Shape Grammars for Creative Decisions

in the Architectural Project

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Abstract— ***shape grammars, used in applications in the field of Computational Creativity (CC), might provide the artists with applications to assist them in the creative process, not only creating solutions but also as a way of creating new ideas. In architecture, shape grammars can work with rules which will convey legal restrictions, space needs and goals that the architect needs or wants to fulfil, creating possible solutions to a project. A wide range of solutions can be tested in computational application based in shape grammars. These applications can also encourage the architect to go further in his creativity through the shape emergence where the conditions are fulfilled and presented as innovative and/or unexpected. Due to the strict rules they have to obey and to the issues they are supposed to respond and, not being a mere artistic intention but rather a response to a specific need/objective intention (space building), architectural projects show a set of common phases which might take a lot of advantages from computational applications and at the same time respond not only to the technical needs but also to the creative goals.******Keywords-shape grammar; Computational Creativity; architectural Project.***

I. INTRODUCTION

In this article we present how shape grammars can be used as an auxiliary for decisions in the architectural project, adding possible solutions to the ones the architect could use. Through the definition of a set of rules that combine the technical and creative purposes of the architect, shape grammars can form a wide range of solutions that enhance the creative response to a problem. Computational applications that use shape grammars can give the architect creative responses that he would not achieve in other way.

In the Introduction we approach the knowledge areas that are connected to our idea giving a brief notion of what are Shape Grammars and how Computational Creativity (CC) presents itself as an important field for the development of new ways of making projects, especially in the area of architecture.

In the second section we present how shape grammars can be an interesting and important contribution for project decisions, adding complexity and variety to the designer's solutions for a problem. As the architectural projects has to answer to a large number of problems and intentions, shape grammars can be a method for the search and test of more solutions that the ones the designer could explore without them.

In the third section of this article we demonstrate eleven architectural problems that can be objectively answered by shape grammars, helping the architect to explore new creative ways and obtain better results by the test of a larger variety of solutions. Being able to identify a set of phases in the architectural project which represent issues whose solutions involve following technical and aesthetic rules, we can define shape grammars with rules to be followed and allowing the architect to get a wider range of responses.

Shape grammars have potential to improve the projects because, even if a final solution isn't provided, the wide range of hypothesis available can be regarded as new ideas and an incentive to creativity. Shape grammars provide the architect not only an endless number of solutions (comparing to the solutions he would get if he didn't use shape grammars) but also a lot of emergent solutions which will enrich his aesthetic vocabulary.

Thus, shape grammars, as it happened with the appearance of Computational Design, provide the chance to explore more solutions in a shorter time, allowing to have more ambitious and complex solutions, as computational applications can assist the architect in verifying shortly the validity of more and/or better options.

CC can be considered an area of Artificial Intelligence (AI) which chases the goal of understanding creativity and building computational applications that emulate human creativity in Arts and Science. Combining knowledge of AI with other areas of knowledge, such as cognitive psychology, and philosophy, CC intends to emulate human creativity using a computer.

CC contributes to the artwork through new forms of interaction with digital information, producing effects that stimulate human perception and potentiate the artist's creativity allowing the artist to obtain a wider range of new solutions [1].

Shape grammars were conceived in the 70s by George Stingy and James Gips [2] and arose when AI was already studying different areas of knowledge and when the first graphic computational editor appeared [3], which can be considered the precursor of CAD (Computer Aided Design) systems. Shape grammars are part of one area of knowledge named "Design Computing" or "Computational Design". They are a specific class of a production system which allows to describe the generation of compositions with shapes or designs [4].

The components of a shape grammar are basic shapes, named the "shape alphabet" and a set of condition action rules which define the ways of combining shapes, according to the space relationships among them. They are a way of generating designs through the use of initial shapes and rules which have their roots in the production system of a mathematician named Emile Post [5] and in the generative grammar of a linguist named Noam Chomsky [6]. They are similar to phrase structure grammars, dealing with an alphabet of shapes which generate n-dimensional shapes.

In the context of shape grammars, besides the use of purely algorithmic processes related to representation and computation with shapes, there are large amounts of specific knowledge concerning the exploration of the design languages that must be represented and organized [7].

Since shape grammars have capacity for synthesis and analysis of styles of design / architecture / art and allow the creation of new forms integrated in a specific language or the definition of new languages [8] [9] its use in the design through computer applications enables the designer to incorporate the unique capabilities of the human mind and those from AI. This combination and the applications that allows it are examples of CC. This way, a synergy between two partners will be produced. Design will be generated not only through formalism and rationalization but also through intelligence and creativity [10].

The present article explores how the use of shape grammars can be an objective help for project decisions divided in two sections: decision making in the architectural project concerning shape grammars and problem solving with shape grammars. It will be exemplified how shape grammars can respond to very concrete questions that exist in the architectural project.

II. Decision Making in the Architectural Project Concerning Shape Grammars

Digital Design and CAD applications are widely used nowadays in architectural projects and Design. As far as creative areas are concerned, computational applications have meant much more than faster and more effective processes comparing to those previously done. They have also allowed the production of more complex and ambitious projects, offering new ways of analysis, control and representation which wouldn't be otherwise available to designers and more time and unaffordable resources would be required.

The architect is responsible for the definition of an individual style of architecture, his own style [11], connected with his intentions and purposes, which might have aesthetic concerns or others. From this point of view, the style is related to the idea of the purposes of the design and to the way the artist resolves a certain problem. Having highlighted the connection between style and problem solving, we should also realize that there is a link between creativity and hypothesis exploration, which leads likewise to the possibility of a wider range of results through the use of shape grammars.

Gero points that creativity resides not only in a new artefact evaluated by society but also in the processes which have potential to generate artefacts that might be evaluated as creative [12].The designer deals with a very specific context, with special features, and the perception of the purposes, restrictions and contexts enable him to explore relationships and solutions in an individual and creative way.

When a designer defines a shape grammar, defining a set of rules and a shape vocabulary, which can be translated into solutions to a certain problem, he generates the principles that will lead the generative process. This process has a trial and error component as it goes through several hypothesis until an acceptable solution. This possible formal solution may not correspond exactly either to the intention or to the planned purpose in the beginning of the process. There can be some lack of control of the outcome, as the generative process might lead to unsuspected results. This lack of control pointed out by Mayer as a restriction to the expansion of shape grammars in practical applications [11] can be an advantage and opportunity in the development of new solutions to the project issues in architecture and Design.

Architectural project, in contrast to other artistic areas, develops in different phases which can be described not only as a need to solve a lot of issues but also the fulfilment of rules and restrictions, no matter they are legal, environmental, economic or formal. It's in the solution of all these issues that the final project comes out, and the architect shows his creativity, combining all the items in an aesthetic and functional product.

If the architect has to respond to challenges, it is obvious that he will look for the ideal solution and follow the recipes that he has already tested and evaluated in his past practice. Therefore, his creativity might be conditioned to his experience or to the lack of time/tools to explore and test the new hypothesis without being sure to succeed.

From our point of view, this way of using shape grammars doesn't bring any problems in terms of creativity and authorship. The architect will have to consider the rules he has or intends to fulfil for each problem or sub-problem and which shape vocabulary will be involved. He will be the author and controller of the shape grammar that will respond to the problem.

The use of shape grammars leads to emergency. An ideal solution may arise to the problem that the architect has provided which he had not predicted. Even if emergencies arise that are not validated, the architect can use them as new ideas, whether by denial or acceptance of the forms generated. Even the non-validation of an emergency allows the architect to restrict the range of hypotheses and gain new settings to the desired solution.

This work of testing and validating solutions given by the created shape grammar is the procedure that defines a creative process of synergy between shape grammars and the architect, allowing the final solution of the project to be potentially improved and unique as well, or, at least, different from what the architect would accomplish without the use of shape grammars.

III. Problem Solving with Shape Grammars

There's a wide range of situations which are common to the overwhelming majority of the architectural projects and even the specific issues of each project can be dealt with the use of shape grammars.

Architecture, in its essence, is made of shapes, spaces and relationships. There's a great deal of themes which are explored by the architect to create his work [13], no matter they are carefully planned or got intuitively. Themes such as relationships between weight and shapes, full and empty spaces, light and shadow, conjugations between similar shapes and/or dissimilar shapes can be recognized in every architectural work and help people understand and define it.

On the other hand, an architectural work is deeply connected with social and legal rules. Every project has to respond to objective and to urban laws which sometimes confine the development of the solution.

The following examples are representative of the huge use of shape grammars and how they can be used in order to achieve solutions or to develop new ideas. Rules applied in each situation will be presented in these examples. It's also important to stress that the architect can insert some others if he wants to. We intend to show how shape grammars can be applied in common phases to the overwhelming majority of urban and building projects.

A. Definition of rules for buildings, public spaces and circulation ways

There is great variety of rules which can be defined concerning the same goals of figure 1. These rules present orthogonal definitions for buildings and circulation ways. Other rules can be defined such as radial intention (as it can be seen in some cities) or be extrapolated to emerging buildings, through a wide range of shape alphabet relationships between them.

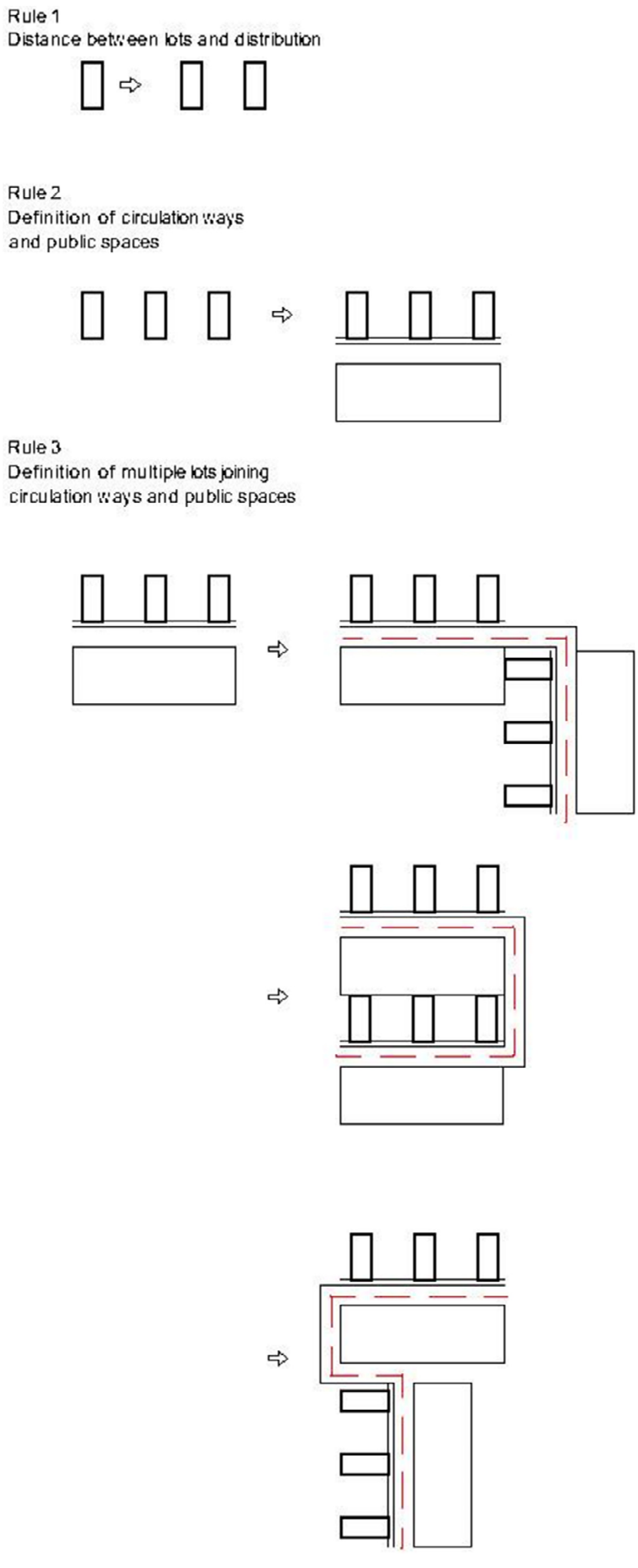

Figure 1 – Lot Distribution

B. Implantation Polygon in the lot

Having a lot to build on, an implantation Polygon of the building has to obey a set of rules as mentioned above, and should include choices concerning the building shape. The implantation area has to consider the number of floors of the building, the larger the number of floors, the smaller the implantation area. It should also take into account the organizational logic of the inner spaces, affecting its outer boundary line.

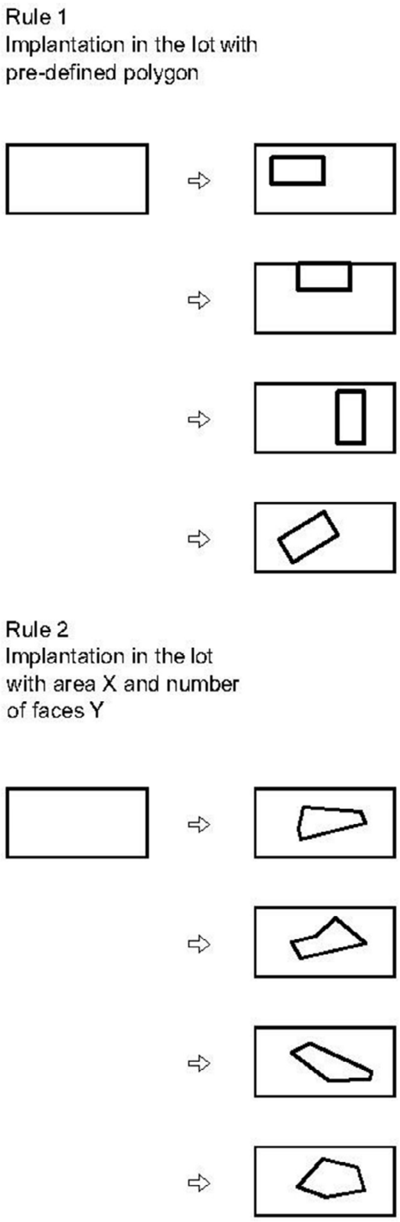

Figure 2 – Implantation Polygon

C. Integration in the Lot – compatibility with terrain curves

Since there are nowadays computational applications to help the architect study the best integration of the building in the lot, minimizing the movement of the top surface and facilitating the construction, the architect's goals might be defined as rules, such as taking advantages of the landscape that can be seen from there, favoring high or low areas, and the shape of the level curves can also be a graphic source to combine lines which will define the shape of the building.

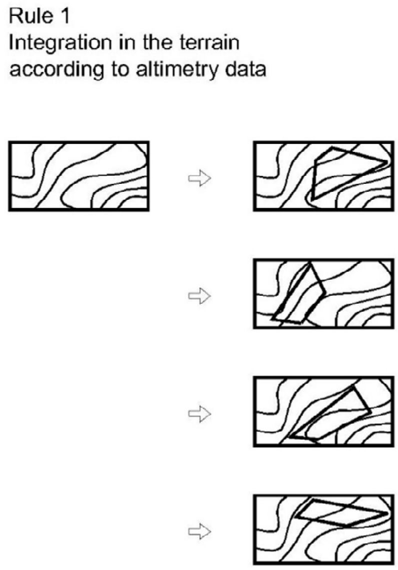

Figure 3 – Integration with the terrain

D. Circulation Ways

The definition of rules to plan the circulation ways, as presented in Fig. 4, can be related, on a larger scale, with the definition of the lot organization and, on a smaller scale, with the definition of the inner communication areas of the building, helping its drawing outline the inner space organization.

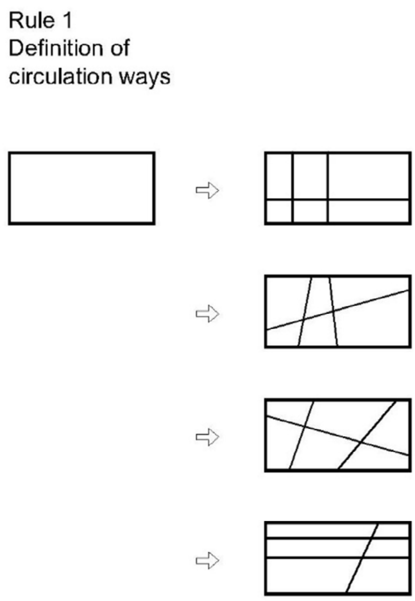

Figure 4 – Circulation ways

E. Garden Design

We can apply the rules of division of lots and those of circulation ways, using shape grammars which will guarantee that the building areas have the green spaces required and being at the same time formal and unique. In the landscaped areas rules might be defined to plan the distribution of floral and arboreal elements, which might also define aesthetic shapes.

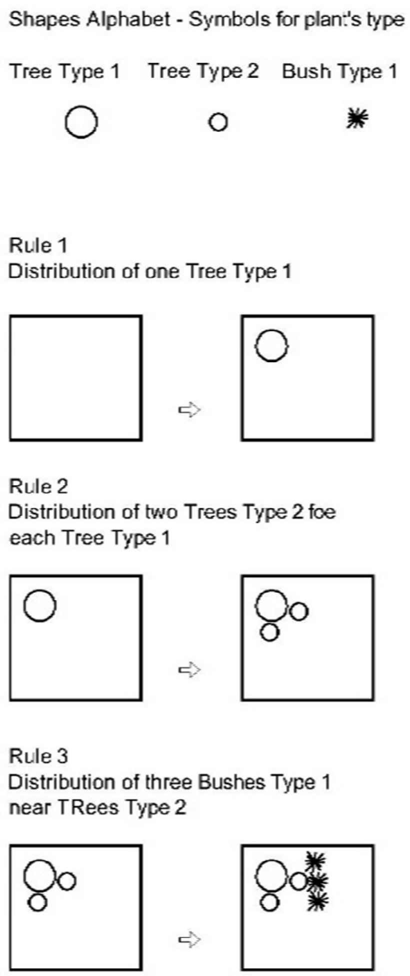

Figure 5 – Garden Design

F. Lot division

The division of the lots follows a wide range of legal rules such as maximum areas of land occupation, distance between buildings around, dimension of circulation ways, green space areas, public space areas, among others. In short, these rules together with the rules the architect intends to insert, concerning the shape of the buildings and the relationships between them may generate grammars which will set the shape distribution in the lot and at the same will define the lot occupation.

G. Balconies definition

Being important spaces, as they connect the inner side to the outer side of the building, balconies are elements which have an effect on the shape building and on its relationship with the surroundings. Stressing the aesthetic aspects, shape grammars might define rules which will generate balcony designs on the “building shell”, matching technical rules, for instance, maximum suspended area, formal aspects such as exploiting the sights.

H. Floor Design

Floor design can change from floor to floor. It can be a regular or irregular design, depending on the geometric design we want. Geometric designs can respond to rules relating to the interior organization, to the need of distinguishing areas or, for instance, separation of flats. They might consider the balconies mentioned above and the optimization of a glassed area if people want to enjoy the surroundings.

I. Interior space organization

Interior space organization depends on a wide range of rules, related to the building typology and its needs (hotel, hospital, housing, school, everyone has a set of specific rules). All the objective and aesthetic goals should be added to in other to regulate the expected shape.

J. Design of façade openings

The design of the façade openings, taking the aspects of floor design mentioned above into account, might be based on rules, such as the definition of the maximum glassed area for each division of the building, for example. They might follow thermal rules, which will guarantee the solar access and shadowing, and geometric rules as well, which will lead to a certain aesthetics of the building

K. Formal combination of materials

The materials used on façades or in the inner spaces might be subject of graphic, formal/creative spaces, which can be defined by shape grammars.

Following the same logic of the examples described above, different project phases and issues can be found out, which can also be solved through the use of shape grammars.

The architectural project gains its identity on the idea developed by the architect and in the creativity through which he has to solve the issues. He has also to obey a wide range of rules. Overall, the architect’s intentions are per se rules, which are not imposed by technical and legal needs of the project but rather by the artist’s aesthetic and creative intentions.

Dividing the project into its elementary parts, we see that the architect elects, consciously or intuitively, a set of rules and makes choices which are responsible for the final work. This is the reason why shape grammars can explain design styles, once the rules, which generate a certain shape, are recognized.

Thus, in the same way nowadays it's common practice to use computational applications, which reproduce the architect's manual design, among other technical aspects of the project (such as automatic measurements, thermal simulations, three-dimensional visualization, etc.) it will be possible to make the architect see in shape grammars and in its applications as a common practice and a way of optimizing his ideas, using not only Computational Design but also Computational Creativity.

IV. CONCLUSION

The architect has been changing the way of doing his job since he had the chance to use the computer. Computational applications allowed to reproduce and get automatically the designs of the architectural projects, besides the simulation of tridimensional models. It became possible to explore multiple hypothesis, reducing project errors and spending less time in searching for more complex solutions, achieving more ambitious, innovative and creative projects.

With the development of Artificial Intelligence and, within this area, the growth of applications to simulate creativity, the architectural projects gained computational applications which boost not only the technical aspects but also the creative and aesthetic ones.

Our goal is to show how the use of shape grammars can be an objective help for project decisions. Applications based in shape grammars can be tools that offer the designer the potentialities of AI and CC.

We start with a brief introduction to shape grammars and computational creativity, presenting how shape grammars can lead to new ways of exploring project solutions, giving the architect new tools for developing his work.

Further work will be the definition of shape grammars for the project phases of the architectural projects, as the examples shown above. These shape grammars will include both rules for the general laws and restrictions the architect has to obey and rules for the creative intentions.

After the definition of the shape grammars, the final objective is to test their use with the use of the Generic Shape Grammars (GSG) system [14], a tool for shape grammar implementation that is being developed by the authors of the article. The GSG project aims to develop a computational tool that supports extensible and configurable work with Shape Grammars, focused on a generic interpreter of Shape Grammars with a visual interface and capability of computing and reasoning with shapes and spatial relationships, with advanced options complex to work with shape grammars.

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