Urban Grammars: Towards Flexible Urban Design

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Abstract. *Traditional urban plans have definitive design systems, without the flexibility required to deal with the complexity and change that characterise contemporary urban societies. To provide urban plans with increased flexibility, it is proposed a design methodology capable of producing various design solutions instead of a specific definitive design. The methodology uses shape grammars as a process for generating urban design. In this approach, design becomes a system of solutions rather than a specific one.*
Through the analyses of a group of urban plans, a design methodology was sketched in which rules are used to enable more flexibility. These plans where chosen for their perceived qualities in terms of language, planning efficiency, and latent flexibility. As a result, a four-phased methodology was identified and thus, proposed for designing urban plans. This methodology was then combined with shape grammars and tested in a design studio setting. Students were asked to use the methodology and shape grammars as auxiliary instruments in the design of a flexible plan for a new town. In the following year, to simulate real-world conditions and oblige students to consider urban ordering and scale, work was structured differently. First, students were asked to develop a rule-based urban plan as in the previous year. Second, they were asked to conceive a detail plan for a sector of an urban plan defined by another group of students following its rules. The plans were then analysed with the goal of refining the methodology.
Results show that shape grammars produce urban plans with non-definitive formal solutions, while keeping a consistent spatial language. They also provide plans with explicit and implicit flexibility, thereby giving future designers a wider degree of freedom. Finally, they provide students with a concrete methodology for approaching urban design and foster the development of additional designing skills.

Keywords. *Shape grammars, flexible urban design.*

Introduction

Traditionally, urban plans and detail plans have been developed with rigid and definitive design systems. To deal with the complexity and change that characterise contemporary urban societies a more flexible approach to design is required.

The traditional approach to design is generally based on the classical principle of designing the whole as a definitive solution. Also, urban plans are usually centered on the definition of urban parameters, which very attached to burocratic procedures, thereby constraining design as if it would be a mere representation of such parameters. Despite this being the standard approach to design, legislation and burocratic procedures constrain neither design nor its representation to such an extent that they forbid design flexibility. The resulting rigidity, thus, derives from an unconscious repetition of procedures instead of an adjustment of methods to specific contexts. In fact, a close look at legislation will show that it does not constrain representations or flexibility, nor does it imply any specific way of designing. It seems that procedures are constantly repeated mainly because this makes it easier to design and to communicate design intents.

The growing condition of complexity and change in urban societies generates the need for more flexible urban design. Plans should prescribe a clear development vision (Friedman, 1997) in the most general and larger scale conditionings, and should have a flexible approach towards the specificity of designing urban spaces. This paper deals with the problem of creating alternative approaches to urban design that can foster the design of flexible urban plans.

To promote the design of more flexible urban plans, we propose a new design methodology that recurs to shape grammars as a design tool (Stiny and Gips, 1972). The idea is to produce a system of solutions instead of the traditional definitive design.

The use of shape grammars in urban design and in teaching

Shape grammars were invented by Stiny and Gips (1972) and had its mathematical foundation defined by Stiny (1980). A shape grammar is a set of shape transformation rules that apply step-by-step from an initial shape to generate a set or a language of designs. Shape grammars are simultaneously descriptive and generative and thus can be used in the automatic generation of designs and as an analytical tool to describe the generation of existing designs. Although shape grammars have been considerably used in architecture, there are very few examples of their use in the field of urban design, both for generative and analytical purposes.

The first mention to the use of shape grammars for urban design is found in the work of Brown and Johnson (1984). They use space syntax for the analysis of London mediaeval city blocks and their evolution and change through time. Referring to the computer model, Brown and Johnson state that a new model could be rewritten recurring to shape grammars.

The work of Catherine Teeling (1996) is one of the few exceptions that use shape grammars for urban analysis. This work concentrates on the geometrical evolution of the urban grids by inferring the polygonal subdivisions that originate the final urban structure. After inferring such rules for an urban site, Teeling demonstrated that they could be mapped onto another site in the same city without changing the structure of the rules or detracting from the site condition. Therefore, she demonstrated that rules could replicate the original urban form but also generate new ones with similar features. Nevertheless, she established no relation between urban form and phenomena such as topography and technological or social change. The urban tissue is treated as a geometrical grid unrelated to the supporting territory. However, design rules could encompass descriptions of territorial

features thereby denoting the close relationship between urban form and territorial conditions.

Recently, Duarte (2001), in his effort to develop a grammar for Siza's houses at Malagueira, included an analysis of the urban plan and inferred its basic rules, but made no effort to encode the underlying contextual features.

One car argue that the use of shape grammars in urban design have been avoided because phenomena in urban design is not simply related to shape transformation but rather is strongly related to urban policies and social dynamics, as well as to the morphology of the territory, among other features. This semantic problem has already been pointed out by Fleisher (1992) as a flaw of architectural shape grammars. The semantic discourse and technical effectiveness in urban design arise from the recognition of territorial and social contexts and thus their correct description is needed for developing effective designing grammars. Duarte (2002a) solved this problem by combining Stiny's description grammars (1981) with shape grammars to produce correct semantic descriptions of designs and thus evaluate the validity of a design against predetermined design goals. This strategy could also be used in urban design and it seems particularly appropriated to deal with its complexity.

The use of shape grammars in teaching also has very few examples. Stiny proposed a program for using grammars in design education, and experiments in this area have been developed by Terry Knight (1999), Ulrich Flemming (1987) and José Pinto Duarte (2002b) respectively at the Massachusetts Institute of Technology, at Carnegie Mellon University, and at the Technical University of Lisbon School of Architecture. Only in the latter case, a teaching program in the use of shape grammars for urban design has been performed. This paper describes research developed within the context of this program.

Research methodology

In order to achieve flexibility in urban design, we propose a new methodology for approaching the urban design process that can recur to shape grammars to deliver a system of alternative solutions instead of the usual unique and definitive solution.

The research methodology used for developing the proposed design methodology encompassed three steps. In the first step, we analysed existing urban plans to infer and sketch the design methodology. In the second step, we asked a group of students in the final year of the professional architecture program to use the sketched methodology and shape grammars for developing rule-based urban design systems. The analysis of results consolidated the sketched methodology and laid down the basis for an experiment with another group of students in the following academic year. This experiment consisted in producing a rule-based urban design system and then testing it by asking other students to use it for developing detailed plans for an area of the larger plan. Results allowed one to draw conclusions on the pros and cons of the proposed methodology. They also permitted one to develop a basic mapping of the type of rules to the effects that they yielded, thereby creating background knowledge useful for future experiments.

Step 1: Analysis of existing plans – inferring a design system

Through the analysis of four urban plans, it was possible to identify a repeated methodological pattern in the process of designing. These plans were Álvaro Siza's Malagueira plan in Évora, Adrian Geuze's plan for Borneo-Sporenburg in Amsterdam, Cândido Chuva Gomes's plans for Quinta da Fonte da Prata at Moita, and for the extension of Cidade da Praia in Cape Verde. Other plans were considered during this study, although they were

not analysed in depth. The reason for choosing these plans was twofold. First, it was possible through published documentation or direct interview to collect information for reconstructing the designers' process and strategy, and therefore, to synthesize their design methodology. Second, these plans were chosen for their perceived qualities in terms of language, planning efficiency, and latent flexibility. A four-phased design methodology was sketched based on the analysis. The four phases are present in the studied urban plans as part of a sequential and thematic approach to design and to deal with the following aspects: pre-existences, basic geometries, city blocks, and materiality. These aspects are organized according to scale and not necessarily to sequence, although a sequential logic is inherently latent in their used and effectively present in most cases.

The analyses of these plans revealed that designers were very systematic in the elaboration of the plans, to such an extent that it would be rather straightforward to encode their approach into shape grammars. Each plan had a subject on which it was possible to get additional information. We could find a large number of articles on Geuze's plan that approached the theme of flexibility (Gausa, 1998). Specifically, the approach to density in low rise construction, suggesting nondeterministic compositions of urban blocks through subtraction, provides an interesting example of the design of flexible urban blocks and identifies a clear design phase concerned with the definition of the urban block. In Siza's case, architectural language and the relation with the site are important issues considered in the designing process and so this plan provided valuable information on how to incorporate such issues in urban design. For instance, the relation with the site is a well documented topic in essays on the Malagueira plan (Molteni, 1997) which clarified how pre-existences are incorporated in the design process by Siza. In Chuva Gomes's case, the comparison of plans for different sites make it possible to identify the same design principles applied in different contexts, thereby revealing the persistence of specific design rules in a designer's method or style, and suggesting that a rule-based design system can be used for generating different solutions that are adequate to different design contexts.

Results in this step revealed that despite variation in style from one designer to another, or changes in the context from one plan to another by the same designer, designers used a similar four-phased approach. The four phases deal with:

1) Territory reading and pre-existences: Rules in this phase deal with the understanding of the territory and are targeted at identifying singular elements in the territory and incorporating them into the grammar.

2) Basic geometries and grids: These rules aim at creating basic geometries and grids and are divided in two subsets of rules, one to structure the main geometries on the territory, and the other to generate urban grids.

3) Definition of urban units: These rules are used to define urban units such as neighbourhoods, blocks, plots, volumes, as well as clusters of any of such units.

4) Materiality: These rules are used for qualifying urban space and architecture by defining materials and details of urban spaces and volumes.

Step 2: designing a design system

During the first semester of the school year 2002-03, we tested the above methodology in a design studio in which shape grammars were used for urban designing. Students were organized into groups and asked to use the sketched methodology and shape grammars as auxiliary instruments in the design of a flexible plan for a new town for 5000 inhabitants. Students would then illustrate their plan with an example generated by the recursive application of their design rules.

The studied area was a vast region in Alentejo, Portugal, with strong development expectations

due to the construction of a water damp in Alqueva. This damp crated the largest artificial lake in Europe and so it is expected that the area will suffer radical transformations in the coming years. Within this context, students would choose whether to expand existing villages or to build a new town in a strategically chosen place.

Due to space limitations in this article, we show only two examples of the produced urban plans in Figures 1 and 2. Figure 1 is the example of a solution in which rules were extracted from the analyses of the territory in an attempt to capture and explain how the villages evolved. In this example, urban fabric is formed by the division of polygonal areas that resulted from the crossing of preexisting roads and rural pathways within the territory. The basic rules are five polygon subdivisions shown in Figure 1a. These rules were then used to expand the existing urban fabric to form new urban tissue with similar features (Figure 1b). It is curious to point out the similarity of these rules to those of Stiny's Ice ray (1977).

Figure 2 shows an example of a new town project using shape rules developed from scratch to generate a diverse and flexible urban tissue. These rules are combinations of four sets of block within a large geometric matrix drawn from the territory morphology and the visual relations with a nearby hill town. The four sets of blocks result from several possible geometrical relations of two different basic urban blocks. The recursive use of these rules would allow progressive growth and flexibility as they have many different possible combinations and can be applied step by step as needed. The plan shown in Figure 2a represents one possible development that could result from the recursive application of these rules.

With this experiment it was possible to detail and consolidate the proposed methodology.

Step 3: using a design system

In the following year, the consolidated methodology was used in a design studio to test its efficiency. To simulate real-world conditions and oblige students to consider urban ordering and flexibility at different scales, work was structured in three parts: theoretical knowledge acquisition and urban analysis, urban plan, and detail plan. In the second part, students were asked to de-

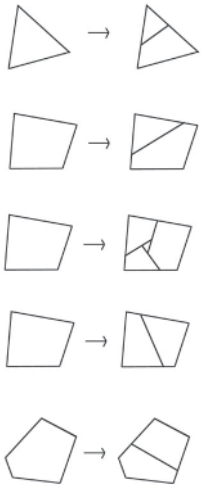

Figure 1. 1a - .urban generation rules 1b – urban plan – example of a possible solution generated by a recursive application of the rules.

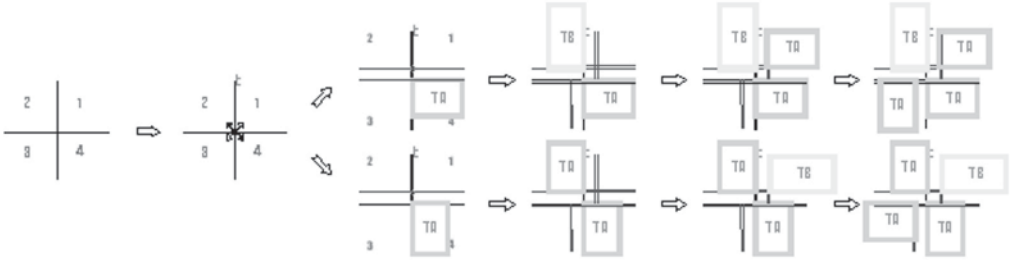

Figure 2a. Example of the first rules – the four block combination urban plan.

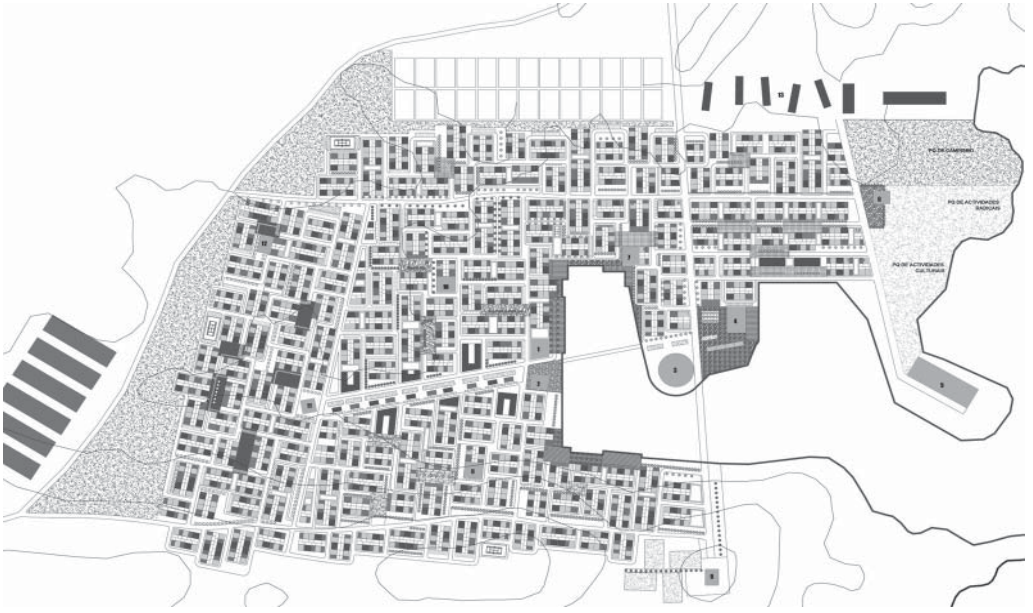

Figure 2b. Urban plan – example of a possible solution generated by a recursive application of the rules.

Figure 2c. Urban plan – 3D ilustrations of a solution.

Figure 3. Rules, urban plan and correspondent detailed plan.

sign an urban plan for a large expansion area for the northern sector of a town with approximately 25000 inhabitants, by developing the rules to use in the generation of urban design for the area. The detail plan was developed based on an urban plan defined by a different group in the previous work phase. In this part of the experiment, copies of the urban plans, along with their respective rules rule set, were given to the different groups. The detailed plan should be developed in an area not bigger than fifty per cent of the area of the urban plan in order to have more than one group working on the same urban plan. The idea was to generate alternative solutions within the limits set by the larger scale plan. The aim of this experiment was to test the planning efficiency of the use of shape rules in urban design.

Figure 3 shows the correspondence between

the analysed urban plans and detailed plans. Students were asked to answer a 14 questions questionnaire defined a priori to curb subjectivity stating their views and difficulties during the design process. This questionnaire focused on the topic of flexibility. This allowed an objective analysis of the resulting plans, and thus helped one to refine the methodology. Results strongly support the argument of using both the four-phased methodology and shape grammars for urban design.

Discussion

The analysis of results provided useful information on the advantages and restrictions of the use of the proposed methodology and shape grammars in urban design. Results showed the following advantages regarding the use of shape grammars for designing urban plans:

a) Shape grammars produce urban plans with non-definitive formal solutions, while keeping a consistent spatial language. The grammar-based plans permit the generation of alternative solutions, each with a specific design, while respecting similar principles and a common development vision.

b) Shape grammars provide plans with explicit and implicit flexibility, thereby giving future designers a wider degree of freedom in the development of final solutions.

c) The use of shape grammars in teaching provide students with a concrete methodology for approaching urban design and foster the development of additional skills by them.

Results also prompted the following reflections, which suggest the need to undertake further experiments:

d) Grammar-based plans could be upgraded with computer programs to evaluate alternative solutions or to serve as a municipality planning instrument. The knowledge gathered from these experiments suggest that the use of a computer program as a planning instrument would be a promising practical experiment.

e) The use of too many rules can constrain operability and make the plan difficult to use. A close relation between rules, the methodology and operability is still to be traced, though it seems to be closely related to the scale of the urban plan. The best plans had a very strong urban concept, which seemed to be strongly related to the definition of an urban unit from clearly defined block combinations, and with a clear definition of neighbourhood boundary.

f) The experiment showed that generating a complete candidate solution within the grammar is an important procedure as it allows the assessment of results during the design process and allows future designers to understand more precisely the intentions behind the plan.

In summary, the proposed methodology has four distinct phases:

Territory reading: The first rules deal with the understanding of territory and are targeted at identifying singular elements in the territory, and incorporating them into the grammar. These elements are generic topographic features, green patterns, physical pre-existences of different kinds, viewpoints, and visual alignments.

Basic geometries: The rules in this phase aim at creating basic geometries and grids and are divided in two subsets of rules, one to structure the main geometries on the territory, and the other to generate urban grids.

Definition of urban units: These rules are used to define the characteristics of urban units such as neighbourhoods, blocks, plots, volumes, as well as clusters of any of these units.

Materiality: These rules are used for qualifying urban space and architecture by defining materials and details of urban spaces and volumes.

The use of this methodology was important in the two experiments because it showed that it could help the students to trace clear aims while designing. Rules can be created within each methodology phase with a certain degree of autonomy,

showing that the four phases can be considered autonomously, though not independently to guarantee the expressive unity of the whole.

Conclusion

Research was undertaking with the aim of showing whether shape grammars could be used in a methodology for developing flexible urban designs. Results show that shape grammars can produce urban plans with non-definitive formal solutions possessing explicit and implicit flexibility. Grammar-based plans allow for the generation of alternative solutions, each corresponding to a specific design, while respecting a consistent spatial language and a common development vision. These characteristics are valuable instruments to guarantee long life efficiency in urban planning as it extends the plan's capacity of reaction to change.

This work sets the experimental and theoretical basis for the development of a real experience in an urban area where these systems can be tested. Given the experimental results already obtained, the potential of their application to practice looks promising. Future work will be concerned with this endeavour. However, the development of practical applications needs to be preceded by studies in representation, as it is the practical instrument to license the plans. The questions that need to be answered at his level are: How to license a plan that has flexible multiple solutions? How can shape grammars be part of a licensing process? Can a set of shape rules and an illustrative plan generated by such rules be used objectively for this purpose?

Acknowledgements

We thank the students in the design studios for their enthusiastic participation in the study and for making their drawings available for analyses. We also, thank the architect Cândido Chuva Gomes for his time and explanations on his work, as well as for the kind access to graphic information on his urban plans.

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