Cognitive Process, Styles and Grammars
The cognitive approach applied to Niemeyer's free forms

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Abstract. *This paper argues that individual architectural styles are ways to express different theories of architecture. These theories, in turn, are related to the architect's design purposes or goals. In order to understand the cognitive process involved in the creation of a particular language or style goals have to be decomposed in subgoals, which will be related, step-by-step, to the vocabulary and syntactic rules adopted by these architects. The study should contribute to the development of models allowing the incorporation of cognitive processes in the generation of synthetic grammars. It is assumed that this will be made possible through the correlation between semantic rules and syntactic rules in shape grammars. As a case, this paper analyses semantic extensions of the architectural language of the Brazilian architect Oscar Niemeyer defined by the constructive approach.*

Keywords: *Cognitive process, style, synthetic grammars, design goals, semantic rules.*

1. Introduction:

1.1.Synthetic grammars and cognitive processes

Style, in architecture is the expression of the similarity of characteristics in built forms and the syntax, embedded in different styles should be related to schools of thought, cultures, geographical areas and periods (for instance, the classical style). On the other hand individual style is generated by any distinctive and recognizable mode of design repeatedly manipulated in the design process by architects [Chan, 1995]. What we call individual style may stem just as much from the decisions about the design process as from alternative emphases on the goals to be realized through the final design [Simon, 1996].

Given a finite corpus of buildings that are perceived to be alike in some sense, the problem of individual style consists of characterizing the basis of this likeness. The characterization of an individual style or architectural language enables the clarification of "(...) the underlying commonality of structure and appearance manifest for the buildings in the corpus (...)" [Stiny & Mitchell, 1978].

Shape Grammars [Stiny & Gips, 1975], enables the description of individual architectural styles through the analysis of spatial grammars. Shape Grammars have been applied in the analysis - Analytical Grammar, and in the generation of designs

- Synthetic Grammar. Analytical Grammars constitutes a model for the graphic representation of the structure of styles, through the determination of constants that originate the rules of this grammar.

Along with synthetic grammars, the designer explores the derivation of designs starting from a group of rules and pre-established vocabulary generating a group of possible formal solutions for a certain problem. The synthetic grammar, in an opposite way to the analytical grammar, starts up from the rules and derives to the generation of designs. In other words, it generates the principles that originate a group of buildings with pre-determined style. The expression “pre-determined” raises some issues on the control of the style. In practice the total control is made impossible since there exists a limited number of elements in the generated building capable to establish relations between its syntactic components and the designer’s goals. The generative process, under these conditions, incorporates a trial and error component, until it reaches a satisfactory solution. The satisfactory solution will correspond to the acceptance of a possible formal result, not exactly an intention or goal planned at the beginning of the process. Considering these aspects, the designer possesses partial control of the generated style, i.e., there is a random characteristic in this kind of grammar, regarding the predictability of the resulting style. The designer builds a grammar as to express an architectural intention, which he does not totally know beforehand, except for its rules and vocabulary. The lack of control of the process constitutes a restriction in the expansion of the use of the shape grammars in practical applications.

This way questions concerning the criteria used by the designer in the choice of the vocabulary may well be raised. The same sort of interrogation can be launched towards the origin of the syntactic rules [Knight, 2000] and to the relation involving grammar elements, the designer’s formal ideas and the purpose of the design.

The definition of a style, in a synthetic grammar, requires the definition of semantic rules. The semantic rules, in turn, incorporate the designer’s goals. The designer’s goal contains the entire problem’s data associated to the intentions of the designer. In traditional design methods, the designer associates two types of components to problem solving: the constraints previously established by the outer environment and the functional requirements (problem’s data) and the limits that the designer establishes as “shape constraints”. These limits usually are referred to two categories of shape constraints: the first incorporates formal intentions and it is materialized through the syntactic rules - shapes, spatial relations and operations that regulate the design generation The second refers to the formal strategies adopted for the design solution of the functional constraints, starting from certain syntactic rules. The connection between the problem’s data of and the designer’s shape constraints would then constitute the cognitive process involved in a generative process.

1.2. Design goals and sub-goals

It is possible to solve a problem by discovering a method for splitting it in sub-problems [Minsky,1986]. Indeed when trying to solve problems, the designer formulates the design problem in terms of goals and subgoals. Proceeding this way, the designer can build up a description of the design intentions step by step. The designer will strategically select from the available alternatives of vocabulary and rules only those relationships that may help him to reach his goals.

A goal driven system treats the things it finds as objects to exploit, avoid or ignore, as though it were concerned with something else that doesn’t yet exist. [Minsky, 1986]

It works by comparing the differences between the desired situation and the actual situation. In such way in design problem the designer can work with the existing solutions to establish the differences from the desired solution.

Designer’s goals are related to shape and its spatial physical properties. The designer's goals can be translated to rules, which in turn define the semantic characteristics of the language. These characteristics could guide the production of style in synthetic grammars.

The designer builds a theory for the solution of design problems, through the definition of the means and the recursiveness of these means. The language, as well as the theory is dependent on the recursiveness. This study builds up from the hypothesis that if architectural languages can be understood as ways to express theories of architecture, then the grammars that codify these languages have two components: a syntactic and a semantic component. According March & Stiny [1984] "the way designs are distinguished depends on two main factors: (1) the rules used to compose the shape that combine to represent them, and (2) the rules used to describe them in other terms pertaining to, for example, purpose, function and use, meaning, type or form. Roughly speaking, rules of the first kind fix the syntax of designs, and rules of the second kind fix their semantics."

From this hypothesis, the study evolve to relate cognitive components to the formulation of a language that would eventually allow the improvement in the control of the language generated through the use of synthetic grammars.

In this paper, an analytical grammar elaborated for Oscar Niemeyer's designs has been used as an example for the connection between shape grammar's formal choices and the architect's goals and subgoals. This example may help to wide up the understanding about the levels of control in the

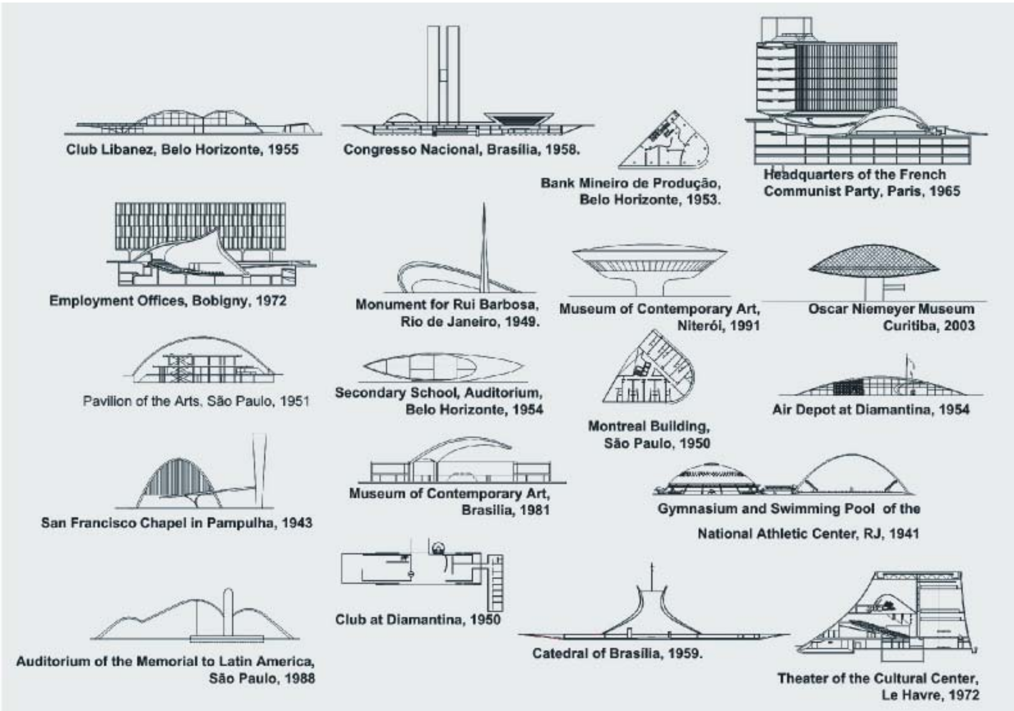

Fig.1 Twenty buildings designed by Niemeyer between 1941 and 2003.

architectural design process of an architect well known for his plastic freedom and, in turn, to open up some possibilities for the computational generation of Niemeyer's style architectural forms.

The paper unfolds in 3 sections: In section 2 the constructive and cognitive aspects of Niemeyer's grammar are discussed followed, in section 3, by the discussion about learning languages of design and the possible computability of Niemeyer's Free forms language through a synthetic grammar. Conclusions are retrieved in section 4 as well as some tentative unfolding steps for the present research are outlined.

2. Constructive and cognitive aspects in Niemeyer's Architectural style

2.1. Constructive aspects in Niemeyer's style

The proposed cognition model associates the cognitive rules to the constructive rules originated by the Niemeyer's language. These constructive rules were obtained from a model created for the description of Niemeyer's architecture based on the idea of Shape Grammars. The model was applied on the description of the volumetry of twenty buildings designed by Niemeyer between 1941 and 2003.

These twenty buildings have as a common feature the curve shape (mainly conic curves, specially the parabola). Only the most essential aspects of the building's volume are considered.

The buildings were generated by the grammar in two stages: First, schematic building sections and plans as ground for the description of basic geometrical relations. This was followed by the description of the volume deploying the least set of rules and operations.

The analysis has also shown that, with only two operations it was possible to generate the initial volume of the complete sample. These were rotation and translation. Second the generative process evolves through a series of complementary operations including reflection, translation, scaling, intersection, addition and subtraction. The combination of the initial and the complementary operations, within Niemeyer's chosen vocabulary, gives rise to an immense set of alternative designs. Figure 2 shows a simplified derivation of a Niemeyer's building using the grammar.

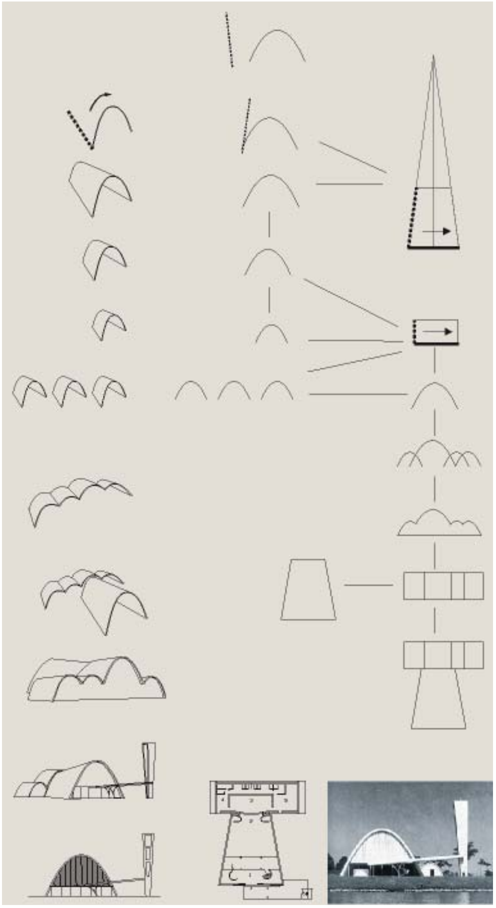

Fig. 2 The main stages of the derivation of a Niemeyer's building – San Francisco Chapel [1943] - using shape grammar.

2.2. Cognitive aspects in Niemeyer's style (derivation of semantic rules related to Niemeyer's grammar).

In this study semantic rules correspond to the translation of goals and subgoals. A design goal corresponds to the final design. Design goal incorporate the designer's intentions to the solution of the design problem. In other words incorporates the designer's way or style to accomplish a design task.

Subgoals can be understood as strategies to reach design goals. They therefore constitute an intermediary step towards the design goals. More than one subgoal can be deployed by the architect in order to reach a design goal, adding a relative flexibility to the design process.

For each subgoal there is at least a syntactic rule. The generation of the subgoals starting from one goal explores the possibilities of relation of the subject goal with various elements of the problem.

Each one of the rules was analysed in order to identify the possible relation between Niemeyer's design goals and the resulting architectural shape (shape features). In other words, to identify what rules allowed the generation of the architectural shape within the context of Niemeyer's design goals.

Niemeyer's discourse concerning the design goals and its relations with the architectural shape was extracted from his methods and work conceptions, as described in his book Conversa de Arquiteto [1993].

Five designer's goals were selected: plastic freedom, plastic unity, relation with the environment, lightness, spatial perception contrast and ten subgoals: curves; proportions; ideograms; scale relation with the environment; single support, inclination line support, landscape views, shape and spatial function, light contrast and scale contrast.

Two semantic rules or goals, considered as paradigms of Niemeyer's work (Pereira, 1987), are recurrent in all of his analysed works: plastic freedom and plastic unity. The expression of plastic freedom to be read in the use of curves should be considered under certain aspect: the presence of the curve was criterion for selection of the study corpus. On the other hand, it was chosen as criterion as a consequence of the recurrence in this architect's work. The plastic freedom expressed by the use of curves therefore is one of the objectives that guide Niemeyer's architectural language. The second objective, plastic unity is coincident with the syntactic rule that it is part of the constructive grammar.

As for the cognitive process, the model allowed to identify where Niemeyer concentrates his design language decisions. The analysis has shown that most of Niemeyer's decisions are set in the first project stages, more precisely in the choice of the vocabulary. Once defined the vocabulary, the operation to generate the volume is launched according to the function and the characteristics of the operation. The limit for the choice of the operation is the adaptation of the volume to the function and to the environment.

The relation with the environment goal has been reached, in Niemeyer's designs, through more than one subgoal.

- A shape relation with the scale of surrounding buildings;
- Openings in the volume generating a interior-exterior relation;
- Use of ideograms to evoke the natural or artificial surroundings.

Subgoals can be used simultaneously. Some subgoals determine subsequent rules and can be achieved through more than one rule. Shapes can be considered as expressing designer's goals and subgoals or simply as results from operations.

This was generated a variety of alternative solutions therefore enabling one to conjecture that the relative flexibility in the choice of subgoals may well explain the so called Niemeyer's plastic freedom.

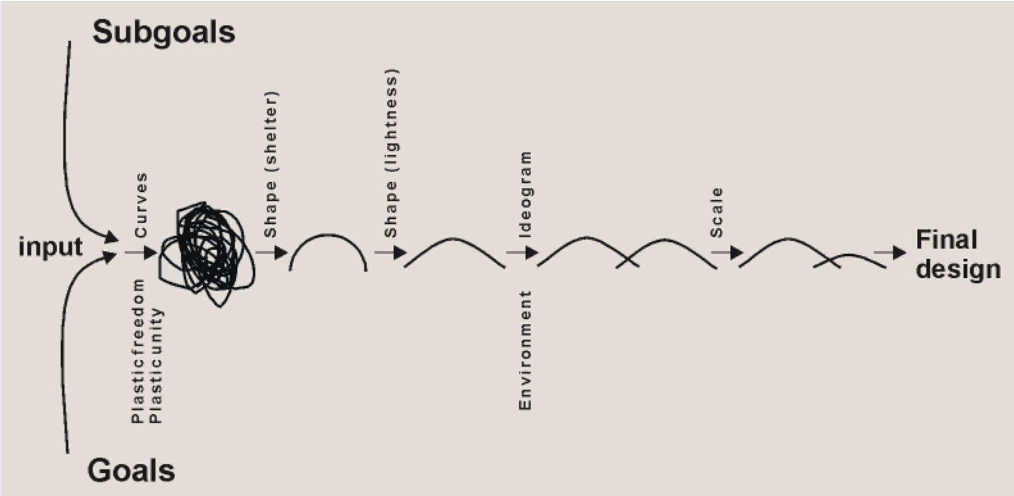

Fig.3 Goals and sub-goals in the generation process of Niemeyer's language.

3. Discussion

3.1. Learning to design in a Constructive and Cognitive way:

According Oxman, [2001] "the cognitive properties of design learning have rarely been the subject of design education." Oxman argues "the need to redefine the learning task in design education from an orientation to the production of design artefacts to a cognition-based approach to Knowledge and visual content."

To approach an architectural language from a constructive and cognitive point of view, means to learn more than only its grammar: once the structure of an architectural language is known, the translation of the knowledge about a building (in a analogous process to those occurring in linguistics) could be done applying a shape vocabulary, a set of spatial relations and correlated operations to design goals and subgoals.

It might be suggested that to learn how to design it is necessary to learn how to write in the language of the architecture. As in the musical language, it possesses its own and unique grammar. Along with the knowledge about shapes physical properties, grammar tactics have to be learned in order to use architecture grammars.

The concept of style coincides with the notion of designer's goal in that it can be understood as an individual way for the accomplishment of a certain task. New approaches for design teaching may well involve the exploration of synthetic grammars thus incorporating tools for the systematisations of a knowledge database for the development of design styles, as to favour the designer's ability to establish goals and their translation into architecture.

This approach could provide effective ways for the learning, systematisation and management of the knowledge database eventually involved in the architectural design process, in a structured format.

3.2 A new approach to design teaching.

According to March and Stiny [1984], the design process may be compared to a computational mode as "the initial information furnished by the designer related to the minimal requirements is processed to answer to these requirements generating new information". This may lead to a pedagogical tool aiming at the study of Niemeyer's architecture through the practical understanding of his design strategies.

As the initial information furnished by Niemeyer, refers to a vocabulary of curves, proportion and rules and a sequence of operations, goals and subgoals. The combination among these elements, as well as the order of their application, would then constitute the information process. Considering this process, the relation between the intervention of the computer and the designer may be summarized in two basic steps:

a) The generation program, following the rules of Niemeyer's language, capable to generate consistent design alternatives with respect to the language.

b) The subsequent development of this program, towards the compatibility of the rules related to the constraints of another nature, which, in turn, has already been processed and selected by the designer.

In the first case, the program should admit only the shape generation according to the inserted grammar. In the second case, should be possible to change the rules of generation as well as to insert new rules. This way, the program will be used to explore alternative languages and design, through the interaction with the designer.

The process of computational implementation of the first step can be divided in three unfolding steps:

1. Translation of rules compositions contained in the geometrical and semantics description in a computational language. Eventually, there will be development and detailing of the rule according to the program elaboration needs.

2. Automatic generation of buildings volumetry, based on Niemeyer's language. The generated volumes, may correspond to the buildings designed by Niemeyer or buildings that could have been projected by him.

3. Each derivation will be analysed to verify the conformity to the generated buildings, under Niemeyer's language.

4.Conclusion

The incorporation of semantic aspects approximates the generative process to the design exploration process, guided by the designer's ideas, through synthetic grammars. This may raise questions such as to what extent is it valid to qualify the designers performance according to the level of proximity between the result of the generation and his goals.

Two subsequent proposals to the computational application of the Niemeyer's semantic and syntactic rules have been presented. The first aimed at the creation of new buildings based on the language and the second, a program concerning the creation of a complete new grammar step by step, in interaction with the designer.

The study on Niemeyer's designs features only a sample of the subgoals that can be associated to his constructive grammar. New knowledge about architecture can be achieved by relating goals to constructive grammars. This can be useful for the derivation of new architecture languages. The recursiveness of goals and the correlation with the syntactic rules in Niemeyer's language suggests that this model could orientate the generation of languages in synthetic grammars.

As an ongoing research there are at least two necessary steps to be followed: the use of protocols of design for the synthetic grammars and the implementation of the computational models. Other ideas may arise during the investigation, which may add new knowledge to existent theories about the generation of novelty in design.

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