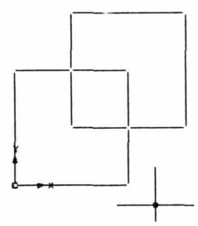
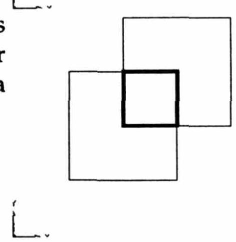
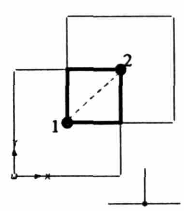
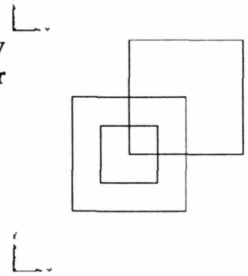
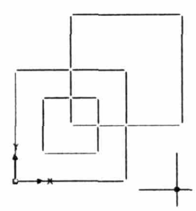
Krishnamurti R., (1981). The construction of shapes, *Environment and Planning B: Planning and Design* 8:5-40

Krishnamurti R., Giraud C., (1986). Towards a shape editor: the implementation of a shape generation system, *Environment and Planning B: Planning and Design* 13:391-404

Stiny, G., and Gips, J., (1973). Aesthetics Systems, Stanford Artificial Intelligence Project, Memo AIM-189.

Tapia, M, (1999). A visual implementation of a shape grammar system, Environment and Planning B: Planning and Design, 26:59-73.

Appendix 1

Notes	VISUAL	COMPUTATION	Notes
Paper drawing, a limited sheet size. Algebras U_{12} Measures/scale are important			Implementation in AutoCAD in a Cartesian plane. A non-limited size space/plane. Scale are not an issue Algebra U_{03}
4 lines, or a square, corners, or other shape			4 lines 4 points Algebra U_{03} but entities perform roles in U_{21}.
A selected square			4 lines and a square The user defines a shape using transformations by given two points of a diagonal. Embedded operations are allowed. A square is imposed over lines and Boolean operation runs.
12 lines, 3 squares and other many possibilities			12 lines 10 points
12 lines, 3 squares and other possibilities and a selected square			12 lines and a selected square. This implementation only allows 3 possibilities. Embedding relations, once again, are allowed.
Many lines, many squares and other different shapes.			20 lines 16 points
…	…	…	…

Appendix Two

```
;------------------------------------------This is a AutoLisp Code, 2005-----------------------
;--It is part of the work for PhD studies in MIT, Luis Romao
;--It provides an application of a simple grammar using the concepts of a standard shape
;--grammar except maximal lines, that will be introduced later.
;--
;--It has four commands:
;----is: It is used in a new drawing to introduce the initial shape for the first time
;----ishape: It is used to reintroduce the initial shape more then once
;----ss: It is used to apply the rule 1.
;----ss2: It is used to apply the rule 2.
;
(defun go ()
	(setvar 'osmode 0)
	(setq pt3 (polar pt1 (+ (/ pi 4.0)(angle pt1 pt2)) (/ (distance pt1 pt2)(sqrt 2))))
	(setq pt4 (polar pt2 (+ (/ pi 4.0)(angle pt2 pt1)) (/ (distance pt1 pt2)(sqrt 2))))
	(if (= nil (and (setq z_line (ssget "W" pt1 pt3))
			(setq z_line (ssget "W" pt3 pt2))
			(setq z_line (ssget "W" pt2 pt4))
			(setq z_line (ssget "W" pt4 pt1))))
		(progn (prompt "\n Sorry! Wrong move. Try again. .... ")(exit))
	(progn
	(setq ei (list 0 0 0))
	(command "pline" pt1 "w" (* (distance pt1 pt3) 0.05) (* (distance pt1 pt3) 0.05)  pt3
pt2 pt4  "c")
	(command "color" "1")
	(command "3dpoly" pt1 pt3 pt2 pt4  "c")
	(command "color" "bylayer")
	(setq dir_ang (getpoint "\n Which side? "))
	(setq dir_ang_f (angle (polar pt1 (angle pt1 pt2)(/ (distance pt1 pt2)2)) dir_ang))
	(setq side (cond ((and (>  dir_ang_f  0.0)(< dir_ang_f  (/ pi 2.0))) (/ pi 4.0))
			((and (>  dir_ang_f  (/ pi 2.0))(< dir_ang_f  pi))  (* pi (/ 3 4.0)))
			((and (>  dir_ang_f  pi)(< dir_ang_f  (* pi (/ 3 2.0)))) (* pi (/ 5 4.0)))
			((and (>  dir_ang_f  (* pi (/ 3 2.0)))(< dir_ang_f  (* pi 2.0))) (* pi  (/ 7
4.0)))
			(t nil)
	))
	(command "move" "last" "" "0,0" (polar ei side (/ (distance pt1 pt2) 2 )))
	(if (= "y" (getstring "\n Do you want this rule applied this way? <y or n> "))
	(progn (command "chprop" "last" "" "color" "bylayer" "")
	(command "explode" "last" "")
	(command "erase" (ssget "X" '((0 . "LWPOLYLINE")))"")
	(prin1 "  ........ DONE .......... ")(princ)(princ)
	(command "zoom" "e")
	(command "zoom" "0.5x"))
	(progn (command "erase" "last" "")
```

```
        (command "erase" (ssget "X" '((0 . "LWPOLYLINE")))"")
        )))
))
(defun ib ()
        (setvar 'osmode 1)
        (command "insert" "rule" pause (setq pt2 (getpoint)) "" )
        (setvar 'osmode 0)
        (setq pt1 (cdr (assoc 10(entget(entlast)))))
        (command "erase" "last" "")
)
(defun int ()
        (setq ab (getvar 'osmode))
        (setvar 'osmode 0)
(setq total (ssget "X" '((0 . "LINE"))))
(setq n1 (- (sslength total) 1))
(setq m1 0)
(while (< m1 (sslength total))
        (while (>= n1 0)
           (setq ptn
                (inters
                (cdr (assoc 10 (entget (ssname total m1))))
                (cdr (assoc 11 (entget (ssname total m1))))
                (cdr (assoc 10 (entget (ssname total n1))))
                (cdr (assoc 11 (entget (ssname total n1))))
                ))
                 (if (and (not (equal ptn (cdr (assoc 10 (entget (ssname total m1))))))
                        (not (equal ptn (cdr (assoc 11 (entget (ssname total m1))))))
                        (not (equal ptn (cdr (assoc 10 (entget (ssname total n1))))))
                        (not (equal ptn (cdr (assoc 11 (entget (ssname total n1))))))
                        (not (equal (cdr (assoc 10 (entget (ssname total m1)))) (cdr (assoc 10
(entget (ssname total n1))))))
                        (not (equal (cdr (assoc 10 (entget (ssname total m1)))) (cdr (assoc 11
(entget (ssname total n1))))))
                        (not (equal (cdr (assoc 11 (entget (ssname total m1)))) (cdr (assoc 11
(entget (ssname total n1))))))
                        (not (equal (cdr (assoc 11 (entget (ssname total m1)))) (cdr (assoc 10
(entget (ssname total n1))))))
                        (not (equal ptn nil))) (lines4))
                (setq n1 (1- n1))
        )
        (setq m1 (1+ m1))(setq n1 (- (sslength total) 1))
)
(command "erase" (ssget "X" '((62 . 1))) "")
        (setvar 'osmode ab)
)
(defun lines4 ()
        (command "line" (cdr (assoc 10 (entget (ssname total m1)))) ptn (cdr (assoc 11
(entget (ssname total m1)))) "")
```

```
        (command "line" (cdr (assoc 10 (entget (ssname total n1)))) ptn (cdr (assoc 11
(entget (ssname total n1)))) "")
        (if (= nil (ssget "X" '((62 . 1))))
        (command "chprop" (ssname total m1) "" "c" "1" "")
        (command "chprop" (ssname total n1) "" "c" "1" ""))
        (if (not (ssmemb (ssname total m1) (ssget "X" '((62 . 1)))))
        (command "chprop" (ssname total m1) "" "c" "1" ""))
        (if (not (ssmemb (ssname total n1) (ssget "X" '((62 . 1)))))
        (command "chprop" (ssname total n1) "" "c" "1" ""))
)
(defun limp ()
(setq total_l (ssget "X" '((0 . "LINE"))))
(setq n1_l (- (sslength total_l) 1))
(setq m1_l 0)
(while (< m1_l  (sslength total_l))
        (while (>= n1_l 0)
                (if (or
                (and
                (equal (cdr (assoc 10 (entget (ssname total_l m1_l)))) (cdr (assoc 10 (entget
(ssname total_l n1_l))))0.01)
                (equal (cdr (assoc 11 (entget (ssname total_l m1_l)))) (cdr (assoc 11 (entget
(ssname total_l n1_l))))0.01)
                (/= n1_l m1_l))
                (and
                (equal (cdr (assoc 10 (entget (ssname total_l m1_l)))) (cdr (assoc 11 (entget
(ssname total_l n1_l))))0.01)
                (equal (cdr (assoc 11 (entget (ssname total_l m1_l)))) (cdr (assoc 10 (entget
(ssname total_l n1_l))))0.01)
                (/= n1_l m1_l)
                ))
                (limpar))
                (setq n1_l (1- n1_l))
        )
        (setq m1_l (1+ m1_l))(setq n1_l (- (sslength total_l) 1))
)
(command "erase" (ssget "X" '((62 . 2))) "")
)
(defun limpar ()
        (if (= nil (ssget "X" '((62 . 2))))
        (command "chprop" (ssname total_l m1_l) "" "c" "2" ""))

        (if (and (not (ssmemb (ssname total_l m1_l) (ssget "X" '((62 . 2)))))
              (and (/= 2 (cdr (assoc 62 (entget (ssname total_l m1_l)))))
                 (/= 2 (cdr (assoc 62 (entget (ssname total_l n1_l)))))))
        (command "chprop" (ssname total_l m1_l) "" "c" "2" ""))
)
(defun c:is ()
(ishape)(mb))
```

```
(defun ishape ()
        (setvar 'osmode 0)
        (command "pline" "0,0" "1,0" "1,1" "0,1" "c")
        (command "explode" "last")
        (command "zoom" "e")
        (command "zoom" "0.5x")
)
(defun mb ()
        (command "pline" "0,0" "1,0" "1,1" "0,1" "c")
        (command "block" "rule" "0,0" "last" "")
)
(defun limp_2 ()
        (setq limpeza (ssget "X" '((0 . "LINE"))))
        (setq n1_l2 (- (sslength limpeza) 1))
        (while (>= n1_l2 0)
                (setq pt1_l (cdr (assoc 10 (entget (ssname limpeza n1_l2)))))
                (setq pt2_l (cdr (assoc 11 (entget (ssname limpeza n1_l2)))))
                (if (< 2 (sslength
                (setq erase_line (ssget "W" pt1_l (polar pt1_l (angle pt1_l pt2_l) (distance
pt1_l pt2_l)))))
                        )
                (command "erase" (ssname limpeza n1_l2) "")
                )
                        (if (and (= 2 sslength)
                                (not (equal  (cdr (assoc 10 (entget (ssname erase_line 1))))
(cdr (assoc 10 (entget (ssname erase_line 0))))0.01))
                                (not (equal  (cdr (assoc 11 (entget (ssname erase_line 1))))
(cdr (assoc 11 (entget (ssname erase_line 0))))0.01))
                                (not (equal  (cdr (assoc 10 (entget (ssname erase_line 0))))
(cdr (assoc 11 (entget (ssname erase_line 1))))0.01))
                                (not (equal  (cdr (assoc 11 (entget (ssname erase_line 0))))
(cdr (assoc 10 (entget (ssname erase_line 1)))))0.01))
                        (command "erase" (ssname limpeza n1_l2) "")

                )
                (setq n1_l2 (1- n1_l2))
        )
)
(defun limp_3 ()
        (setq limpeza_3 (ssget "X" '((0 . "LINE"))))
        (setq n1_l3 (- (sslength limpeza_3) 1))
        (while (>= n1_l3 0)
                (if (equal 0.0 (distance
                (cdr (assoc 10 (entget (ssname limpeza_3 n1_l3))))
                (cdr (assoc 11 (entget (ssname limpeza_3 n1_l3))))) 0.01)
                        (command "erase" (ssname limpeza_3 n1_l3) "")
                )
                (setq n1_l3 (1- n1_l3))
```

```
        )
)
(defun go_2 ()
        (setvar 'osmode 0)
        (setq pt3 (polar pt1 (+ (/ pi 4.0)(angle pt1 pt2)) (/ (distance pt1 pt2)(sqrt 2))))
        (setq pt4 (polar pt2 (+ (/ pi 4.0)(angle pt2 pt1)) (/ (distance pt1 pt2)(sqrt 2))))
        (if (= nil (and (setq z_line (ssget "W" pt1 pt3))
                    (setq z_line (ssget "W" pt3 pt2))
                    (setq z_line (ssget "W" pt2 pt4))
                    (setq z_line (ssget "W" pt4 pt1))))
                (progn (prompt "\n Sorry! Wrong move. Try again. .....  ")(exit))
        (progn
        (setq ei (list 0 0 0))
        (command "pline" pt1 "w" (* (distance pt1 pt3) 0.05) (* (distance pt1 pt3) 0.05)  pt3
pt2 pt4  "c")
        (command "color" "1")
        (command "solid" pt1 pt3 pt4 pt2  "")
        (command "color" "bylayer")
        (setq dir_ang (getpoint "\n Which side? "))
        (setq dir_ang_f (angle (polar pt1 (angle pt1 pt2)(/ (distance pt1 pt2)2)) dir_ang))
        (setq side (cond ((and (>  dir_ang_f  0.0)(< dir_ang_f  (/ pi 2.0))) (/ pi 4.0))
                    ((and (>  dir_ang_f  (/ pi 2.0))(< dir_ang_f  pi))  (* pi (/ 3 4.0)))
                    ((and (>  dir_ang_f  pi)(< dir_ang_f  (* pi (/ 3 2.0)))) (* pi (/ 5 4.0)))
                    ((and (>  dir_ang_f  (* pi (/ 3 2.0)))(< dir_ang_f  (* pi 2.0))) (* pi  (/ 7
4.0)))
                    (t nil)
        ))
        (command "move" "last" "" "0,0" (polar ei side (/ (distance pt1 pt2) 2 )))
        (if (= "y" (getstring "\n Do you want this rule applied this way? <y or n> "))
        (progn (command "chprop" "last" "" "color" "bylayer" "")
        (command "explode" "last" "")
        (command "erase" (ssget "X" '((0 . "LWPOLYLINE")))"")
        (prin1 "  ........ DONE .......... ")(princ)(princ)
        (command "zoom" "e")
        (command "zoom" "0.5x"))
        (progn (command "erase" "last" "")
        (command "erase" (ssget "X" '((0 . "LWPOLYLINE")))"")
        )))
))
(defun c:ss2 ()
        (ib)(go_2))
(defun c:ss ()
        (ib)(go)(limp_3)(int)(limp_3)(limp)(limp_2)(limp_3))
```

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77 Massachusetts Avenue
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