Schemas and Rules in the Design Process: A Case Study

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Abstract. The present paper describes the design process of a new prototypical building for the State University of Campinas, with the use of shape schemata and rules. The use of this construct or method made the design process more intelligible for the students who took part in the project and helped managing the team work. We expect that these rules will also allow the automation of the production of design alternatives and construction drawings for new buildings in the campus.

Keywords. Design process; shape grammar; rules; schemata; standard design system.

Introduction

Although shape grammars were originally created for design, they have been used in architecture mostly as an analytical tool. In synthesis, they have been used mostly in the early phases of design, and particularly in education, for the generation of spatial arrangements, augmenting the number of alternatives considered and thus enriching the process. Many examples of these applications are available in the literature, such as in (Smyth and Edmonds 2000) (Celani 2002) and (Colakoglu 2007).

However, in most cases the use of shape grammars are proposed a priori, and rarely chosen as an answer to an actual design necessity. In other words, usually the research question asked is “how to use shape grammars to design?”, instead of “which is the best method to solve this design problem?”

The objective of the present paper is to describe a case study in which shape grammars were used to solve a specific design problem: the design of a new standard building system for a University campus.

Case study

Unicamp is a public university in upstate São Paulo, Brazil, ranked the second best in the country. It was founded in 1966, and its main campus started to be built in 1967, in the suburbs of Campinas, a two-million people city. The area of the campus is almost 3 million square meters (300 hectares), with a total built area of 522,000 m² and a population of 40 thousand people - 30 thousand students, 2 thousand faculty members and almost 8 thousand staff members. The campus’ gross population density is 133 people per hectare (Harvard University’s is twice as much), and its floor area ratio (the total floor area of buildings divided by the land area of the lot) is 0.174. Less than 6% of the total campus area is occupied.

Based on its present growing rate, Unicamp is expected to double its number of students by the year 2030. The campus density is thus expected to grow from 600 people per hectare to almost 1,000 people per hectare. In order to accommodate the increasing population, there is need to construct new buildings in a fast, efficient way.
Since Unicamp is a public university, the construction process involves a long bidding process, which requires very detailed construction documents. These documents need to be readily available whenever there is a funding opportunity to add a new building. This has been solved so far with the use of a standard building design. However, it does not fit all necessities. There is an urgent need to make both the design and the construction system more dynamic, introducing the possibility of variations, in a fast, effective way. However, commissioning architectural offices for developing new designs for each new building is not feasible due to limited budget and tight schedules. Having a standard set of construction documents makes the public bidding process more practical.

The case study consists of developing a new standard building system for the University campus. The buildings will be used for multiple purposes, such as classrooms, offices, laboratories and libraries. The study was developed at the Model Studio (EMOD) of the School of Civil Engineering, Architecture and Urban Design of the State University of Campinas (Unicamp). EMOD is a laboratory for the study of innovative design methods in practice, similarly to Open University’s design observatory (see http://design.open.ac.uk/research/design_observatory.htm) (Celani and Medrano, 2009).

At EMOD designs are developed by undergraduate students from the six-year undergraduate professional program in Architecture and Urban Design and graduate students from the graduate program in Design and City Theory and Methodology. The projects developed are mainly for the University campus, under the advice of professors and graduate students. The present case study was developed by nine students, under the advice of this paper’s authors.
The design process

The starting point for the project was the analysis of the existing standard design, a three-storey rectangular building without an elevator, which has been repeatedly built in the campus since the 1970’s. The construction system consists of load bearing concrete block walls and precast pre-tensed slabs. The University has decided to change the standard building design due to the following reasons:

• The building does not comply with present accessibility regulations;
• Built in concrete, the building is not considered sustainable;
• The construction time is too long;
• The plan is not flexible enough to accommodate multiple programs;
• The building’s thermal comfort is not good, and air conditioning is required in most cases;
• The building’s ground floor plan doesn’t allow urban permeability, which is a new requirement, considering the expected density increase.

In order to understand the existing building’s logic, basic composition schemata were drawn. Figure 1 shows schemata that describe the existing standard building type. They allow inserting a rectangle with fixed dimensions; creating two floors and a roof above it; inserting the core (staircase and restrooms); inserting a hallway in the spaces on each side of the building; subdividing the spaces on each side of the hallway; Joining adjacent spaces to create offices, labs or classrooms; and dealing with the spaces at the end of the hallways. Figure 2 shows an example of a building generated with these schemata.

It is possible to notice that the schema that introduces the hallway is responsible for most of the buildings thermal comfort problems, since it eliminates the possibility of cross ventilation. Other problems identified in this building are the lack of passageways across the building on the ground floor, the lack of differentiation between the ground floor and the upper floors, the lack of differentiation between the lab, classroom and office spaces, and the difficulty in siting the building in sloped areas.

The next step in the design process was the definition of all the possible architectural programme requirements that the new buildings should meet. Since the programs can vary so much, it was decided that the new building should not offer just a single solution, but rather be developed as a system that allowed different combinations of parts. However, since construction documents must be prepared on the fly, this can only be feasible with the automation of both the combinatorial exploration and of the production of drawings. These two requirements – the need for multiple arrangements and the need for automation – naturally resulted in the selection of the shape grammar formalism as a design method.

The design of a standard system with parts that can be combined in certain ways, and that can respond to all the requirements, started with the definition of basic schemata. According to Stiny (2006), schemata are similar to shape rules, but they are less specific. The process evolved in subsequent generate-and-test phases. Specification mechanisms, such as labels and parametric dimensions, were added to the schemata as the process evolved (at the present point they still need some refinement). In each phase some of the previous schemata were kept, others were transformed, and new ones were added.

Three phases have been developed so far. In Phase 1, the basic features of the new system were laid out, with schemata that generate plans with maximized natural ventilation and circulation/net
floor area rate. The new schemata were based on a modification of the existing building’s schemata (Figure 3).

After some meetings with the university administrators, new functional requirements were added. In Phase 2, new schemata were created for adding auditorium, laboratory and library blocks (Figure 4). Schemata for making the ground floor more permeable to pedestrians were also added, after simulations of the expected future land occupancy of the campus (Figure 5). At the end of Phase 2 the system was considered “ready” by the team. It allowed designing a four-storey building with a maximal floor area of 2,000m². It was exposed at the São Paulo 2009 International Architecture Bienal, where it won an honorable mention (Figure 6).

Phase 3 consisted of developing actual designs for two specific buildings with the schemata developed so far. One of the buildings is the School of Pharmacy, with a multifunctional programme, including classrooms, laboratories and administrative areas. The other building is an office building for the faculty of the Institute of Language Studies. Besides having completely different program requirements,
each building has a different building area (one is 1,300m² and the other one is 1,000m²) and each one is located in a different urban and topographic situation.

As expected, the instantiation of the first two buildings revealed the need for adjusting the system once again. Some of the schemata had to be changed and new rules, with a greater level of detail, had to be created with the introduction of labels and parameter ranges. Figures 7 and 8 show the present set of rules, still under development. Figure 9 shows an example of a building design generated with those rules, and Figure 10 shows a computer model of one of the buildings being developed. As the buildings evolve, new rules are being created in a dynamic process, firstly in an implicit manner, as a schema and then in a more explicit, specified rule. For example, the images show the need for new rules for creating void spaces in the middle of the offices area, and the need for creating a double-height ceiling area at the entrance of the building. These rules guide the design team in the design of new instantiations of the prototypical building.

The proposed system is expected to be further refined during the development of the structural project, and construction details. The next phase of the project will consist of developing a software implementation that automates the design process and the production of drawings.

**Discussion**

In a chapter curiously named “I don’t like rules – they are too rigid”, Stiny (2006) explains the difference between schemas and rules in shape computation. Schemas are more general, allowing multiple interpretations (“...for schemas I have to constantly remind myself that there are indefinitely many predicates equivalent to anyone I’ve got”, p.281). Rules are more rigid and they usually include labels, which makes them even more specific. According to Stiny, schemas are more useful in the initial phases of a design process, in which designers still don’t have a very precise definition of what they actually want:
Figure 7
Present set of rules.
Figure 8
Present set of rules.

Figure 9
An example of a building designed with the present set of rules.
“schemas are useful in the first place” (p.278).

The rules used in the beginning of the design process described above were very informal (for this reason they were referred to as schemata) and they tended to become more specific as the design evolved. Once these schemata result in actual, formal shape rules, it will be possible to develop a computer program for exploring different combinations of the building elements. Next, the program will be combined with BIM capacities for the generation of building documents.

In the present case study shape grammars proved being an appropriated design method for the type of building developed, but also for the characteristics of the design team. It allowed a very effective process, in which once a rule was established by the team, it was either accepted and followed by everyone, or re-discussed in a collaborative way. We hope that this paper will contribute to the field by illustrating a use of shape grammars that was originated from an actual necessity.

References


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