Shape Grammars for Analyzing Social Housing

The case of Jardim São Francisco low-income housing development

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Abstract. This paper presents an analysis of Jardim São Francisco, a low-income housing development in São Paulo, Brazil, using shape grammar as an analytical method. It is part of an ongoing research that aims at analyzing the different types of sitting in low-income housing developments and their consequences for public spaces. The final objective is to propose a design method that allows designing better quality urban spaces in this type of development.

Keywords. Low-income housing; urban design; shape grammar.

CONTEXT OF RESEARCH
Along the twentieth century, the housing shortage problem in Brazil has progressively increased, as a result of industrialization, demographic explosion and the intensification of migration of the population from rural to metropolitan areas. Solving that problem has been a major objective of the government in the past years, with lots of investments and many specific programs, such as the widely known “My house, my life”. There has been a lot of debate by the National Department of Housing, the Ministry of Cities and many graduate programs about low-cost construction systems, minimum area requirements, and even about location of housing developments in relation to city centers. However, research on social housing in the country has focused primarily on the analysis of public policies and novel housing construction systems, while few studies have emphasized the importance of the design of public spaces in these projects. In most housing developments one sees either the typical image of repeated identical houses along streets, or dense apartment buildings. Most solutions used are still based on obsolete approaches to sitting, which results in communities not just visually boring, but also lacking quality public spaces.

OBJECTIVES
This ongoing research aims at analyzing the different types of sitting in low-income housing developments, and their consequences for public spaces. The final objective is to propose a design method that allows obtaining better quality urban spaces in these developments.

In the analytical part of the research, the following projects will be analyzed: Malagueira, in Évora, Portugal, designed by Alvaro Siza in 1977; a housing development in Mexico city, Mexico, designed by Christopher Alexander in 1976; and Jardim São Francisco, – in São Paulo, Brazil, designed by Demetre Anastassakis, in 1989.
This paper presents an analysis of Jardim São Francisco, a low-income housing development, aiming to assess the design method used to obtain a satisfactory result in defining the internal layout of the housing units as well as the configuration of public spaces. Shape grammar was used as an analytical methodology to understand the underlying compositional logic of a section of this large development (Section VIII), which is located in the eastern part of São Paulo City, in Brazil.

**DESCRIPTION OF THE CASE**

The housing project Jardim São Francisco, Section VIII, was the result of a national competition for the construction of social housing in the city of São Paulo in 1989. The winning team was coordinated by architect Demetre Anastassakis. This part of the development occupies an area of approximately 10.000 m², with 154 dwellings. The sitting includes hierarchical open spaces, ranging from the most private to the most public, breaking the traditional spatial forms used in typical housing projects in Brazil, based on the concept of individuality of the house, yet articulated with collective spaces. A limited number of different house plans are combined in different types of clusters, forming semi-open courtyards that promote community life (Figure 1).

This village-like structure, characterized by a complex network of spaces, also considered the possibility of expansion of the houses over the years, according to the resources and needs of families.

Aiming to combine the cost-reduction with principles of comfort and beauty, the project aimed to combine groups of townhouses asymmetrically, with access in different levels and small semi-public courtyards (Figure 2).
The public space in the Jardim São Francisco

The concept of the houses in Jardim São Francisco was based on the idea of an embryo module built with brick masonry, a local material and construction method, and some basic rules used in the composition and expansion of the houses, which provided flexibility. This compositional system, which was based on a simple architectural program (living room, kitchen, bathroom and two bedrooms) resulted in seven different types of houses. The occupation of the ground followed a system of rules aimed at the minimum change in the topography, adapting buildings, gardens and public spaces to the existing topography. The objective was to create a structure characterized by a strong territorial definition (inside/outside) and increased permeability of the spaces, with a variety of shady areas and sunny places. The different spaces have different qualities in terms of ventilation, lighting and visual privacy.

SHAPE GRAMMAR

The formalism known as shape grammar was first started from a paper published by Stiny and Gips in 1972, in which foundations of what would become the most important algorithmic approach to design were established.

Since its invention by Stiny and Gips, the use of shape grammar has grown exponentially, involving an increasing number of examples of applications and research problems. Shape grammar consists of a method of generating forms based on rules and has its origin in the production system of the mathematician Emil Post and the generative grammar of Noam Chomsky. Over the years, shape grammar has been used in several applications to solve design problems, allowing the generation of alternatives from an initial shape, through the use of recursive application of compositional rules (Duarte, 2007; Knight, 2000; Celani et al, 2006).

Figure 3
Vocabulary of shapes for the housing units and rules.
A shape grammar is developed from the definition of the following elements (Celani et al, 2006):

1. **Vocabulary of shapes** – For developing a grammar, first, it is necessary define a finite set of primitive shapes that will compose the grammar. These shapes might have two or three dimensions.

2. **Spatial relations** – Then, spatial combinations between the primitive shapes of the vocabulary are established.

3. **Rules** - From the spatial relations, transformation rules of $A \rightarrow B$ type (when find $A$, substitute for $B$) are defined. These rules can be either additive or subtractive.

4. **Initial shape** – To start the application of the rules, it is necessary to select an initial shape, belonging to the vocabulary of shapes.

**DEVELOPING THE GRAMMAR**

The shape grammar formalism was used in order to analyze this housing development, to understand the methodology used in the design process and to develop proposals for similar cases. In this shape grammar, we studied the housing units, their grouping to form clusters and the sitting of the clusters. The following part describes each of the grammars developed:

**Housing units**

The houses of the Jardim São Francisco low-income housing development are characterized by plans with simple combinations of rectangular rooms, specially developed to make construction easier, since they were built under a scheme of collective effort. However, the simplicity of the forms does not mean monotony, as the different possible combinations allowed a variety of types. The future dwellers were able to discuss their ideas with the architects...
responsible for the design. Seven different types of housing units were developed. The corpus of analysis in this research considered just 4 of them - R1, R2, R3 and R4. The plans are combinations of rectangles in two-dimensions, whereas the clusters are combinations of housing units in three-dimensions.

5. Vocabulary of shapes for the housing units
The vocabulary is composed basically of two types of oblongs with two standard sizes: 3.00 m x 4.50 m x 2.50 m (width x depth x height) and 3.00 m x 3.00 m x 2.50 m (Figure 3).

6. Spatial Relations / Rules
The spatial relations refer to the possible ways of positioning the set consisting of oblongs side by side or one over the other, meeting the following conditions:
• The upper floor area should be less than or equal to the area of the ground floor.
• The minimum ground floor area shall be 4.50 m x 6.00 m.
• The maximum number of floors is 2.
The grammar developed can generate all the houses of the corpus of analysis and propose new designs, thus demonstrating its effectiveness and potential (Figure 4).

Housing clusters and courtyards
For the composition of the clusters (or blocks) formed by housing units, the rules are 2D (Figure 5), with the following restrictions (Figure 6, next page):
• Maximum number of houses per block - 4 units.
• Maximum number of floors - 3.

Courtyards
The rules for generating courtyards are defined using pre-defined distances between blocks, ensuring circulation - rules Rc1 and Rc2 - and the creation of public spaces in the housing complex.
To generate a courtyard, it is necessary to insert up to 6 perpendicular adjacent clusters (Figure 7, next page).

Alleys
To generate the alleys of Jardim São Francisco housing development, 4 rules (Ra) were created that define different distances between the clusters. The distances range between 1.50 m and 3.00 m (Figure 8, next page).

COMPARISON WITH OTHER LOW-INCOME HOUSING DEVELOPMENTS
As stated above, the analysis of Jardim São Francisco is part of a larger study, aiming to analyze several case studies of low-income housing developments in Brazil and abroad. In this section, a preliminary comparison between Jardim São Francisco, Malagueira development - designed by Alvaro Siza - and Mexico housing complex - designed by Christopher Alexander - is presented.

The urbanization of Malagueira, located in Évora - Portugal, was designed by Alvaro Siza and includes 1200 dwellings. It has been built from 1977 until today. This housing development has more than 35 different plants, all of them lined up with the streets. Jose Duarte (2007) used the shape grammar formalism to analyze this project, identifying the design rules subliminally followed by Siza and his collaborators in the development of these houses. This method allowed the definition of a generative system to create customized houses that belong to the same language. In this case, the use of grammars focused on the internal organization of houses and did not aim at defining the organization of public spaces, which, in this case, was relatively simple, based on houses lined up along streets.

The housing project developed by Christopher Alexander and his colleagues in Mexico, built in 1976 with collective effort, differs from Siza’s project because in this case the housing units are organized in clusters, thus creating more fluid and diverse public spaces between them. This approach resulted in a greater variety of urban spaces and their appropriation by the dwellers, as well as better adaptation to the topography. According to Alexander (1985): “… before they come to the stage of laying out their hous-
Figure 6
Derivations of blocks and generation of new blocks.
Figure 7
Rules for generation of courtyard and derivation

Figure 8
Rules for generating alleys.
es, they must first play a role in laying out the common land between their houses, so that this public unit of space, this common land which leads into their houses, is not some abstract mechanical thing, done for them by the city or by a developer, but is itself unique and personal to all the families, a collective expression of their will, a permanent part of the world which is uniquely ‘theirs’.

Jardim São Francisco housing development has, on the one hand, the rule-based character of Malagueira, but on the other hand the complex public space system of Alexander’s project, organized in “villages” that follow the topography of the land, with permeable public spaces and a diverse set of houses, courtyards and squares.

The analysis of case studies showed that the shape grammar method allowed to identify the existence of combinatorial systems in the design of the houses created by Alvaro Siza and Demetre Anastassakis and present in the urban sitting of Jardim São Francisco housing complex.

The situations in which it was possible to detect the existence of underlying rules of combination have a complexity and/or geometric variety that result in greater diversity of spaces and consequently of urban situations, however, without overly burdening the design process and construction, as there are repetitions, even though they are “disguised”.

DISCUSSION
This research has shown that the shape grammar method allowed to verify the existence of combinatorial arrangements in the projects analyzed. Therefore, this method can be considered a viable and efficient strategy to generate new designs. It allows to obtain a variety of options from a relatively small number of parts that can be rooms - in the case of a shape grammar to define the housing unit design - or blocks/clusters of houses/apartments, considering the scope of urban sitting.

Although neither Alvaro Siza or Demetre Anastassakis used an explicit shape grammar to develop their social housing projects, this method presents itself as a good strategy for understanding the underlying logics of these designs, generating new compositions with much better quality of internal and public spaces, and, thus, allowing greater diversity of urban areas in low-income housing developments.

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