INTEGRATION OF SHAPE GRAMMARS
WITH ARCHITECTURAL DESIGN STUDIO PROJECTS

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Abstract. The use of shape grammars in the context of actual architectural design projects is an area that has been under explored. This paper describes the development of grammars in conjunction with a student design project and the issues in creating grammars that respond to a specific project brief.

1. Shape Grammars in Design

Shape grammars have been shown to be useful design aids by their use as analysis tools, primarily through the development of grammars based on existing sets of designs and the modification of existing grammars to demonstrate stylistic change (Knight, 1994b). Although they are also viewed as potentially powerful generative tools (by facilitating design automation and allowing greater exploration of design alternatives), less progress has been made in this area. In architecture, synthetic grammars have been used primarily in design education, through the teaching of concepts of formal composition, and simple design exercises (Knight, 1999). With few exceptions (Brown, 1993; Knight, 1992; 1994a; 1998), the use of grammars has not been integrated into larger scale design projects.

Towards the goal of using grammars as generative mechanisms, Stiny (1980) has described five stages in a constructive approach to grammar definition:

1. A vocabulary of shapes is specified.
2. Spatial relations between elements in the vocabulary are defined.
3. Shape rules are specified based on the defined spatial relations.
4. An initial shape from the vocabulary is defined.
5. Shape grammars are specified based on shape rules and an initial shape.

This approach to defining new shape grammars and new languages of designs has been used successfully in architecture programs at schools such as UCLA and MIT, where students use simple grammars to develop forms which are fur-

ther elaborated and used in architectural design projects (Knight, 1999). However, because these grammars typically deal only with form and spatial relations, the designs generated may not meet the constraints and goals of a design project. Another difficulty is the translation of forms into spaces that satisfy the design brief and fit the site of the project (Knight, 1992).

Another approach to the creation of new languages of designs is to derive them from existing ones. An existing language of designs is analysed to produce a shape grammar. This grammar is then transformed so that the new grammar generates new languages of designs (Knight, 1994b).

Woodbury (1993) adopted a similar approach for a design course at the University of Adelaide. Students were asked to construct a plausible derivation of an existing building from rules. These rules were then modified and applied to create new architectural designs. However, no attempt was made to formalise these rules as grammars.

As these grammars are based on existing designs, this approach may have fewer problems in dealing with the goals and constraints of a design project, providing the precedents chosen for study are appropriate. The designs generated may also be more coherent as architectural spaces.

However, neither of these approaches addresses the problem of designing shape grammars that generate designs appropriate for a particular project. The problem of the first approach lies in the uncertainty over the appropriateness of generated designs. The problem of the second approach lies in the selection of a suitable precedent or style to analyse. Both do not adequately address the constraints and requirements set up by the design brief and the site.

In this paper we describe the development of several shape grammars in the context of a student's design project (Koh, 1999). The project used for this study was one of the studio projects offered to B.Arch students at the University of Sydney in 1999. It was one of the few real projects with clients available to architecture students in our faculty.

2. Design Brief

The project, redevelopment of a biological research station to include conference and accommodation facilities, was skewed toward the development of ecologically sustainable designs. Thus, it became an exercise in dealing with actual clients and the dual realities of limited budgets and environmental management. Lofty principles had to be backed up with hard numbers.

The client's aims included a) provision of accommodation at a three star standard; b) an ecologically sustainable design; c) environmental education facilities for community use; and d) improvement of existing teaching and research facilities. Development of the brief focused on a) site planning, access, parking and new buildings; b) visitors; c) cost and stages; d) revenue, electricity

and water; and e) sustainable systems. This led to requirements for the following new buildings, connected by a boardwalk system:

- huts accommodating 40 visitors;
- two communal bathhouses;
- a communal building.

3. Grammar Development

The focus of the design studio was not form or aesthetics. The primary concern was to produce a design that worked for the clients at all levels, and meet the constraints imposed by both the clients and the site. This meant that in order to use grammars appropriately and successfully in this project, they could not be based on purely formal considerations.

Shape grammars were not an integral part of the development of the project brief, although some of the implications of the brief were explored using spatial relations and grammars. Figure 1 illustrates spatial relations between a boardwalk and an accommodation unit. The grammars developed were:

- A 22 rule infill grammar, based upon the construction system developed, and used in conjunction with the following building grammars:
  - accommodation grammar (5 rules)
  - bathhouse grammar (5 rules)
  - communal building grammar (15 rules)
- plus a boardwalk grammar, to link the various buildings (4 rules)

In this project, the process of designing with shape grammars was not that of generating the design from an existing grammar. Instead, the shape grammars and the design were developed simultaneously. Throughout most of the project, the grammar existed mainly as sketches, drawings and ideas of how design elements should be related.

It should be noted that shape grammars alone may not define a design. It can even be argued that the most important aspects of the design may not be addressable by grammars. One of the obvious distinguishing formal features of the design, a skillion roof, was determined by the need to collect rainwater. Much of the site planning involved issues that cannot easily translate to shape grammars. Much of the design work was actually concerned with defining and elaborating the brief.

The shape grammars were based on ideas for the structural system, and spatial and structural relations between different elements. The grammars helped to clarify, articulate and test these ideas. At the same time, designing shape grammars meant that each design modification could result in a change or complete rewrite of the grammar. The grammar gave the design process a certain discipline by defining what could be generated within the existing rules and spatial

relations, and which design changes might require modifying the grammar and challenging the ideas behind it.

3.1. BOARDWALKS

The use of boardwalks disturbs the sensitive South-western part of the site minimally, and protects the bush from human traffic. The boardwalk also allows pipes and conduits of the electrical, water and sewage systems to be clipped onto its structure, obviating the need for trenches and additional structures. Servicing and circulation are thus incorporated in the one structure.

The main trunk of the boardwalk connects the communal building and the bathhouse (Fig. 6). Each branch in the boardwalk leads to an accommodation hut. The idea of the boardwalk is a hierarchy of branches forming a tree-like structure. Seats are events on the boardwalk that signal changes of direction and provide a place to sit and rest. The boardwalk grammar (Fig. 1) begins with a non-terminal shape that defines the width of the boardwalk. The boardwalk is generated through a process of adding segments of various lengths and direction. The final rule terminates the boardwalk and erases the non-terminal shape.

3.2. CONSTRUCTION SYSTEM AND INFILL GRAMMAR

The inaccessibility of the site and the difficulty of building on uncleared land meant that the construction system used had to be light and easy to erect. It had to be inexpensive and the construction should disturb the land minimally. A frame structure thus became the obvious choice.

The concept of a modular structure with a base module of four columns and a platform was developed. Additional modules could be added depending on the size of the space required. This approach lent itself naturally to a grammar based specification.

The next problem was the cladding of the frame. The idea was that the walls would span between column supports and also function as furniture (e.g., shelves and bench tops). This would reduce the cost of furnishing, although possibly not the total cost of the project. However, an additional benefit was that it could increase available space without increasing the size of the module.

The design of the buildings in the project was essentially the design of different ways of combining and arranging these structural modules so that they formed coherent and functional social spaces. Although different sized modules could be used for each building, they were standardised to 3.6 x 3.0 m to reduce costs further and minimise the structural design required.
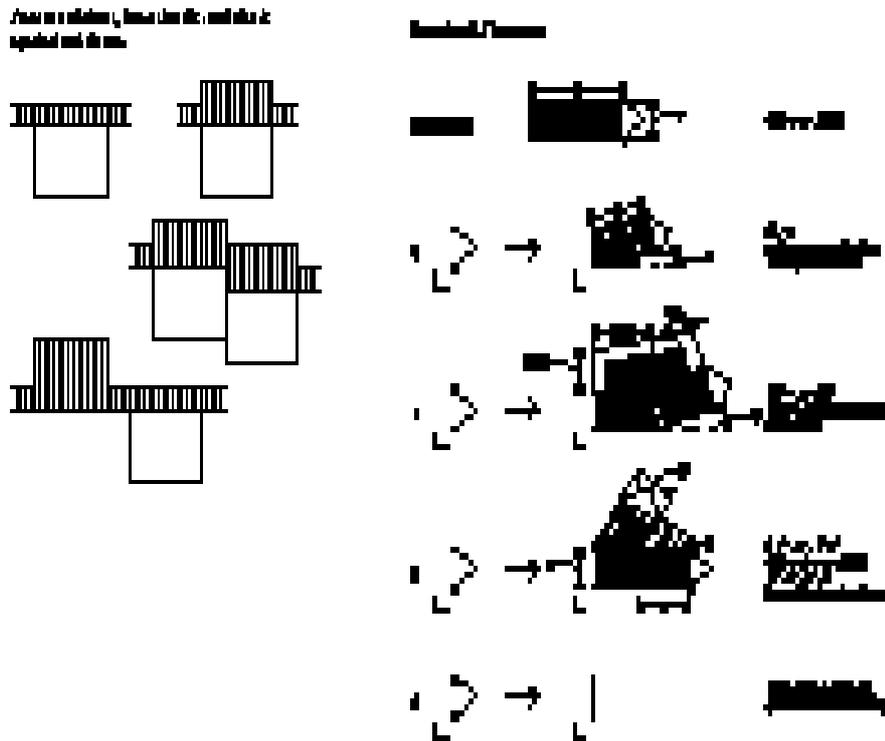
Figure 1. Boardwalk spatial relations and grammar

The final infill grammar (Fig. 2) incorporates features found in the accommo-dation huts, the communal building and the bathhouse. It describes the types of infill in this language of design and their spatial relations with the structural system. This grammar is not used in isolation, but sequentially with the struc-tural configuration generated by the accommodation, communal and bathhouse grammars.

An existing structural configuration is assumed as a precondition for use of the grammar. The labelled shape /____A____\ denotes an external wall span-ning between two columns. Rules 1-10 define different types of infill that can make up an external wall. Rule 1 is applies to double storey configurations by adding a staircase on one side of the structure. A minimum linear dimension of each type of infill is defined. Additional rules add internal walls and doors and erase labels. A derivation using the infill grammar is illustrated in Figure 4.

3.3. ACCOMMODATION HUTS

For the design of the accommodation huts, the main considerations were size, amenity, the needs of the different types of visitors, and the integration of water, power and sewage management strategies. The size of the hut had to be minimised in order to lower costs, allow greater flexibility in siting, and to provide greater spacing between a hut and its neighbours. A smaller size would also reduce damage to the land.

Analysis of the proposed visitor profiles indicated that all visitors could be accommodated in just two basic types of rooms: a two-person room for conferences and couples, and a four-person room for the other groups. A single type adaptable for 2 or 4 persons was proposed.

Figure 2. Infill grammar (partial)

This idea was further developed with the use of the structural module. The initial design was an accommodation hut of consisting of four modules, each module 3.6 by 3.0 m. The overall size was larger than originally envisaged and

would have resulted in the huts being sited too close together. Adding another storey and reducing the area of the hut to one module solved this problem. In the process, the original configuration of the accommodation was abandoned. In the final design, the different functions are separated vertically, with the upper storey a sleeping room and the lower storey a living area with kitchen and toilet.

The accommodation hut grammar (Fig. 3) generates one or two storey huts of dimensions ranging between 1800 x 1800 and 4800 x 4800. A derivation of two-storey huts uses labels at their corners that are subsequently used by the infill grammar for staircase positioning. A derivation of the accommodation hut used in this project is shown in Figure 4. Additional hut designs generated by this grammar are illustrated in Figure 5.
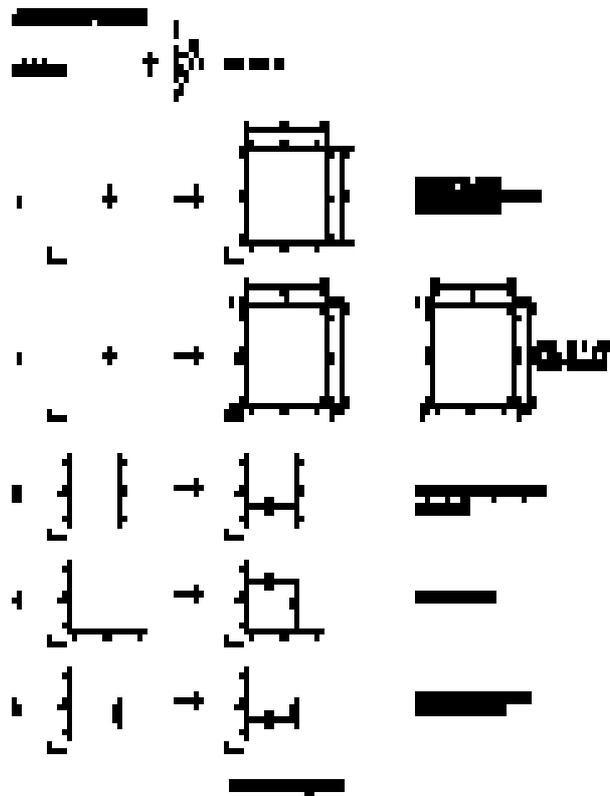
Figure 3. Accommodation hut grammar.

3.4. COMMUNAL BUILDING AND BATHHOUSES

The design of the communal building was based on the concept of a series of rooms opening onto a common outdoor space. Uses for the rooms include a) lounge and informal use; b) kitchen; and c) reception office.

The communal building grammar defines building groups with clear space on their northern and southern sides, and specifies the spacing between one building and the next. Each building is composed of one of more standardised structural modules. The grammar generates designs in two stages. In Stage 1, rules generate a grid that determines where structural modules may be placed and how they may be combined. In Stage 2, the modules are positioned onto placement anchors, which are used to ensure that the module has clear space to its north and south.

The grammar generates a wide variety of designs, of which many may be inconsistent with the design brief. The grammar does not define the outdoor space on the northern and southern sides of the buildings, but merely leaves room for it. After considering designs generated by this grammar, it became clear that, rather than generating the buildings, the grammar should generate the common outdoor space and then place the buildings around it.

The bathhouse grammar generates designs with 0-3 structural modules grouped around a central platform.

Figure 6 depicts the final project site plan, with the communal building design at the upper right (with the rooms surrounding the deck space), and bathhouse design at the lower left.
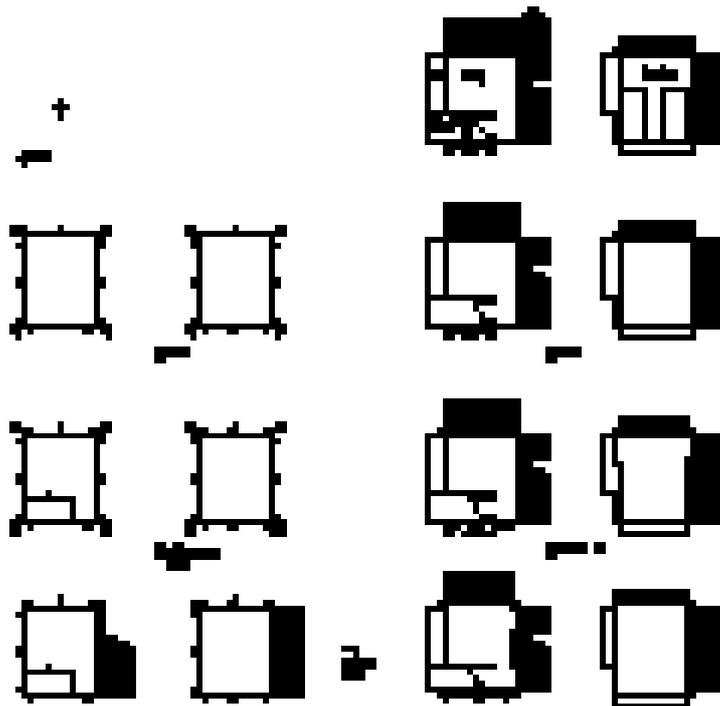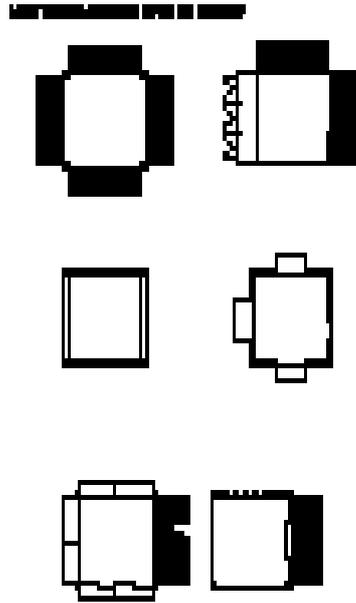

Figure 4. Derivation of two storey accommodation hut.

Figure 5. Alternative hut designs

4. Discussion

Since the studio focused on function rather than form and aesthetics, the grammars were created based on ideas about spatial relations between architectural elements that address functional and constructional considerations. This suggests a program for the creation of new architectural shape grammars that parallels the constructional approach to shape grammars:

1. Architectural idea, that satisfies the constraints of the design situation.
2. Architectural spatial relationship that articulates the idea.
3. Shape rules based on spatial relations.

The transition from spatial relations to grammar in this project was not always smooth. For example, the communal building grammar can generate designs that bear little resemblance to the concept of rooms opening onto a common open space. However, this is a case for refining the grammar or rethinking the idea rather than abandoning the approach.

For most buildings, functional fitness is at least as important as appearance. These functional constraints should be incorporated into grammars, rather than left as problems to be solved after the form of the building has been determined.

Traditionally, design precedents have been the source of architectural ideas. Translating these ideas into grammars may facilitate better understanding than

is possible through drawings and photographs. Existing shape grammars can act as a library of precedents.

Rather than restricting design, shape grammars are useful design tools that can be used to clarify architectural ideas, articulate them precisely and test them through the generation of designs. By encapsulating architectural ideas, they become a resource for the creation of new designs and new shape grammars that generate new languages of designs.

Figure 6. Site portion with accommodation huts, bathhouses and communal building.

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