Sloping Façade Buildings in Brazilian Modern Architecture

Characterization of a Group with the Use of Shape Grammars

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Abstract. Sloping façade buildings have been present throughout XXth century architecture, for different programs and in different countries. One of the first architects to use sloping façades was probably Frank Lloyd Wright. Two early examples are Taliesin West (1937) and Annie Pfeiffer Chapel at Florida Southern College (1938-41). In Brazilian Modern architecture sloping façades soon became a recurrent solution, the earlier examples being produced by architects Oscar Niemeyer, João V. Artigas and Affonso E. Reidy, possibly influenced by FLW, as suggested by Irigoyen (2002). The present research proposes that these buildings may have influenced other architects in Brazil and abroad. In order to confirm this hypothesis, a design process was modelled and a shape grammar was developed to describe a small corpus of buildings designed by these three architects in the 1940’s and 1950’s.

Keywords: Sloping façade buildings; shape grammar; Brazilian modern architecture.

Introduction

Sloping façade buildings have been present throughout XXth century architecture, for different programs and in different countries. In some cases it is possible to relate the use of sloping planes to function (as in stairs, ramps and bleachers), structural performance (such as proposed by Nervi, 1956), climate control (shading), and even to visual perception (as suggested by Arnhein, 1975) (Figure 1). However, there are many cases in which sloping façades cannot be fully explained by functional requirements. In these cases, the morphology may be related to external influences, commonly referred to as the use of precedents in design.

One of the first architects to use sloping façades was probably Frank Lloyd Wright. Two early examples are Taliesin West (1937) and Annie Pfeiffer Chapel at Florida Southern College (1938-41).

In Brazilian Modern architecture sloping façades
were also very common, the earlier examples being produced in the 1940’s and 1950’s by Oscar Niemeyer, João Villanova Artigas and Affonso Eduardo Reidy, three of the most prominent modern architects in the country. There are evidences of early contact between these architects and Frank Lloyd Wright and his work.

Irigoyen (2002) has described in detail Wright’s trip to Rio de Janeiro in 1931. Wright was invited to be a member of the jury of a design contest. During his stay in the city, he lectured at the ‘Escola Nacional de Belas Artes’, where Niemeyer was then a student and Reidy was a professor. Irigoyen also describes Artigas’s journey throughout the United States in 1946-47, when the young architect visited and photographed many buildings designed by Wright, including Taliesin West.

The hypothesis of the present undergoing research is twofold: firstly, we propose that the sloping façade buildings designed by Niemeyer, Artigas and Reidy may have been influenced by Wright’s work; secondly, we suggest that these buildings may have influenced other architects in Brazil and even abroad. In order to confirm this hypothesis the main characteristics of these buildings are described by means of a model of the design process and a shape grammar (Stiny and Gips, 1972). In the next phase of this research this model and grammar will be used to find out to which extent other sloping façade buildings can be considered similar to the buildings in the corpus of analysis.

**Shape Grammars**

The present research proposes an intersection between the study of precedents in architectural design and the formalism known as shape grammars. This idea is not new. Eilouti and Al-Jokhadar (2007), for example, have proposed the use of shape grammars to structure the “unstructured information embedded in precedent designs” (p.34) that are present in Mamluk architecture.

Shape grammars have been used for identifying architectural styles focused on common factors such as a specific designer, style or cultural setting. Examples of the use of the shape grammar formalism for these purposes can be found in Mitchell and Stiny’s (1978) Palladian grammar, Flemming’s (1987) grammar of the Queen-Anne houses, and Çolakoglu’s (2003) study of traditional Bosnian houses, respectively.

In the present study we propose to focus on a morphological aspect – the sloping planes – as the starting point for the definition of the corpus of analysis. Referring to the purposes of computer implementations of shape grammars, Gips (1999) suggests four reasons for the use of grammars:

- **Synthesis** – generating shapes based on a shape grammar (‘the most common task’);
- **Analysis** – determining if a given shape can be generated by a given grammar and, if so, determining the sequence of rules that must be used;
- **Inference** – defining a shape grammar that can generate a given set of shapes;
- **Generative design** – defining grammars as a process of designing; an approach based on Knight’s (1998) statement that “the process of developing an original grammar is analogous to the traditional design process”.

In the first part of the present study a shape grammar was developed by inference. In the next phase, it will be used for analysis. As a final outcome,
we expect to modify the grammar, in order to use it for synthesis.

**Methodology**

The common building element used to define the corpus of analysis in this study was the sloping façade, a recurrent feature in the XXth century, especially in Brazilian modern architecture.

The research has been developed in six steps so far:
1. It started with the definition of a corpus of buildings
2. Next, their main characteristics were defined and the buildings were grouped according to them, in three main types: those with a sloping body, those in which the sloping plane is just suggested by structural elements, and those which combine a sloping body and sloping structural elements.
3. Next, the design process was modeled. Each action and each decision point in the process were identified, resulting in a flowchart.
4. The chart was tested to see if it allowed designing all the buildings in the corpus.
5. Next, 2D shape rules were developed to generate the sections in each step in the design process, and 3D rules were created to generate the volumes, by means of extrusion.
6. Finally, the shape rules were also tested to see if they allowed designing all the buildings in the corpus.

In the next phases of the present research, sloping façade buildings designed by other architects will also be analyzed according to the shape rules, to see to which extent they are related to the buildings in the corpus of analysis.

**Corpus of analysis**

The corpus of analysis contains six sloping façade buildings designed by architects O. Niemeyer, J. V. Artigas and A. E. Reidy in the 1940’s and 1950’s. The buildings in the corpus are listed in Table 1.

**Main characteristics of the buildings**

The main characteristic that the buildings in the corpus have in common is the fact that their volume is based on the extrusion of a trapezoid section. Unlike

<table>
<thead>
<tr>
<th>Architect</th>
<th>Year</th>
<th>Building</th>
<th>Location</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>O. Niemeyer</td>
<td>1946</td>
<td>Mendes house</td>
<td>Rio de Janeiro, Brazil</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>O. Niemeyer</td>
<td>1950-51</td>
<td>Duchen Factory</td>
<td>Guarulhos, SP, Brazil</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>E. Reidy</td>
<td>1952</td>
<td>Brazil-Paraguay High School</td>
<td>Assunção, Paraguay</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>E. Reidy</td>
<td>1953</td>
<td>Museum of Modern Art</td>
<td>Rio de Janeiro, Brazil</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>J. V. Artigas</td>
<td>1959</td>
<td>Itanhaém School</td>
<td>Itanhaém, SP, Brazil</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>
in Le Corbusier’s famous phrase, “the plan is the generator”, in this type of building “the section is the generator”.

The buildings in the corpus typically present the following parts, all of which are contained inside a maximal section shape (M). Some of these parts are always present while others may be absent:

- Terminations (T) – optional; when present, these structural elements ‘cap’ both ends of the volume.
- Structural elements (S) – optional; they are porticos placed at regular spans, and present sloping sides. They can be combined with orthogonal bodies, with sloping bodies, or both. Sometimes they include longitudinal elements that are used for shading or simply for connecting the porticos. When there is no termination, then the sloping structural elements are mandatory.
- Main volume or body – mandatory; they can be:
  - Sloping (SB) - in this case, they may or may not be combined with an orthogonal body.
  - Orthogonal (OB) - in this case, they are always combined with sloping structural elements or a sloping body. When combined with sloping structural elements, there may be two separate orthogonal bodies.

There are ten different possible combinations of the parts above, as shown in the state-action-graph in Figure 2. The buildings in the corpus of analysis are indicated in the graph.

**Modeling the design process**

The process of designing the buildings in the corpus includes different tasks, some of which are mandatory while others are not:

1. Defining the section:
   - a. Defining the maximal shape of the section (mandatory) – this is the most important step, because all the other elements in the section will be defined within the maximal shape.
   - b. Defining the section of the termination elements (optional).
   - c. Defining the section of the sloping structural elements (optional); optionally there may be brise-soleil related to the structure.
   - d. Defining the section of the sloping body (mandatory if there is no sloping structure); optionally there may be brise-soleil related to the sloping plane.
   - e. Defining the section of orthogonal body (optional)

2. Extruding the sections generated by steps 1.b, 1.c, 1.d and 1.e, in order to create the 3D volumes.

3. Putting all the 3D parts together.

   Each type of building includes a different combination of these tasks, and not all of them are present in all the buildings. Figure 5 shows a flowchart of the design process.

**Checking the design process flowchart**

In order to check if the flowchart allowed designing all the buildings in the corpus, they were all checked. The design process for Reidy’s Museum of Modern Art is shown in Figure 3. It is possible to notice how the design process skips the ‘Defining sloping body’ action after the third decision node. The image also shows how each part of the section is defined and extruded along the process, and how all the parts are put together at the end.
Developing the shape rules
A set of shape rules was developed for each of the five different steps of the design process. Each set is described below.

The major difference between the buildings in the corpus of analysis is the fact that some of them have symmetric sections while others are asymmetric. For this reason, it was necessary to create two variations of some of the rules, one for symmetric sections and the other one for asymmetric sections.

Maximal shape rules
The maximal shape is the outline that contains all the other elements of the section – the terminations, the structure and the body.

Most of the building sections are contained within a single trapezoid, which is described by rules I-1 and I-2 (Figure 4). However, the section of Niemeyer’s, Duchen factory is contained within two overlapping symmetric trapezoids. In order to handle this case, rule I-3 was created. Rule I-4 inserts labels that allow applying the next group of rules. The maximal shapes are not extruded; they serve only as a reference for defining the other elements of the section.

Termination rules
Not all the buildings have terminations at the ends. In some cases the termination shape is equal to the maximal shape (rule II-1, Figure 5). In other cases, the termination is a little smaller than the maximal shape, opening a ‘pilotis’ at the ground level. This can happen both in symmetric (rule II-2) and asymmetric (rule II-3) sections. Rule II-4 inserts labels that allow applying the next group of rules. Rule II-5 extrudes the termination shape, taking into account information about the termination walls width and position (which is directly related to the overall length of the building).

Sloping structure rules
In buildings with porticos the shape of the structural elements is defined directly from the maximal shape (or the termination shape when there is a termination), as shown in rule III-1, in Figure 6. Rule III-3 shows how the offset distances of the different sides of the structure vary according to the span and to the type of stress that each part of the portico is subject to. Rule III-4 is similar, but for asymmetrical sections, and introduce a ‘pilotis’.

Rule III-6 handles the double portico in sections formed by two overlapping symmetric trapezoids. Rule III-8 inserts labels that allow applying the next group of rules. Rule III-9 extrudes the sloping structure shape, taking into account information about the structural elements’ width and position (which is directly related to the overall length of the building and the span between the porticos).

Sloping body rules
Sloping bodies may or may not be combined with
sloping porticos. In the first case their section corresponds to the internal section of the structural elements (rule IV-2, Figure 7); in the second case their section corresponds to the maximal shape (rule IV-3).

**Orthogonal body rules**
Orthogonal bodies are always combined with either a sloping body or a sloping structure. When there is a sloping structure, they fit within the portico, as shown in rules V-1 and V-2 (Figure 8). If there is no sloping body at all, there may be two orthogonal bodies, one on top of the other. Rule V-3 handles asymmetric sections.

**Testing the shape rules**
Figure 9 shows the derivation of all the buildings in the corpus of analysis with the use of the shape rules described above.

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**Next stages of the research**

In the next stage of the research other sloping façade buildings will be tested to see if they can be generated with the design process and the shape rules described above. It is already possible to affirm that many buildings can be described by them, such as those in Figure 10. However, it may be necessary to add a few new rules to the grammar in order to describe a larger number of instances of the language.

**Discussion and further work**

Although this is still a work in progress, this study is expected to show that it is possible to establish categories of buildings based on morphologic criteria, which can be confirmed by the application of shape grammar rules. It also proposes that the use of precedents in design does not necessarily result in a rigid style, but rather in family resemblances. Being able to recognize such resemblances is an important skill for both professional architects and architecture researchers and critics. With this ability, one can establish relationships between different designs, and identify the possible influences.

According to Knight (1998), there are two reasons for the use of grammars in design. Firstly, rules make ideas more explicit, allowing designers to examine and change them more quickly. Secondly, rules can
Figure 6
Sloping structure rules.

Figure 7
Sloping body rules.

Figure 8
Orthogonal body rules.

Figure 9
Derivation of the buildings in the corpus with the grammar developed.
be used to generate different compositions, instead of a single design solution. “Just like any other creative process, the design of rules involves intelligence and discipline on the one hand and intuition, imagination and guesswork on the other” (Knight, 1999/2000). This study will go on with the adjustment of the grammar as needed to allow the derivation of other buildings in the language. Finally, we intend to apply transformations to the grammar, with the purpose of generating novel designs.

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