NIEMEYER’S PROPORTION RULES

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The recurrence of strategies of proportion in the geometric structure of Oscar Niemeyer’s designs were determinant in the characterization of his architectural language. This study is based in a twofold analysis of 30 buildings designed by Niemeyer in different periods of his career. In its first part, the golden rectangle is confirmed as a generative module for the sample; in the second part, a Shape Grammar model is used as to identify the generative code of 5 buildings of the sample. This generative code may constitute the basis for the computational formulation of synthetic grammars whereby architects’ languages could be developed, taught and automatically reproduced.

Keywords: proportional systems, architectural language, regulating lines, geometry, Shape grammars

1. INTRODUCTION

In order to create dimensional and formal patterns during the design process, architects make use of lines and circumferences as to regulate and organize architectural compositions (regulating lines). The regulating lines constitute geometric tools employed, by architects and artists since ancient times to correct their work and for the satisfaction of their artist’s sense and of their mathematical thought. [Corbusier, 1927]

The use of proportional systems in the design process does involve the choice of geometric or arithmetic tools in order to generate patterns of relationships of mathematical proportions between the linear dimensions of the design [Scholfield, 1958]. The appropriation of these patterns and its apparent order (by the repetition of similar figures) to the architect’s eye,
while establishing a way of doing [Simon 1975], could be understood as an important characterization of style\textsuperscript{1}.

Considering that proportional systems do establish relationships between shapes and parts of shapes, a shape grammar could describe a proportion language of designs or the implicit structure of complex shapes generated by means of these relationships. It could then be argued that any procedure searching to identify a subjacent proportion system reproduces, to a certain extent, the geometric schema used in the design process whereby the architect, regulating spatial relations of the building elements, assigns harmony and unity to the architectural composition.

Oscar Niemeyer, one of the most influential architects of the Modern Brazilian Architecture, has challenged the right angle paradigm, one of the rationalism’s rules of the thumb\textsuperscript{2}, with his curves and the almost unlimited freedom discourse.[Niemeyer,1993] For Niemeyer, the adverb almost accounts for the limits or principles of Architecture: (...)on permanent ratios, eternal laws of balance, proportion and harmony (...) constants that I found invariably in the major works of the past [Niemeyer, 1962]. The apparent paradox between freedom and limits, quite frequent in Niemeyer’s discourse, remained without significant references in the existing literature on his work until recently, when Turkienicz, 1994; Mayer, 2003; Mayer & Turkienicz, 2005 have shed some light on the underlying concepts of freedom and limits existing in Oscar Niemeyer’s architecture. Through the description of different control mechanisms such as the proportional system based in the golden section, used in the generative phase of his designs, these studies demonstrated that Niemeyer applied concepts of order, which became more sophisticated as his career progressed. It looks as if he has evolved from Le Corbusier’s lessons, referring to the geometry of architecture, the golden section properties and the composition around a unifying principle [Corbusier,op.cit.], regarding his search for plastic unity [Niemeyer,op.cit.]. The choice for studying Niemeyer’s designs opens up

\textsuperscript{1} According to Simon [1975], style could be seen as a way of doing things chosen from a number of alternatives, what it could mean that the designer’s choices made during the design process could determine some common characteristics among the instances of the same style.

\textsuperscript{2} Despite the discourse of rupture from shapes and classical canons, we could easily trace in the design approach of the exponents of the Modern Movement as Le Corbusier and Frank Lloyd Wright, the restraint and submission to strict geometric laws [Papadaki, 1950]. According Le Corbusier [1998] the regulating lines would be the guarantee against willfulness. The so-called L’Esprit Nouveau would be a spirit of geometrical and mathematical order, owner of the architectural destinies. This architectural destinies referred to by Corbusier would be respect to modern architectural language.
the possibility to measure the extent to which Le Corbusier’s concepts about the geometry of architecture could be interpreted and evolved, in applied and theoretical terms.

This paper describes the first phase of an ongoing research aiming at the development of an interactive computational system which goal is to assist design processes involving the use and creation of architectural languages by means of proportional systems. The system should generate shapes according to rules related to architectural languages characterized by the use of proportional systems. It intends to be a learning tool to students of architecture in a way as to improve knowledge and skills in developing their individual architectural language.

The present phase of the research is based in the construction of a computational model for the generation of buildings according to Oscar Niemeyer’s architectural language. The model departs from the representation of Niemeyer’s proportion rules and it is based in the correlation between regulating lines and a shape grammar. The analysis of regulating lines allowed the depiction of the golden rectangle as a generative module for his architectural compositions. The correlation with the shape grammar model has enabled the description of an embedded generative code present in his different designs and, very likely, an important reference for the identity of his architectural language.

This paper is divided in 3 parts. In the first part, material and method, the model is described translating the generative and normative nature of the regulating lines into the algorithmic behavior of a Shape grammar. The second part presents the analysis and the results obtained so far, and finally, and last part presents the conclusions and future developments of this research.

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3 Mayer, R . Doctoral research at the SimmLab, (Propar-UFRGS)
4 According . Shape Grammar model(Stiny and Gips, 1975)
2. MATERIAL AND METHOD
The correlation between regulating lines and a Shape Grammar was applied to the description of the shape volume of thirty buildings designed by Niemeyer between 1943 and 2003 as to cover a variety of building types designed by Niemeyer throughout his career irrespectively of period [fig1]. In order to assess the generative aspects related to golden section, drawings were originated from the available sources on Niemeyer’s work⁵.

*Figure 1  Thirty Buildings designed by Oscar Niemeyer*

Assuming that these buildings were different from each other but bearing a common feature i.e. the recurrent proportionality between their parts, the goal was to incorporate the golden section parameter as to verify similarities and differences regarding the use of rules of proportion in Niemeyer’s architectural grammar.

Schematic building plans and facades were drawn in order to create the basis for the correlation between the regulating lines and the building representation along with the depiction of the operations necessary to the generation of each building. To simplify the emergence of a grammar, functional aspects were not to be taken into account but actual volumes. As a result of this simplification, drawings have to be considered as abstract representations of buildings or, to put it simply, as abstract shapes⁶.

3.0 ANALYSIS
The first step consisted of a preliminary analysis of schematic plans and facades as to identify the existence of a proportional system by means of the regulating lines⁷. These relationships were established by intersecting points between the lines of the schema and lines of

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⁵ One of the questions generally arising from any analysis of building proportions is the reliability of the data or the eventual differences between versions of the same building as designed or as built. This study takes into account the recurrence of the same relationship between the parts of a building designed by Niemeyer regardless of its real dimensions being a building or a design. What seems relevant is the architect’s actual intention in establishing a kind of proportion throughout his work and there hence his concern with the plastic unity of his architectural language.

⁶ Likewise the object of the study was not to describe the architect’s way of designing but to synthesize a possible minimum set of rules capable of generating all the buildings from the sample.

⁷ As previously stated, regulating lines are geometric schema constructed by drawing orthogonal and diagonal lines, squares, circumferences, and the golden rectangle on the composition, in order to identify dimensional and spatial relationships between the whole and its parts.
the composition [fig.2]. The intersection points, resulting from diagonal lines, demonstrated the repetition of similar rectangular figures in a geometric sequence. This sequence was preliminarily understood as Niemeyer’s design’s underlying structure.

Figure 2  Regulating lines in Niemeyer’s buildings

The incidence of spatial relations related to the golden section in all analysed buildings determined the search for golden rectangles following the previous procedure. Successive regulating lines were applied in five cases, using only golden section rectangles as to decompose the buildings in modules, abstract compositions of golden section rectangles in different scales. In another words, the golden section rectangle could be considered as the initial shape of a shape grammar model related to the proportional system used in Niemeyer’s designs [fig 3].

Figure 3  Niemeyer’s buildings as abstract compositions of golden section rectangles in different scales
Employment offices building Bobigny, Fr, 1972

The generation of a rectangular grid, having as a module the golden section rectangle, has worked as a topological reference for the transformations applied to the golden section rectangle, the initial shape of the vocabulary. The grid was either horizontally or vertically oriented, depending on the incidence of the golden section rectangle in the original composition. The reproduction of the composition in detail demanded the construction of a hierarchical grid of dissections whereby each rectangle has been successively disaggregated in smaller rectangles thus constituting secondary grids [fig 4].

Figure 4  The rectangular grid and the operations of transformation

Shape rules, depicted from the analysis of the composition of rectangles, were constituted by the geometric operations needed to generate the final shape of the five cases by the transformation of the initial shape. Translation $T$, rotation $R$ and the change of parameters through scale were identified as the basic transformation operations.

A derivation of shapes, through operations of transformation, was allowed by insertion $I$ of a rectangle from the given vocabulary. Subdivision $S$ of the grid allowed the interpolation of rectangles in points not present in the initial grid, but in the secondary grids.
Shape rules were applied to the derivation of the transformations of the initial shape until the completion of the design schema, which in turn was equivalent to the reconstitution of the regulating lines, containing all the rectangles found in the preliminary analysis.

Each derivation was represented by capital letters identifying the shape rules $T, R, I, S, E$. The set of rules applied in the generation of each of the designs gave origin to a generation code. Spatial labels were used to indicate points in the grid where the shape rules were applied (initial and final stage) and as the insertion point of rectangles. [fig. 5]

**Figure 5** A complete generation of a Niemeyer’s building

A further analysis of the generation code, as in the example below, has allowed the assessment of the incidence of shape rules and string of rules as determinant factors for the similarities and differences in generative processes and there hence in the final shape aspect.

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A preliminary analysis of the generation codes did not show significant similarities among the building’s strings of rules. However, the focus on the relation between the string of rules and each part of the design, shed light on the coincidence between parts of string of rules and a complete derivation of transformations applied to an initial shape. These sequences, called hereon blocks, contain a complete derivation of an initial shape – a golden section rectangle – in their final shape in the design. A derivation starts with a dissection of the grid or insertion of the initial shape and finishes when a new dissection of the grid or insertion of a new rectangle is achieved. The strings of rules were reorganized in sequences, according to the blocks, assuming that these will not imply in changes in the final shapes, as follows:

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<tr>
<td>ITS SIET T</td>
<td>Employment Offices Bobigny, Fr, 1972</td>
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<td>II SIT ITET</td>
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The blocks and the string’s new ordering of rules allowed the emergence of patterns as the sequence \( SITE \). The emergent patterns in turn suggested that some adjustments had to be made such as the reorganization of the generation codes, as follows: the sequence \( ITRE \) (Congress) was substituted by the insertion of the rotated\(^8\) rectangle allowing the elimination of some exceptions (as the rotation operation), resulting in the sequence \( ITE \) instead of \( ITRE \). The new organization of the blocks resulted in the emergence of the pattern \( SITE \) and its variants \( ITE, IT \) and \( SIT \) and some exceptions as \( T, I, IE \).

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\begin{array}{|c|c|}
\hline
ITE SITE ITE & Day Nursery, RJ, 1937 \\
IT SITE IE ITE IIT & National Congress, DF, 1960 \\
ITE SITE ISE T T & Xavier Residence, RJ, 1936 \\
SIT SITE T & Employment Offices Bobigny, Fr, 1972 \\
I I SIT ITTE & Ministry Offices Buildings, DF, 1960 \\
\hline
\end{array}
\]

The development of the grammar by the unfolding variants of the rules [Fig.4] required changes in the sequence of rules, where some adjustments had to be made between the grid and the design schema. Thus, insertion \( I \) was unfolded according to two topological criteria:

a. the rectangle’s orientation concordance regarding the grid
b. the rectangle’s position of insertion with respect to the module of grid

Translation \( T \) had three variants according to the orientation of the derivation by the axis \( x, y \), or both of them.

Subdivision \( S \) has four variants. These are to be related to the number of proportional dissections of the grid. Finally, four types of scale \( E \) operations were described based on the number of concomitantly scaled rectangles.

**Figure 6** Shape rules variants

\(^8\) Considering that the grid was horizontally or vertically oriented, the rectangle can be inserted in both directions without the need for a rotation
The shape rules variants are basic elements of generative matrixes and can be used to multiply the possibility of the emergence of different shapes. Further studies on the each variant’s relations and its shape impact could help to clarify the variant’s role in the grammar.

3.1 Results

Regulating lines indicated the presence of proportional relationships based in the golden section in the thirty buildings of the sample. The size of the sample allowed determining the consistency of the presence of golden section proportion in Niemeyer’s designs. Given the complexity of the grammar the model was based in five initial cases to be confirmed with the analysis of the rest of the sample.

The model works as a generic system that could generate designs according to a golden section based on proportional system\(^9\). As a partial result, the model supplied a set of rules that were tested for the synthesis of designs in the language in order to verify descriptive flows as a generative system. The synthesis product, a schema, is still very dependent on the designer’s decisions such as the start and the end of the derivations. The evolving parts of the design schema where choices about emergent shapes, ambiguity or interpretation of solids and voids are made constitute another source of further investigation. As for the depiction of rules to guide these decisions according to the language the analysis of the relation between the design schema and the grid will permit the systematisation of groups of compositions according to, for example, the predominance of solids or voids.

4. CONCLUSIONS

Although the results only partially describe Niemeyer’s architectural language, the recurrence and preponderance of a proportional system in his architecture have shown strong evidences of the correlation of his individual language with a mathematical structure.

A computational implementation will be a necessary step to improve the grammar that, due to the increasing of rules, could become very complex to be derived manually. This

\(^9\) Preliminary tests with Mies van der Rohe’s building indicated some differences in the string of rules with respect to the same tests in Niemeyer’s buildings. These differences in the sequence of rules could be one of the keys to characterize individual language with relation to proportional systems.
implementation will have to take into account the possibility of shape generation automatically or by interacting with the architect.

In the first case, the program should admit only the shape generation according to the inserted grammar. The generation program, following the rules of Niemeyer’s language, should be able to generate design alternatives pursuant to the language. One possible application for this program could be the assessment of the compatibility of the rules related to different requirements already been processed and selected by the architect. In the second case, the regulation alteration should be possible as well as the insertion of new rules. This way, the program could be used to explore alternative languages and designs, through the interaction with the designer.

REFERENCES:

"The regulating line brings in this tangible form of mathematics which gives the reassuring perception of order. The choice of a regulating line fixes the fundamental geometry of the work.“
Le Corbusier