

Favela's Houses as Design Reference: Using Shape Grammar

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Abstract: Shape grammar has been used by many researchers to identify and/or define languages in architectural design. This paper presents a methodology developed using shape grammar to analyze the informal city, specifically Favela da Rocinha's buildings, in Rio de Janeiro. The goal was finding the organizational foundations of self-built houses in an informal settlement. A methodology was developed to find composition patterns and to infer a set of rules which defines a shape grammar of Rocinha houses, allowing synthesis and analysis of low cost solutions for house designs. And above all, it highlights underlying design solutions produced empirically by inhabitants of favelas, emphasizing the diversity in favela's architecture, and, that is also able to reflect the particular necessities of targeted population.

Key words: Shape grammar, shape analysis, informal architecture, favela.

1. Introduction

In a previous paper about the use of shape grammar formalism to the informal city, Dias [1] sought to recognize the peculiarities in land occupation and buildings' volume at Favela da Rocinha, Rio de Janeiro. In this context, we present the continuation of this study, applied now to residential inner spaces.

Brazilian slums, also known as favelas, exist in most of medium and big cities all over the country. In Rio de Janeiro city, about 22% of the population live in this kind of settlement [2]. Favela's dwellers generally live in self-built houses or ones built by workers with no formal education in architecture or engineering.

In governmental initiatives, many projects for improvement of favelas have been conducted over the past four decades. And despite their enhancement year

after year, none of them has ever considered the most common solutions empirically developed by the dwellers themselves. Minha Casa Minha Vida, the latest federal government initiative to provide housing to low income population, has been very criticized. Along with the location of many of the settlements—too far from the urban centers—and low-quality material, the architectural design has also been disapproved, since the same house model is given to every family, no matter the differences there might be between each other.

Rocinha, in the south zone of the city of Rio de Janeiro, is the biggest favela in Brazil, with about 70,000 inhabitants, according to Governmental Statistics [2] from 2010. It is located in between two upper-class neighborhoods, Gávea and São Conrado, over the mountain that separates them. In Fig. 1, satellite image of Rocinha (in red) and its surroundings: São Conrado, Gavea and Leblon are neighborhoods of the formal city. Vila Parque da Cidade, Chácara do Céu and Vidigal (yellow spots) are other favelas.

Generally, favelas' dwellers solve their housing needs without any governmental support. Many times,

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Fig. 1 Rocinha (red) and neighboring districts and other favelas (yellow).

houses are built by the inhabitants themselves in a joint effort, called *mutirão*, where people help each other building or extending their houses. Some of those people are employees in civil construction sector and have experience on masonry. Even though academic research has been made about favelas, including Rocinha, none of them presents objective tools for architectural and urban design, nor do they consider dwellers' *savoir faire* as data in design of social housing.

This paper presents an application of the formalism known as Shape Grammar, applied to Rocinha's houses, and is part of a bigger study which includes also investigation of the urban fabric. It intends to recognize particularities in land occupation, buildings shapes and interior spaces layout. The methodology developed seeks to gather the local morphologic characteristics in a set of rules that will allow new designs, always taking into account the processes of adaptation and transformation, peculiar to informal settlements and appropriate to families' profiles. The intention is to provide information to development of customized house design. The outcome would be based in dwellers' own experience, instead of houses

conceived by architects or engineers' own ideas of how those should be, and also, taking advantage of solutions present on favela's buildings for more creative solutions.

This study is being developed by a research team called Teaching Observation, which explores observation as a strategy to understanding geometric shapes. Shape grammar has been investigated due to its potential for analysis and formal composition. It has been used as means of analysis and synthesis of architecture since the 1970s, and many residential buildings groups have been studied ever since. Traditional Taiwanese houses, Queen Anne houses, Buffalo Bungalows are some examples. For this study, shape grammars developed for Wright's Prairie Houses [3] and Siza's Malagueira houses [4] were the main references. Both studies state rules for tridimensional development and use zoning, with dynamics which analyses and makes composition of spaces through shape grammar, considering functional characteristics. Color grammar, conceived by Terry Knight [5] is also a reference, since it makes possible to associate colors to characteristics to a given shape, function.

1.1 Land Occupation

Initially the land was occupied by Quebra-Cangalha farm, which, in the beginning of the 20th century, and was divided for private housing purposes. Due to legal issues, the companies in charge of these projects went bankrupt and during the 1920s, the area started being invaded. During the 1960s illegal occupation increased, Rocinha's location became very privileged, due to a combination of factors. One of them was the opening of Lagoa-Gavea Highway, which includes the Dois Irmãos tunnel. This road links the south to the west zones of Rio de Janeiro, two main economical areas of the city. The west zone has been having a great economic development ever since, and the south zone holds the neighborhoods with the most expensive squared meters of the city. With the tunnel opening, Rocinha, which is located right over the Dois Irmãos tunnel, became close to both south and west zone of the city.

As a result, the land occupation is very dense, and buildings are relatively verticalized, with a great recurrence of three to five floors. Land occupation that has not followed any legal requirements is also a consequence of the challenging topography and

building shapes. The outcome is a very particular urban fabric, shown in Fig. 2. Its contrast with São Conrado land occupation and building shapes is one of the most impressive images of the city.

Even though the occupation started almost 100 years ago, there was no previous infrastructure work before the occupation, including water supply chain and sewerage system. This would explain the lack of interest of higher income classes in the area. In 1981, Rocinha was chosen as a pilot program for slums urbanization. Part of a river was channeled, and families were transferred to houses built in a higher part of Rocinha. In 1993, it was promulgated a law (Lei nº 1995 de 18 de junho) that creates and delimitates the Rocinha neighborhood. The statement of this law would allow the creation of special legal rules for the area, since most of the streets, allies and buildings are not in conformity to city's codes. Those new rules were, actually, never stated, probably due to the lack of both political interest and knowledge of the most common practices. The latest project for Rocinha was the *Plano Diretor Socioespacial* (2005-2007), developed by a team led by Luiz Carlos Toledo. This Social-spatial Plan established rules for land reorganization and Rocinha's growth.



Fig. 2 Tall residential buildings at São Conrado and the dense urban fabric of favela da Rocinha. The main road is Auto-estrada Lagoa Gávea (Source: Google earth image.)

2. Recognizing Rocinha's Language

2.1 Shape Grammar

Shape grammar was first developed by George Stiny and James Gips in early 1970s. It is a formalism based on the statement of rules that make up a system for generating shapes. This model for creation of design languages conceived by Stiny and Gips is based on Chomsky's work. Chomsky [3] has analyzed the structure of English grammar based on logical-mathematical rules. Gips and Stiny [4] used the same scheme, replacing symbols for shapes and using Euclidian transformations¹ as shape changing operations. According to Stiny [5], a language of designs is defined by a shape grammar, which is constituted by four elements: vocabulary of shapes, spatial relations, rules and an initial form, the last one as part of the vocabulary.

Shape grammar may be used for both original designs and analysis, and the frontier between analytic and generative grammar is subtle. Knight [6] states that it is an effective way of understanding any given design style or family. A set of rules established for an analytical grammar may be used for original designs, which will belong to the same style of the corpus of analysis.

Duarte has been employing shape grammar for analysis of architectural and urbanistic groups. He has analyzed Siza's Quinta da Malagueira's [7] houses and the Medina of Marrakech [8].

2.2 Finding Patterns

To infer rules for Rocinha's Grammar, field trips were made to find out its shape characteristics. The chaotic aspect of the site, which can be seen in Fig. 3 is a result of self-made buildings, with no official regulation, in a very steep land. The first houses appear in the lowest part of the site, and many lots keep the original shape of the original land division, from the first decades of the 20th century. But in the

steeper portions of the favela, roads and pathways have diverse shapes, following the level curves or searching for a gentler inclination. When shorter paths are needed, the alleys are stairways. The buildings are also extended according to families' needs and occasionally, houses expansions invade public ways, sometimes in ground level, and others, in higher levels, making alleys become narrower, as seen in Fig. 4.

Most of the houses are set side-by-side and end up with almost no space left between each other, nearly 100% of lot occupation. The little spaces left are generally used for plumbing and sewerage systems, as well as electricity and data, like a kind of "open air" shaft. Sometimes it is also possible to find small windows facing these narrow spaces. Buildings and some units must be accessed by distinct levels with overhangs which end up covering some sections of the access ways, forming tunnels. All those elements cause little or no ventilation as well as no direct sunlight, factors for many insalubrious problems.

These houses' extensions start by occupying almost all the empty space left on the lot and then go upwards. It may have different purposes: building new rooms to accommodate the growth of the family, making a new home for one of the members, and also to have a new source of income, renting apartments. There is an internal real estate with its very own rules, like the *direito de laje* (slab right), where one can sell the top of its building to someone else, like a land sell. This factor led many buildings to be occupied by more than one household.

The corpus of analysis is constituted of nine residences, located in five different buildings. Those are all in the same sector of Rocinha, called AI-2 by the socio-spatial Plan. This area was selected because of the existence of a previous research on the area and consequently more documentation—very important for the urban analysis. This study [9] was made by a team led by the architect Luiz Carlos Toledo, who is also the author of the Socio-Spatial Plan. Getting permission to enter inside houses is not a simple task,

¹ Translation, rotation, mirror, scaling, addition, subtraction.



Fig. 3 A view from a higher position, the chaotic image of the buildings.



Fig. 4 Narrow alleys, with buildings over public areas.

people in favelas might be very suspicious about strangers. Also, it is important to avoid drug dealers' areas, since they are also suspicious and might become violent. We had the aid of an undergraduate student who lives at Rocinha and established contact between research team and inhabitants.

All the residences studied were measured and photographed. Since the goal was not to define the

actual design, but layout concept, information such as quality of building material were overlooked to simplify the work. In the same sense, angles were considered all to be right, although many of them were not. We were granted full access to three of the buildings, which were measured in its totality. We have only partial measurements of the rest, since we could not enter in all the units. Two of the buildings

contain only one household, the rest of them have more than three. In some of those buildings, each floor contains more than one household. Informal conversations with inhabitants aided the team to understand the dynamics of the houses and real state.

2.3 Inferring Rules

In studio, technical drawings were made, as well as analysis sketches. The use of color to identify the function of each room was essential and was also used in the rules inferred. Rules organization was inspired by the Malagueira Grammar, by Duarte [7], and is divided into stages: (1) lot occupation; (2) internal space division; (3) walls realignment; (4) openings; (5) insertion of new floors; (6) end. Labels are placed in the end of layout composition stage to allow realignment stage, and then those labels are replaced so that openings stage may begin.

The initial shape is the lot, and the first stage will indicate the way it is occupied by the building, which may be totally or partially. Rules make division of the lot and inserts ground slab to indicate built area. Colors are used to identify built from no-built spaces.

Even though the initial shape is represented in rules as being a rectangle, its actual shape is defined in a parallel grammar: urban grammar. Since it is an informal settlement, the government has few or no interference in urban design, public and private spaces are defined according to people’s necessities and will, and rules for this design are being investigated by the research team in a parallel study. Streets are generally natural paths, and houses are built alongside. Because of topography, those pathways tend to follow the level curves or even become stairways. Lots are defined according to streets shapes or as residual spaces between other lots. As a result, many of the lots are configured as irregular polygons.

The second stage (Fig. 5) defines the inner division of each floor. Recursive subdivisions are made, first defining the “wet zone”—bathroom and kitchen—always present at the back part of the lot, and then the subdivision of each zone, defining bathroom and living room (both obligatory), kitchen, sleeping room, stairways. Labels are put to indicate that the following stage must take place. The next one realigns walls according to parameters, defined by

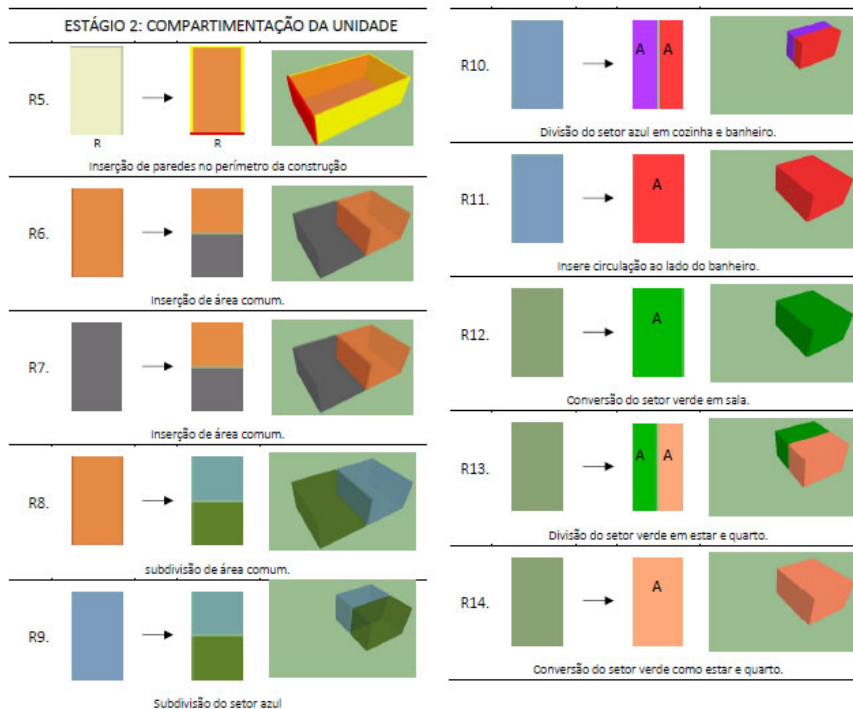


Fig. 5 Stage 2, inner space subdivision.

minimum and maximum areas observed in site. This realignment is also about outside walls, which may be moved according to the use of the room. After realignments, labels are substituted to permit the insertion of doors and windows, the fourth stage. Labels are erased, and the arrangement of the floor is finished.

The fifth stage inserts new slabs and defines the way it must be used: whether it is a new floor, or it will become a sort of “backyard” on the top of the building. In this case, there are rules which will define how this area will be occupied: roof, small built area, placement of water tanks. In case of new floors, second, third and fourth stages must take place once again.

But different from the Duarte's work, where labels are inserted to guide the upper level walls, the buildings studied do not usually show links between floors. Every one of them tends to have independent layout from the one below, walls are not structural, although made of clay bricks. Most of the people who build those houses do know empirically how to make concrete beams, pillars and slabs, but since they do

not have formal education in structure calculation, they tend to oversize the structural system, allowing walls to be located in a very independent way.

Social dynamics also should be mentioned. It is quite common inserting new floors to their own children that are getting married and need a house. These floors might have the layout arranged in a different way. With the *direito de laje*, buyer will make their house on the top of the building, according to their own needs, normally disregarding how the layout is resolved downstairs.

Every house has at least one bathroom, composed by toilet, shower and sink. The majority has the kitchen in an independent space, usually besides the bathroom. They are both in the back side of the house. Plumbing includes pipes passing outside the building, avoiding internal work in the neighbor's unit. Stairways may be placed in any room, except for the bathroom.

Most of the houses have three to five floors, and the floor adding stage operates more or less independently of layout stage, but peripheral walls may be changed according to layout. Some of the external elements like

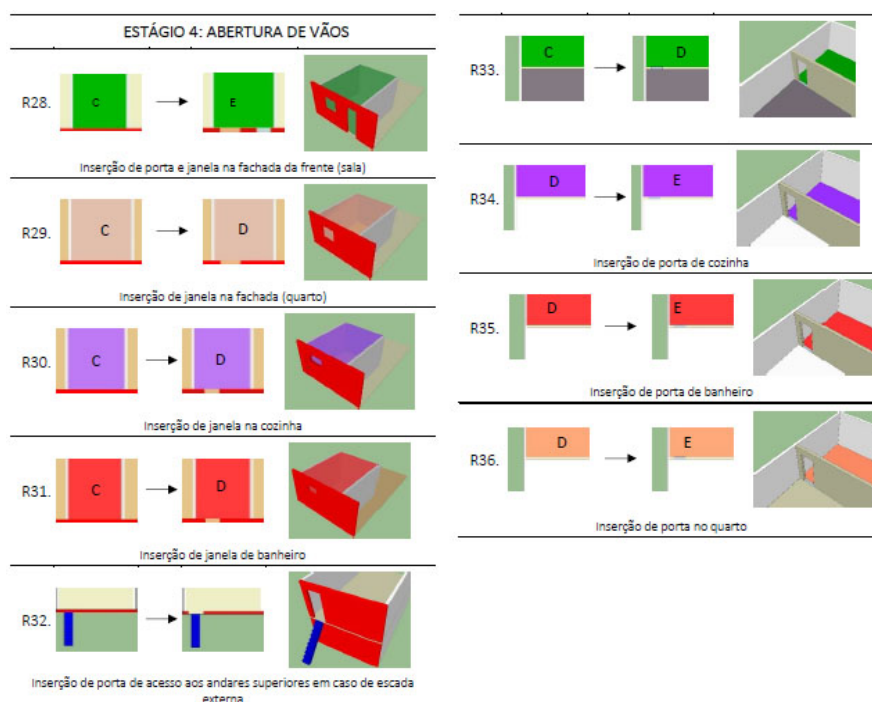


Fig. 6 Stage 4, insertion of doorways and windows.



Fig. 7 Stage 5, insertion of new floors.

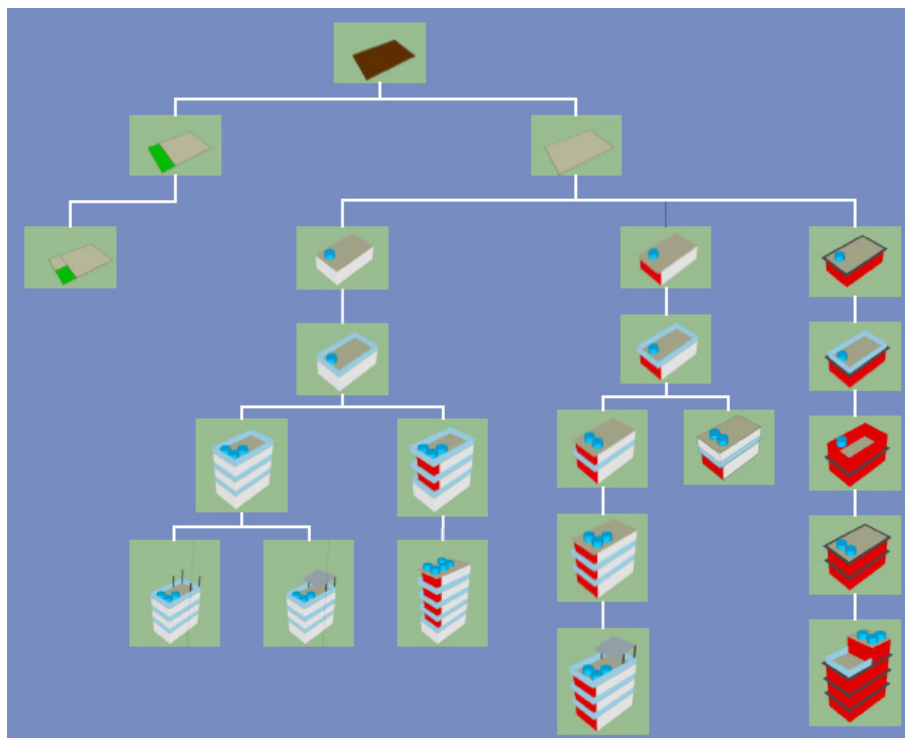


Fig. 8 Tree diagram showing possibilities of arrangements.

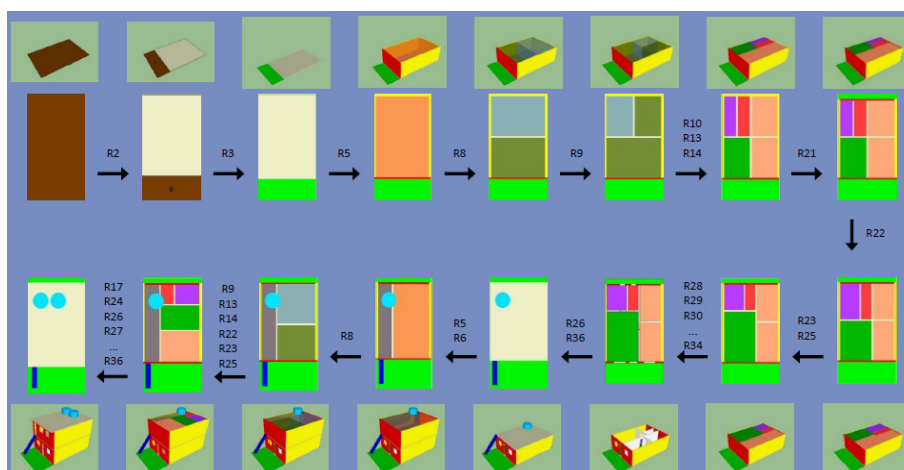


Fig. 9 Rules computation.

stairways are still under investigations, since its positioning is linked many times to public spaces. The occupation of top slabs was also considered along with its elements: water tanks and roofs.

3. Results and Discussions

Composition rules were inferred, and parameters defined based on data collected in each and every house visited, which, by their turn, were built in complete disregard to law's regulations, established by the municipality. The grammar defined, as well as the computation presented in Fig. 9 has a very objective character: illustrating composition patterns, with no judgement implicit.

Rules presented in this paper are meant to be applied in plan lots. And since the corpus of analysis does not hold any building located in steep lots, it is ignored whether these may be applied in the same way, but we believe supplementary rules should be defined. Multipurpose buildings were not investigated as well, even though in one of the buildings investigated the first floor has commercial use. But it is not possible to infer rules from only one example. Since inner economy in Rocinha is very intense, that kind of buildings should also be studied, as possibility of income resource.

4. Conclusions

Favela da Rocinha has been built in a collaborative

way by its dwellers, in individual or cooperative initiatives. Nevertheless, the "Favela Style" may be an architectural and urbanistic model for low income housing design, which may reflect the particular necessities of each family.

In this sense, research intended to point out what might be apprehended from self-built houses and understand how to infer rules of spatial organization based on these houses. We believe that simple adjustments in rules parameters may provide data that will allow architects to design new houses or even give proper technical support. The ultimate goal would be providing housing design well suited for each family reality, in terms of cost, size and cultural values, so that dwellers may recognize themselves.

Respecting people's own conceptions about space design was the core of this study. It allowed us to highlight underlying composition patterns from self-built houses analyzed. On the other hand, Rocinha's inhabitants struggle with insalubrity, caused by low quality water supply and sewerage system—provided by the government, and also by the lack of natural illumination and ventilation, caused by badly dimensioned spaces.

Even though the intention of this research is to provide information for development of housing design strategies at informal settlements, rules presented here must be adapted. Many of the problems lived in daily basis by the dwellers are provoked by the

way houses are made. The next step of the research is the investigation of adjustments of rules, additional studies on illumination and ventilation parameters, as well in structural system. This study must also consider how urban shape enhances the problems diagnosed: distance between buildings and alleys' width, topography gradient.

The research team continues the analysis of Rocinha using shape grammar and has been participating, for two years now, of a collaborative design studio, Rio Studio, led by Prof. José Duarte, from Penn State University. This group is studying Favela Santa Marta, also in Rio de Janeiro.

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