Urban design with patterns and shape rules

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Abstract

The goal of an urban plan is to provide a development vision for a given territory. Three crucial issues in the conception and implementation of urban plans are how to define the program, how to convert the program into a flexible design, and how to adapt the design to changes in the program. This paper describes the preliminary results of ongoing research aimed at devising a methodology for addressing these issues. This methodology uses Alexander's pattern language to define the program and Stiny´s shape grammar formalism to convert the program into design solutions. A design studio has been used as the basis for developing and testing the methodology. Preliminary results suggest that the use of patterns helps to tie the urban plan to a specific development vision, and shape grammars are successful in generating alternative design solutions that match varying programs.

Context

Urban design is a complex activity that implies the participation of agents with conflicting interests. The impact is twofold. First, it raises communication difficulties due to the lack of a common language among such agents. Friedman[2] has proposed the notion of development vision to refer to the set of somewhat general and abstract features underlying any urban plan. This should shift the focus of the discussion among urban planners from the specific layout formalization to concrete planning concepts as main generic goals. In practical terms, the development vision corresponds to a conceptual urban program. Designing vast urban spaces usually involves two long stages before a final implementation. First, the design process begins with the definition of an urban program and then converts it to a design layout. Second, the complexity of the large scale developments often implies a long term implementation throughout which changes in social and economic context may occur. Therefore, a mechanism to adapt the design to programmatic changes is also required.

In this paper, we explore two formalisms to overcome the difficulties raised by the complexity of the urban design process. The first is Alexander's pattern language[3] and the second is Stiny's shape grammar formalism[4]. The pattern language is proposed as the language common to all urban design actors that can be used to define the urban program. Shape grammars are proposed as the means to generate alternative design solutions. To convert the program into designs it is suggested to use Duarte's notion of a discursive grammar[5], although this aspect will not be covered in this paper. A discursive grammar is composed of a programming grammar which generates design briefs according to contextual data, a designing grammar encoding a design language or style and a set of heuristics to guide the generation towards a solution that matches the design brief.

This paper was developed within the context of an ongoing research focused on flexible urban design that has used a regular design studio as the platform to develop and test a methodology for attaining such a goal. A previous paper focused on the use of shape grammars during two design studios[6], whereas the current article relates the use of shape grammars to pattern language concepts that were addressed in the same studios. The following sections analyze the use of the pattern language in three urban plans produced during the design studios and focuses on details of its use in a fourth plan. The goal is to show how patterns help to guide and organize the shape rules into meaningful sets.

The general framework of the design studio

In this studio, students were challenged to design large developing areas for small towns in Portugal. They were asked to produce both an urban program and flexible design solutions. The urban program should respond to collective needs and flexibility should satisfy private necessities, thereby allowing customized solutions.

To develop the urban program and structure its distribution on the site, students were asked to define a pattern language using Alexander's Pattern Language theory. To produce flexibility, they were lectured on generative design through the use of shape grammars. They were also lectured on how to use shape grammars in urban design through a four phase methodology developed a priori and described further below.

Subsequently, students' work encompassed three aspects. First, they had to come up with a group of approximately 10 patterns to define an urban program. Second, they should develop shape rules to generate urban designs that matched the program. And third, they should produce a specific urban design based on these rules to illustrate the qualities of the proposed design language.

Results showed that the use of the pattern language helped to define the urban program, as well as the qualities and the characteristics of the urban space, and that the use of rule based design systems can produce flexible designs, that is, a system of alternatives within a specific urban design language. Results also demonstrated that there was a direct relation between the rules and the patterns.

The four phase methodology

Before beginning the design studios, a basic methodology was developed based on the analyses of four well documented and well known existing urban plans[7]. The analysis permitted the researchers to identify four significant design phases, the first dealing with territory reading and identifying pre-existent features to set the structural geometries, the second establishing basic geometries and grids, the third defining the urban units, and the fourth specifying the materiality and details of the design. Each one of these phases could be translated into a corresponding set of rules written in the shape grammar formalism, and thus, one could replicate the process or even obtain alternative solutions without changing the design language and the design goals. It was proposed to use this methodology for devising more flexible urban design plans and, consequently, for dealing with the evolution of requirements that usually takes place during the development of the urban plan.

The design studios

Several design studios were undertaken within the general framework described above. This paper discusses the results of two of them, which were undertaken in two consecutive academic years (2002/03 and 2003/04). The first design studio dealt with the creation of a planning strategy for a wide developing area. The studied area was a vast region in Alentejo, Portugal, with strong development expectations due to the construction of a water dam in Alqueva. This dam created 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 choose whether to expand existing villages or to build a new town in a strategically chosen place. They are organized in teams and asked to use the sketched methodology and shape grammars as instruments in the design of a flexible plan for 5000 inhabitants. The pattern language, together with existing urban regulations, was suggested as a tool for developing the urban program.

In the second design studio, a slightly different approach was followed. To simulate real-world conditions and oblige students to consider urban ordering and flexibility at different scales, work was structured in four parts: theoretical knowledge acquisition, urban analysis, urban plan design, and detailed plan design. In the first part, students were lectured on Alexander's pattern language, on Stiny's shape grammars, and on the four phase methodology. In the second part, they were asked to analyze the territory of the intervention and to take into account existing regulations. In the third part, they were asked to design an urban plan for a large expansion area for the northern sector of a town with approximately 25000 inhabitants by developing shape rules to use in the generation of the design. They were also asked to select a set of patterns from Alexander's pattern language to guide their way through the design towards specific programmatic goals. In the fourth phase, the detailed plan was developed based on an urban plan defined by a different group in the previous phase. A copy of the assigned urban plan, together with its rule set, was given to each group. 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 team working on the same urban plan. The idea was to generate detailed alternative solutions within the limits set by the larger scale plan.

The results proved that the rule-based design approach helped the students to deal with complexity and flexibility issues. However, it should be stressed that no automated generation was used. Students used basic blocks and 'copy and paste' functions to generate their designs and eventually some additional routines. Thus, although the generation process was slow, they did not have to face the usual automation details that they would have if trying to use a fully automated process. Technically speaking, the shape grammars the students proposed were usually incomplete, but still very clear in terms of the goal definitions for their designs. We should stress that some intermediate steps might therefore be unclear in terms of formal rule definitions because students used common design procedures to solve them. However, this process produced complex and finished results without facing the constraints of an automated design derivation.

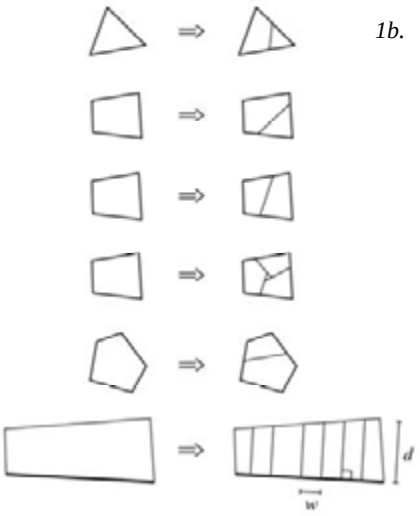
On the use of the pattern language

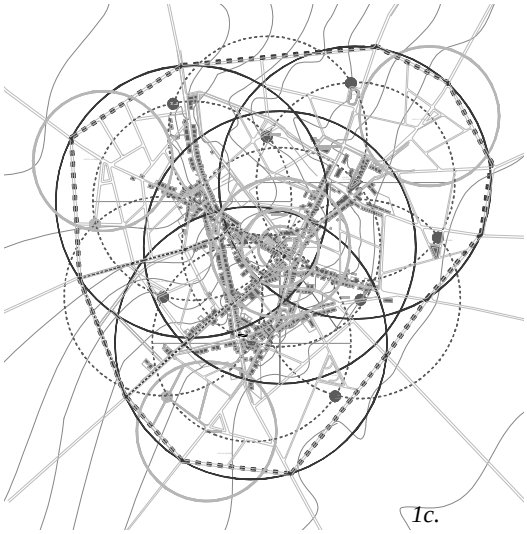
The two design studios involved a total of 19 teams – 9 in the first design studio and 10 in the second one – that produced 19 urban plans, which constituted the body of analysis. In the majority of the plans students resorted to Alexander's Pattern Language and it became clear that one or two patterns played an important role in configuring and characterizing the urban solution. Some patterns were recurrent and used by almost every team, although only a few had a real recognizable impact on the proposal. We could say that the selection of a few patterns creates a strong sense of urban characterization which gives a clear identity to the design proposal.

These are some of the recurrent patterns that were used by the students following Alexander's book: community of 7000; identifiable neighborhood; neighborhood boundary; web of public transportation; ring roads; network of learning; nine per cent parking; parallel roads; sacred sites; access to water; activity nodes; eccentric nucleus; promenade; shopping street.

Figures 1 – 3 show the layout of three of the plans.

The plan in Figure 1 shows a solution for an expansion of an existent village and some of the underlying generation rules, which were inferred from the analysis of the existing urban tissue. The rules are basically polygon subdivisions (Figure 1b) very similar to those defined by Stiny for the generation of the traditional Chinese lattice windows[8] and they correspond to divisions and subdivisions of properties that could be identified in the territory (Figure 1a). The last rule in Figure 1b represents the final division of the blocks into plots. The thick line represents the main street related with the block. The plots are drawn perpendicularly to the main street. The parameter *w* is a multiple of 3 meters foreseeing construction standardization processes to be addressed in the following semester. Along with these basic rules, others were used to place activity nodes and new centralities (Figure 1c) in accordance with the corresponding patterns 'activity nodes' and 'eccentric nucleus'. In Figure 1c we can see the distribution of these 'activity nodes'. The rule places a public building related with a public space ata similar distance from the two nearest nodes. The distances between nodes are taken from an interval defined by the shortest and longest distances between existent activity nodes. This knowledge comes from the analyses of the villages in the area. The big subdivisions or polygons defined by the larger streets correspond to differently characterized neighborhoods, each including its own activity node (Figures 1d and 1e). The whole formed by the village and its planned expansion was considered as a community for 5000 inhabitants, which is in accordance with the definition of the Alexander's pattern 'community of 7000'. Figure 1e briefly shows the generation sequence for one sector of the village.





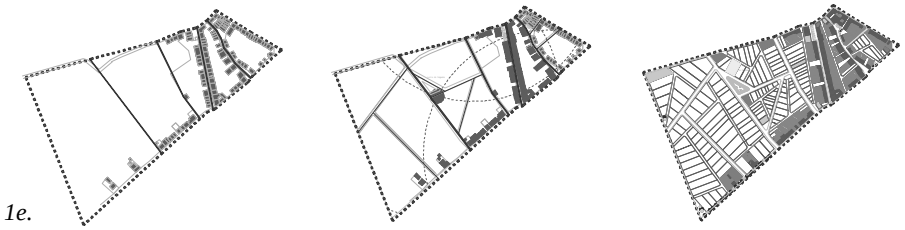
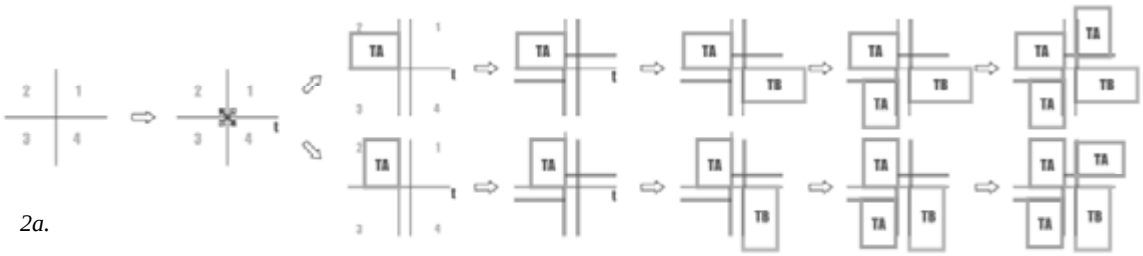


Figure 1. 1a – Aerial photo of existing urban structures. 1b – Main generation rules. 1c – Rule application – rules to adapt to territorial parcels. There is a new rule created to develop new centralities. These centralities have a close distance relation between each other and constitute a kind of neighborhood center. 1d – Urban plan – example of a possible solution generated by a recursive application of the rules. 1e. Rule generation sequence: there is an additional rule for plot generation.

Figure 2 shows a plan for a new town and some of its generation rules. The basic idea of this plan is to create an urban tissue by repeatedly adding clusters of four city blocks. Figure 2a shows the generation of two different clusters of four blocks by sequentially applying the rules for adding blocks. Students used two different block sizes, TA and TB. They have the same width but different lengths. TB is longer than TA. The addition of blocks follows three basic principles: first, two orthogonal axes define the initial reference for the generation sequence; second, blocks facing each other by their longest side should keep a distance of 12 meters; third, blocks should keep a distance of 10 meters when a shorter side faces the longest one. Figure 2a shows the derivation of two different clusters. The derivation sequence explains the implicit rules. A rule creates wider public spaces in front of commercial spaces (Figure 2b). To generate the urban tissue, students then developed rules for adding clusters. Figure 2c shows one example of a rule. The urban tissue results from the recursive application of these addition rules within a predefined set of main streets applied along morphological features, such as water lines and hill top lines (Figure 2d). As in the previous plan, students expressed a concern for creating differently characterized neighborhoods. They did so by placing an activity node in each neighborhood using a rule for subtracting one of the blocks and creating a small square (Figure 2e). Other patterns can be recognized within the plan and were deliberately used as a way of distributing and controlling the urban program. Patterns such as ‘small public squares’, ‘promenade’, ´house cluster’, ‘row houses’, and ‘access to water’ can be easily recognized in the layout.

Figure 3a shows another plan for a new town proposed for the same site. Apart from the obvious patterns, such as ‘parallel roads’, ‘T junctions’, ‘row houses’, and ‘access to water’, the use of ‘sacred site’ and ‘high places’ was particularly interesting as the students used them to place the first structural elements of the program on the site and to define the first basic geometries of the plan (Figure 3b). The interesting aspect regarding this plan is that, although these are not the most graphically expressive patterns, they were crucial to clearly define rules concerning the first phase of the methodology, that is, those rules concerning territory reading. This team spent a significant effort in defining the rules for this phase of the methodology and the use of the referred patterns played an important role in this process and in connecting the geometric decisions to the urban program and to the morphology of the territory. The pattern ‘parallel roads’ clearly characterizes this plan.

In each plan, we can recognize a strong sense of urban discourse or design language embedded in the team’s grammar. This is easily recognizable in the strong morphological characteristics of each plan, and is most likely due to the use of patterns, as the generation rules were defined within the context of each pattern. It is possible to state that the set of patterns along with the corresponding set of shape rules define the urban design language of each plan, and furthermore, we could extend each plan within the same design language without expecting expressive changes in the results apart from those related to scale. We can also anticipate that if someone tries to apply the same design language, meaning the same patterns and rules, to another site with similar characteristics, the result will probably be perceived as having the same features and spatial relations and therefore as being of the same type.



2a.

2b.

2c.

2d.

2e.

Figure 2. Urban Plan: example of a possible solution. 2a – Sequence showing the generation of two different clusters of four blocks. 2b – Rule to create a commercial space and locate a wider public space in front of it. 2d – Example of a rule for adding cluisters. The right side shows four alternative rules. 2d – Sequence showing the generation of the urban tissue (hand sketches). 2e – Subtraction of a block to create an activity node.

Nevertheless, we need to point out that scale seems to interfere with the perceived result and, as a consequence, with decision making. Students often raised the problem that if they continued to apply the same rules indefinitely, after a certain point the generation process would fall into a rather tedious repetition and the result would become rather monotonous. They tried to avoid this flaw within their plans by defining different rules to characterize different neighborhoods. They also raised the hypothesis that after a certain point a new plan with a different design language would have to be considered to avoid too much repetition. As all the groups worked on plans for about 5000 inhabitants, all falling into the pattern 'community of 7000', it seems that this pattern represents a limit and that from this scale on, different premises would have to be considered, but this issue needs further research.

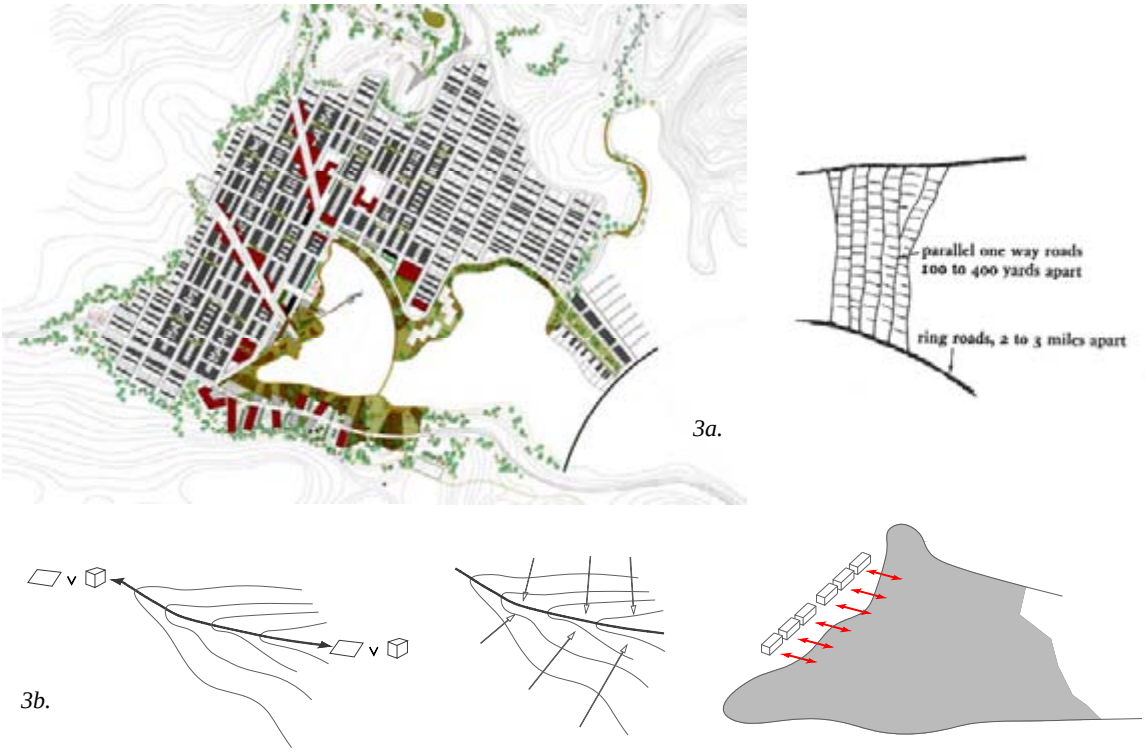


Figure 3. 3a – Urban plan using 'parallel roads' pattern – on the right there is an illustration showing Alexander's original pattern. 3b – Ideograms translating some of the patterns related with territory approach.

In the second design studio, students were obliged to explicitly identify the patterns that had been decisive in the development of their plan and in the definition of their development vision. Figure 4 shows the plan and some of the rules developed by one group (Team 1) and finished according to the same set of rules by another group (Team 2). In this particular plan, it is clear that a single pattern was central to all other decisions and pattern selections – the 'identifiable neighborhood'. The cell used to generate the design was defined as a neighborhood unit and the rules designed by Team 1 follow this aim. Other patterns, defined in 'A Pattern Language' as related to the 'identifiable neighborhood' are used to support it as a development vision for the plan. We can find rules following patterns such as 'main gateways', 'small public square', and 'accessible green' just as suggested in Alexander's book (respectively, rules 8, 2 and 4 in Figure 4a).

rules


cell/neighbourhood
250m
250m
rule 1
plot division
rule 2
urban patio
rule 3
streets
rule 4
green areas
rule 5
equipament
rule 6
local commerce
rule 8
neighbourhood entrance
rule 7
boundary relation
pedestrian streets
max 2 paralel streets
parametric variations

4a.

4b.

4c.

Figure 4. 4a – Rules. 4b – Urban plan – generation of one solution following the rules. First iteration shows pre-existences defining main compositional axes. 4c – Detailed plan of the urban plan south half generated after a different rule application.

Figure 4b shows a sequence toward one possible solution obtained through repeated rule application presented by Team 1 to illustrate their design system. Figure 4c shows the results of a different solution produced by Team 2 using the same set of rules and adding a more detailed characterization of neighborhood materialization. This step is important because it shows that the set of rules defined by Team 1 is able to generate alternative solutions while keeping the same urban language. The neighborhood is clearly recognizable as part of the same design language, although it corresponds to a different rule sequence and the final solution is formally different. The plan in Figure 4c clearly shows, apart from the added details, a different distribution of the main features of the neighborhoods, such as the position of the urban patio, streets and entrances. This result suggests that by selecting patterns and applying corresponding rules one can guarantee language consistency and, consequently, safeguard the intended development vision, while leaving room for the designer to generate different layouts and express his design skills.

Finally, we can recognize, particularly in the first three examples, a kind of progressive quality, capable of growing in a bottom-up fashion. Although the students' work lacked a bit of definition in this respect, it seems that rules could be added to define more clearly

how the generation process could evolve. Moreover, if we consider the possibility of adding changes to rules or substitute some of them by new ones, similar to the process unveiled by Knight in Transformations in Design[9], we can anticipate the possibility of developing not only an evolutionary design system but also evolution within the design language. This could be useful to overcome the difficulties raised by changes in scale or to simulate, more accurately, the effect of time passing.

Conclusion

The results showed that:

- The use of the pattern language helps define the qualities and characteristics of the urban space as well as the urban program;
- The use of rule based design systems can produce flexible designs, that is to say, a system of alternatives within a specific urban design language;
- Rules may be arranged to codify patterns and can be interpreted differently by different designers, leaving room for design creativity while keeping the qualities defined within the pattern language.
- The use of the proposed methodology and the patterns to guide a rule based approach can play a powerful role in academic work allowing the students to tackle complex urban design problems and design goals related with flexibility.

The use of such tools is useful in urban design, we would argue, because by manipulating rules they allow one to manage stakeholders and municipality interests, or to cope with changing factors while maintaining the qualities intended for the urban space.

Future research will establish criteria for selecting patterns and formally define them as an urban grammar. The correct establishment of these criteria will be of ultimate importance if an automatic generation system is to be implemented. If a customized procedure is aimed towards a bottom-up design approach, criteria for the creation of an efficient interface should also be developed. Furthermore, it seems that these procedures may bring us one step further in the development of computer-assisted urban design systems and they are consistent with a possible plug-in system as supported by Fargas y Texidó[10] for designing rules for computer expert systems, allowing easy adaptation to the specifications of the design problem. Work is now being developed for such goals and will be the subject of future articles.

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