Shape Grammars in Architectural Design Studio

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1. INTRODUCTION

Shape grammars applications have been developed in various fields including architectural design, landscape architecture, engineering, painting, furniture design, ornamental design, and others. A nice overview of the history of shape grammar applications in architecture and the arts has been given recently by Knight[1], and a similar account of applications in engineering has been given recently by Kagan.[2] An interesting issue about the history and the role of shape grammar applications in education and practice is that even if these applications originated in the architecture literature and since then they have met a remarkable success in so many different and diverse fields, yet they haven't manage to establish themselves in the core of architectural discipline and education, the design studio. Several exciting proposals and projects have been generated at UCLA, MIT and Carnegie Mellon during the last decade but it seems that a range of possibilities is still out there for creative usages and systematic applications of grammars in pedagogy and studio. This paper addresses some of these possibilities and raises some questions regarding the applicability of this powerful paradigm in design theory in creative work and particularly in architectural design studio.

2. APPLICATIONS IN ANALYSIS AND DESIGN

Shape grammar applications have been developed for analytic and design purposes.[3] Typically in analytic applications, a set of designs is selected, abstracted versions of these designs are extracted to bring forward some aspects of the composition that are of interest to the designer of the shape grammar, spatial relations between parts are selected, shape rules are defined in terms of these spatial relations, an initial shape is selected to start the computation, and shape rules are applied successively to an evolving shape starting with the initial shape. Designs generated by the grammar typically include the original set of designs that was chosen for analysis, and many other hypothetical designs that share the same spatial and functional characteristics with those of the original set. Typically in design applications, a set of spatial relations is selected, shape rules are defined in terms of these spatial relations, an initial shape is selected, and shape rules are applied successively to an evolving shape starting with the initial shape. Spatial relations between shapes may be taken from a predefined set of spatial relations that are of interest to the designer of the grammar, or can be constructed from scratch as instances of generalized types of spatial relations between shapes. These generalized versions may include all possible relations that can be constructed between any two shapes and shapes may be any finite arrangements of points, lines, planes and solids, including the empty shape.

Analytic grammars draw much of their significance from their capacity to generate descriptions that comprise well-known designs. Often various design processes are simulated but they may not correspond to historical fact. Additionally, there are no definitive grammars for any given set of designs in the sense that different grammars may generate the same designs in the corpus utilizing very different design strategies. There is nothing wrong about that. Quite often the designer's or architect's or composer's account can and may be informative but other times is confused or even unfaithful to events in order to create a better story. And still grammars that somehow capture possible design processes or actual modes of construction are better than other grammars that reconstruct final designs through unintuitive or seemingly impossible routes. Nice examples that illustrate this dichotomy include the shape grammar for the Chinese lattices that seemingly captures actual processes of tectonic assemblage[4], and the Palladian grammar that does not pretend to reconstruct any of the design strategies and compositional tools historically attributed to Palladio.[5]

Synthetic or design grammars draw much of their significance from their capacity to capture rigorous processes in a design derivation; there are no definitive designs for any given set of rules in the sense that any of the designs produced by the grammar could serve the role of the leading, best candidate for a design solution. The final designs, plans, or scores may be informative but often they are presented as samples of a wider set of designs, plans or scores that all of them could be equally potential candidates for the final design or composition. And still grammars that promote a singular design or a very limited set of candidate designs are closely related to the discipline of design, especially in architectural discourse, where a single design is always preferred. Nice examples that illustrate this dichotomy include

the shape grammar for the Ocean Observatory and Educational Facility that proposes two single designs as a solution to the design problem[6], and the computer-implemented kindergarten grammars that typically generate many design solutions mostly for educational purposes rather than architectural purposes and concerns about a particular design problem or site.[7]

Such distinctions between analytic and synthetic applications are offered here only for pedagogical reasons and as frameworks for discussion rather than as rigid classificatory devices. For example, in the two extreme cases discussed so far, analytic applications of grammars basically simulate designers that want to create constantly one specific type of design while having no clue about how to create any other type of design, and synthetic applications of grammars simulate designers that want to control their process while having no clue about where this process will lead up to. Things in life are not exactly as black and white as it has been suggested thus far especially when the whole discussion is about design, a discipline that involves a continuous loop between analysis and synthesis, seeing and doing, reflection and action. There is a lot of gray ground between these two approaches and in fact several models have been proposed that in some way or another appropriate some space between the two modes of composition. One of the best models in this area is Knight's method for developing new languages of design on the basis of existing ones.[8]

Recently a considerable effort has been channeled to the computer implementation of these types of grammars that allow for rapid exploration and identification of design possibilities. Recent examples of analytical grammars include the computer application for Alvaro Siza's Malagueira housing system by Duarte in architectural design[9], and the computer application for coffeemaker designs by Agarwal and Cagan in mechanical design.[10] Recent examples of synthetic or design grammars include the GEdit, a computer application by Tapia for the generation of two-dimensional sets of designs based on spatial relations selected by the user[11], and the Space Truss Grammar, a computer application for non-symmetric geodesic-like dome designs by Shea in mechanical design.[12] A concise overview of computer implementations of shape grammar applications can be found in Gips.[13]

3. POSSIBILITIES AND PROCESSES

Analytic and synthetic grammars capture modes of inquiry routinely applied in design studio. Design often starts from the analysis of an existing corpus of designs in terms of some spatial, programmatic, functional, or other types of descriptions pertinent to the design problem at hand, or alternatively, from the direct synthesis of some spatial, programmatic, functional, and other types of descriptions that are of interest to the designer. And often, an analysis of some descriptions is part of the synthesis process in a studio setting and synthesis of some descriptions is part of an analytic process for the better understanding of the design problem.

This interchangeable role of analysis and synthesis in a design problem is nicely captured in the structure of the two types of grammars. In both types of applications a set of shape rules is selected and designs in a language are specified by successive applications of these shape rules — whenever there is a part of a design that matches the left hand of a shape rule under some transformation T, this part is replaced by the right hand side of the shape rule under the same transformation T. In any application of a rule, there is a seeing part – corresponding to analysis– that specifies that a part of a design is subject to transformation, and the doing part – corresponding to synthesis– that specifies what happens to this part of the design. At any given moment in a design derivation, the application of rules reflects the continuous loop between analysis and synthesis, seeing and doing, reflection and action, all primary parts of design activity.

If applications of grammars capture modes of inquiry routinely applied in design studio then both types of applications should be suitable to be implemented in a design process. The first question that arises here is how the structures of both types of applications support these two modes of inquiry. It seems that the answer to this question is not very simple because the structures of both types of grammars appear identical. In fact both types could be indistinguishable if there is no context to define their role. For example, a grammar may be considered by an end-user as an analytic one if some of the end descriptions that the grammar produces are well known examples of an architectural or an engineering discourse and alternatively the same grammar may be considered as a synthetic one if the examples upon which it is based are not shared within an theoretical discourse or are based on a private spatial language of the designer. It seems that the distinction between the two types of grammars should be sought not after a difference about what an analytic or a synthetic grammar is, but rather about how a grammar or when a grammar becomes an analytic or synthetic one. The use or functionality of the grammar in a design context defines its characterization as an analytic or a synthetic one rather than its structure or properties.

If then the grammars in themselves do not reveal anything about their potential functionality in analysis or synthesis of existing or new designs, perhaps it is their design and the requirements about their formation that tell more about this distinction. The major difference between the two types of grammars here is that that in the first type of studies some or all of the final designs are given in advance while in the second type of studies some or all of the shape rules are given in advance. Alternatively, in the first type of studies nothing is known in advance about the shape rules that can generate the chosen designs, while in the second types of studies nothing is known in advance about the final designs. The success of the first type of studies is that they manage to reconstruct well-known designs along with a potentially

infinite number of other designs that share some of the same spatial or functional characteristics observed in the original set of designs. The success of the second types of studies is that they manage to construct designs that comply to a set of spatial or functional criteria considered essential or valuable by the designer who authors the grammar.

This distinction between analytic and synthetic grammars in terms of what is known in advance before the set up and design of the grammar itself suggests an analogy to the typical distinction in understanding design as product description or process: in the first case what is important is the notion of design as an element that arises in an *n-ary* relation among many different spatial, functional and other kinds of descriptions; in the second case what is important is the notion of design as a problem solving activity, as a process driven computation involving a variety of spatial, functional and other descriptions to achieve specific tasks. If this correspondence is right a variety of possibilities emerge to further illuminate the role and applicability of grammars in a design studio setting.

Diverse notions of design may be captured by the two types of applications of grammars. In this context, analytic applications could be implored in a design context that involves heavily established norms of prediction of final outcome and synthetic applications could be respectively implored in a design context that emphasizes process and problem solving activities. In the first case analytic applications could be used for design of well-established languages, such as urban typologies, brand products and so on. These languages may involve existing sets of designs such as architectural styles, brand design or entirely new such as imported private spatial languages contrived by the author of the grammar. It is the outcome that is important rather than the process through which the designs are derived. In the second case, synthetic applications could be used for control of design process, even if this control could involve indefinite application of rules or re-description of rules as need arises. These processes may involve existing sets of spatial or functional relationships or may introduce any other sets of spatial or functional relationships at any stage of the design derivation. It is the rigorous process that is important rather than the outcome of the computation.

The always-elusive character of design activity may be also captured in different degrees by the two types of applications of grammars. Architectural design studio typically promotes a critical evaluation and reflection of the design at any stage of its derivation and advocates a critical continuous redescription of the elements involved in the composition so that latent opportunities and emergent properties may be brought forward. Well-established strategies of introducing shape grammars into studio methods, such as for example, Eizenberg's approach based on an analysis of a corpus, extraction of rules, transformation of rules and construction of designs points to a design world whereas primitives and relationships are selected in advance. Other strategies, such as for example, Flemming's model for teaching architectural composition based on given categories of architectural form points as well to a design world whereas primitives and relationships among them are selected in advance.[14] Both models, even if they are traditionally classified as different types of applications, the former analytic, the latter synthetic, signify thoroughly analytic processes. It is rather the alternative readings of the descriptions either of the corpus of designs or the set of spatial and functional relationships that may be introduced as rules at any moment in the design derivation that renders the whole process as a thoroughly synthetic process. Ironically, it seems that it is the process of analysis and redescription of a given relationship and the corresponding continuous redefinition and redescription of the rules and their free import in a design that renders this process as synthetic or creative. In this context, it seems that the great success of the analytical applications of grammars versus the synthetic applications of grammars can be easier explained; reconstruction of designs based on some selected primitives and their spatial and functional relations is a much more straightforward task rather then the construction of designs based on a continuously changing set of spatial and functional relationships.

4. CASE STUDIES

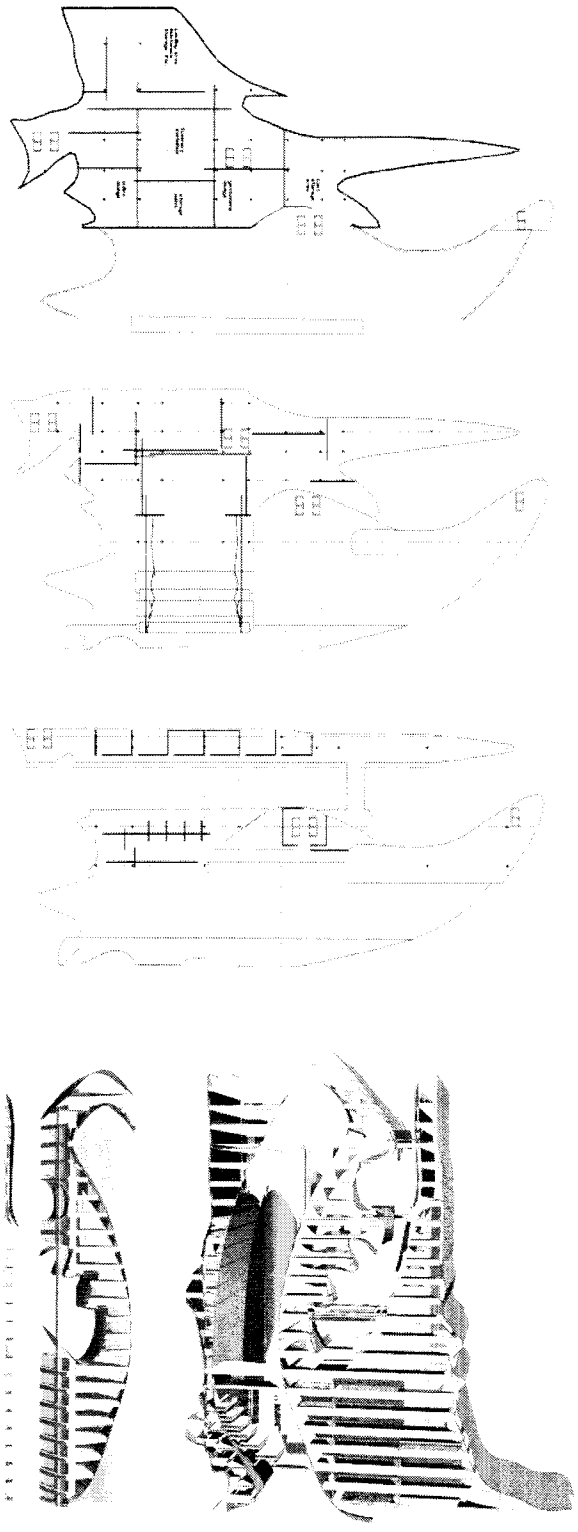
A variety of different examples address some of the questions raised so far in this paper and attempt to illustrate a range of different strategies on employment of shape grammars in creative studio. All examples are drawn form the recent graduate architectural design studio at the College of Architecture at Georgia Institute of Technology. The program given for this elective studio was based on the concurrent international architectural competition for the New Opera House at Oslo, Norway. The program and the constraints of the design problem were extremely difficult to fully unpack because of the sheer complexity and size of the program, the unfamiliarity and remoteness of the site, and the elusive, underlying relation between architecture and music, a topic particularly prominent in the design of a building type such as an Opera House. For all these purposes the discussion of shape grammars, languages and configurations, was informal but well illustrated in terms of previous work in the field. The relation of architecture to music was particularly pursued through the field of generative systems in architecture and music domains and simple design studies were initially devised to further illuminate this relationship.[15]

The pivotal role in the design studies during the course of the studio was the informative redescription of the designs at any stage during the design process as a series of parametric spatial relations that readily suggested possibilities for the evolution of the design. Sketches, cheap board models and rough computer models were continuously redescribed as spatial relations between 1-dimensional, 2-dimensional or 3-dimensional spatial elements and were tested to provide choices in the derivation of the design and smooth transitions from phase to phase. Once spatial relations were suggested,

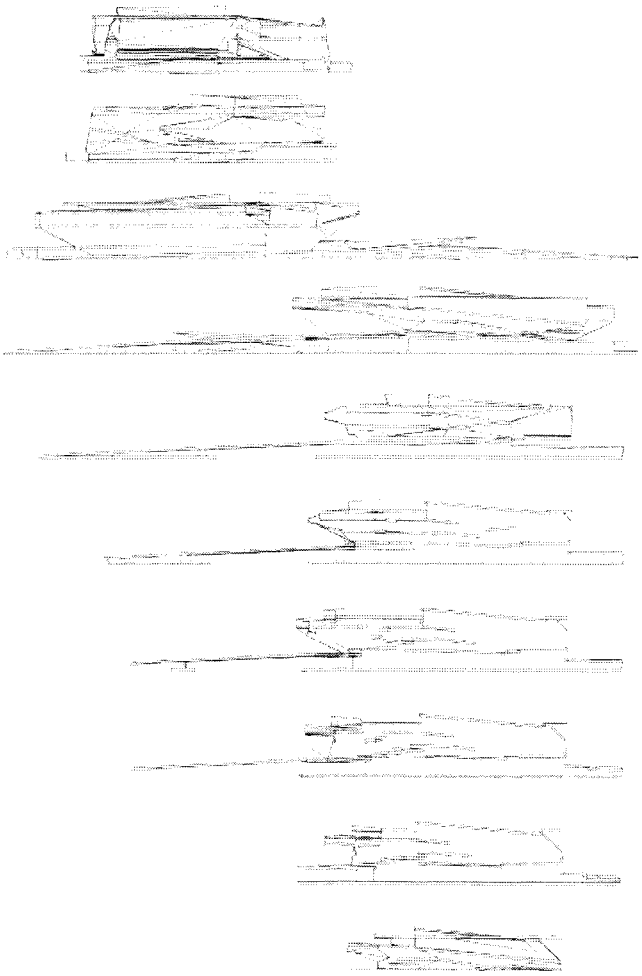
shape rule schemata were formulated and possible paths of explorations of the design space defined by these spatial relations were explored. A continuous backtalk and reflection in what was accomplished at any given time of the studio process was established to provide the means for further exploration of the design space implied by the spatial relations selected by the designer during any particular stage of the design.

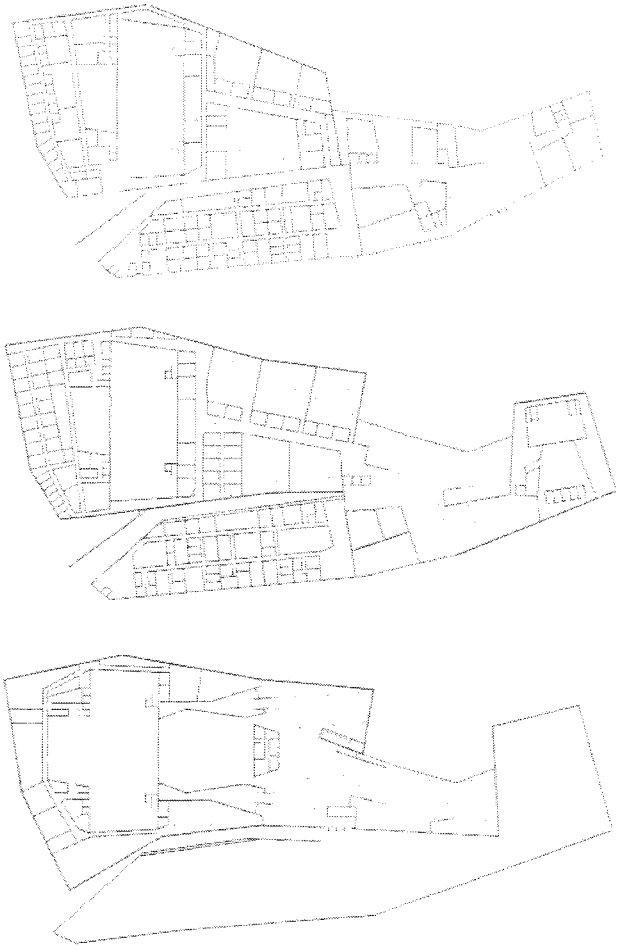
The complexity and size of the program, a program involving urban design considerations, acoustics, ergonomics of production spaces and performance spaces, and so forth, led to a variety of different approaches, each emphasizing some part of the originally given design problem. All these parts, spatial or functional, were mapped upon a continuously evolving range of parametric spatial relations. Sometimes the overall configuration of the spatial relations remained the same while the parts that comprised the spatial relations were wildly different. Other times the parameterization of the spatial relation was very different from the original assignment of values because of some insight gained later in the design process. Still, other times new spatial relations were introduced altogether in light of some new insight in the nature of the design problem. Designs ranged in their process from those that utilized a very limited set of spatial relations to those that utilized a wide set of spatial relations, typically very different for different design scales. A detailed description of some of these projects and their relation to evolving sets of spatial relations will be given elsewhere.[16] Some of the final designs are shown in Figure 1.

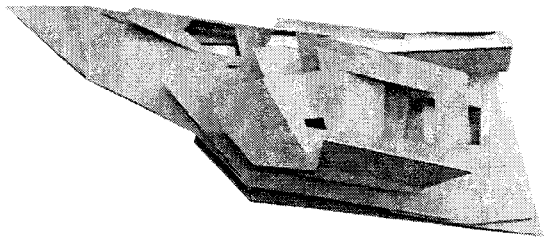
Fig. 1. Designs for the New Opera House at Oslo, Norway.

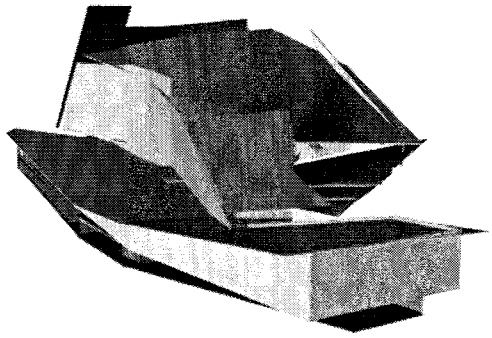


a-b. Steven Shaw: Plans and section model



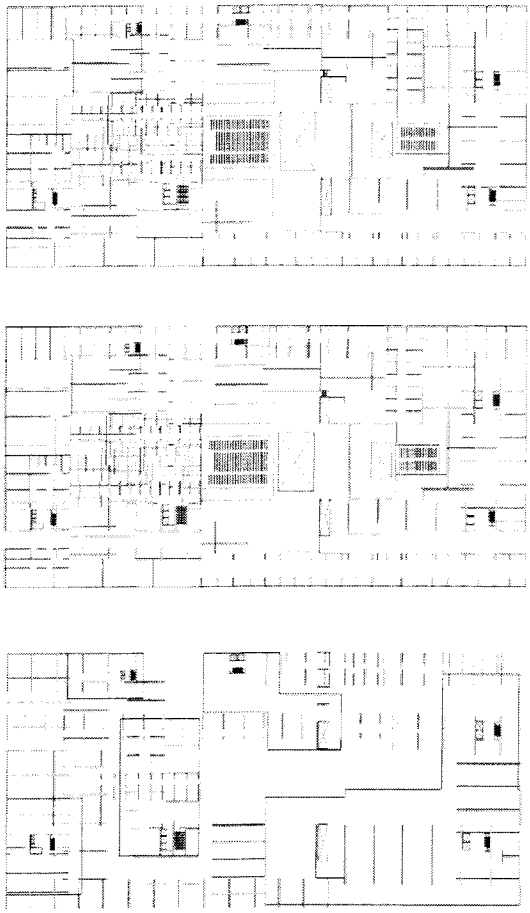






c-d. Ryan Crooks: sections and model

e-f. Laura McLeod: Plans and model



g-h. Sean O'Hara: Plans and model

5. DISCUSSION

Shape grammars can simulate processes of design, capture compositional conventions and intuitions, and offer parsimonious ways for construction of designs in specific languages. There is no doubt that grammars are suitable for sets of problems that demand specific tools such as mass customization and infrastructure problems. And grammars can be used to support irregular composition and complex geometries. In a way, in the former case grammars offer better ways of doing things that are done anyway while in the later case grammars offer better ways of doing things that are done in the hard way. Still, if grammars are to be developed and established as a design paradigm in a design studio setting, in theory they should be suitable for all possible sets of problems and should support the multiplicity of processes that architects engage routinely in this setting. Creativity, intelligence, guesswork, and intuition, qualities typically associated with design processes ubiquitous in design studios are the very same qualities required for the setting of grammars and this is nicely shown when design solutions at any stage of the design process are mapped as rules. Designs and grammars are developed till the very last moment and are constantly under revision. Organizational strategies in architectural production often require structured design spaces to identify and search for design solutions, and still other times require elements and relationships in a state of flux, always ready to be redescribed and utilized in a fresh and invigorating manner; composition with shapes is the best candidate for such informative play between design process and emergent possibilities.

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NOTES

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