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REPRESENTATION OF TYPE IN GRAMMATICAL DESIGN

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Abstract. Grammatical design is useful for the generation of a set of related designs. The concept of type aids designers in generating designs with a specified structure. However, existing studies in grammar are ambiguous in their definition of type in the language of designs generated by a grammar. Extending our previous study of defining style in grammar, this paper provides a formal definition of the concept of type in the language of designs generated by a grammar. This is done with the help of a description scheme which is developed by augmenting grammar primitives and spatial relations with descriptors. The description scheme allows the computation of descriptors for designs generated from grammar thus making possible the comparison of various design types in the language of a grammar. Such a description scheme for defining design types is especially significant for less restricted grammars that generate a large number of designs that are varied in nature. A formal definition of type in grammars allows users to sift through designs with particular features, and thus select desired designs.

Keywords. Type; Design grammars; generative design; description scheme; product design.

1. Introduction

Shape grammars are an algorithmic system for the analysis and generation of designs through spatial computations. Grammars have been used to describe languages of design in the domains of architecture, product design and automobile design (Stiny and Gips 1972, Knight 1994).

Although grammars were invented forty years ago, their use in actual practice is fairly limited. One of the reasons for this is that it is difficult for users to predict the nature of designs generated by grammars (Knight 1980). Further-

more, often due to the large number and varied nature of designs generated by grammars, it is difficult for designers to find design solutions that match design goals. In order for grammars to be of practical use, it is important that designers working with grammars are able to generate designs with desired features.

The concepts of style are two commonly used devices for design analysis and synthesis. The former deals with sets of designs with similar aesthetics and mood, whereas the latter deals with the classification of designs based on parameters such as function and morphology (Krier 2003). For instance, a building type based on morphology is a courtyard type building, and building types based on function are airports, hospitals, museums etc. On the other hand, the concept of style transcends functional or morphological divisions – the Mackintosh style can be used to describe chairs as well as buildings.

We hypothesise that if formal definitions of concepts such as style and type are provided in the design language of grammars, it will be easier for designers to examine and select designs with desired features. However, the distinction between design style and type has been ambiguous in grammar literature so far and the two terms have been used interchangeably. A number of previous works have dealt with the ideas of paradigmatic and syntagmatic substitution in rule based systems (Carlson et al. 1991, Woodbury et al. 1992, Madrazo 1999). In continuation to our previous work in which we presented a definition of style in grammars (Ahmad 2009), in this paper we present a definition of type in grammars.

2. The concept of type in grammatical design

Type (2005) has been defined as "the general form, structure, plan, style, etc. characterising or distinguishing the members of a class or group or "a kind, class, or group having distinguishing characteristics in common". The concept of type is useful for not only analysis and synthesis of designs, but also it provides a basis for design evaluation. Although the origins of the concept of type lie in plant taxonomy, it has been beneficial for the classification and analysis of buildings as well.

Typological classifications may be done on the basis of function, form or design components (Achten 1997). Function-based classification involves grouping buildings on the basis of the function they fulfil. For example, types of public buildings are hospita ls, libraries and museums. A form-based classification is based on levels of spatial organisation. For example, houses may be classified as L-type houses, U-type houses or courtyard types. Component-based classification relies on topological analysis and groups design artefacts based on prominent design components. For instance, dwellings may be clas-

sified on the basis of their roofs such as flat roofed houses, two-way sloped houses, and single-slope roofed houses. Figure 1 shows examples of the aforementioned typological classifications.

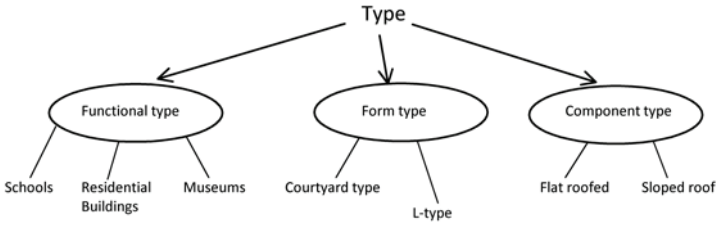

Figure 1. Examples of typological classifications.

Grammatical design is useful for the generation of a set of related designs. A corpus of designs is selected based on similarities in design elements. Rules are authored by reverse engineering to generate extant as well as new designs. Previous studies in grammars have often made use of the term 'style' to describe the set of designs generated by a grammar (Knight 1980, Chiou and Krishnamurti 1995). However, it has been argued that style involves the description of spatial features as well as aesthetic qualities of design artefacts (Ackerman 1963). Without the description of the latter, it is more apt to state that such studies deal with the concept of design type rather than style.

This raises the question whether a grammar generates only one type of design or many different types of designs? This study contends that the answer lies in the nature of the grammar and its rules. A small restrictive grammar with few rules would possibly generate designs of a particular type. On the other hand, a large unrestricted grammar could possibly host a number of design types. Thus, a formal definition of type would be extremely useful for designers as it would enable them to select designs with particular features.

In the following section, a method to define type in the design language generate by a grammar is demonstrated using the example of Greek temple façade design. The method relies on the use of a description scheme that augments verbal descriptors to grammar elements. First, the basic units of the design are identified and specified as primitives and spatial relations. Based on the concept of a set grammar with clear form-function decomposition, design rules are developed. Type descriptors of constituent primitives and spatial relations appended to them. Rules are then arranged hierarchically in function based rule sets, in order to support the generation of topologically valid designs.

3. Example of Greek temple grammar

The Greek temple design consists of a rectangular plan surrounded by a colonnade either all around, or towards the front and back. The façade of the Greek temple design primarily has three elements—a base, a set of columns, and a low pitched roof known as a pediment.

A rule base was authored for the design of Greek façade designs. It had rules that generated 'correct' sub-designs, as well as hypothetical designs. The rules were organised into six rule sets, depending on the operation carried out by the rules. Rule sets A, B and C have 'composition rules' that determine the location and positioning of primitive markers and their inter-relationships, i.e. the spatial relations. Rule sets D, E and F have 'specification rules' that decide the design of each element and articulate the compositional forms. The aforementioned rule sets were put together in a rule base consisting of 77 rules.

Two initial shapes were given. The initial shapes comprise of a set of orthogonal axes. Initial shape l included a set of markers on the opposite ends of the horizontal axis, indicating the extremities of the sub-design. These end markers are absent in initial shape 2. The two initial shapes present two different procedures of developing column sub-designs.

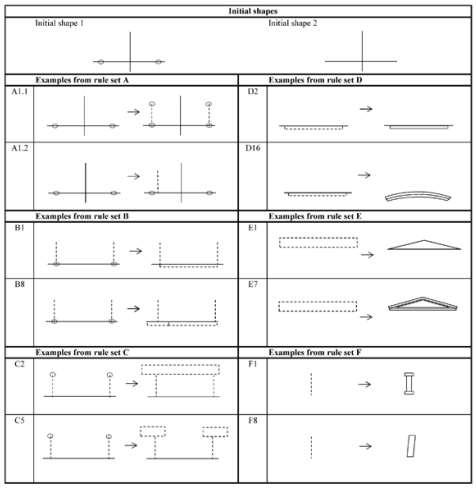

Figure 2. Examples of rules from each rule set.

Figure 2 shows the initial shapes given in the rule base and examples from each of the rule sets. Rule set A adds column markers to the sub-design. While rule set A1 is based on sub-division of the given length, rule set A2 adds columns in an outward fashion. Circular symbols identify the exterior most

columns on either side of the central axis. Rule set B has rules that add base markers underneath the exterior-most columns. Rule set C has rules that add the pediment marker over the exterior-most columns. Rule set D has 18 rules that modify the base marker into base designs. Rule set E has 18 rules that specify pediment designs. Rule set F has 18 rules that specify column designs. The complete set of rules is given in (Ahmad 2009).

The development of a correct facade design requires the application of at least one rule from each set. After the selection of an initial shape, composition rules are applied first, which place design element markers into the sub-design. Subsequently, specification rules are applied, which replace the markers with shapes specifying the design element.

A number of designs were generated from the rule base. Figure 3 shows some designs that were generated using the rules in the rule base.

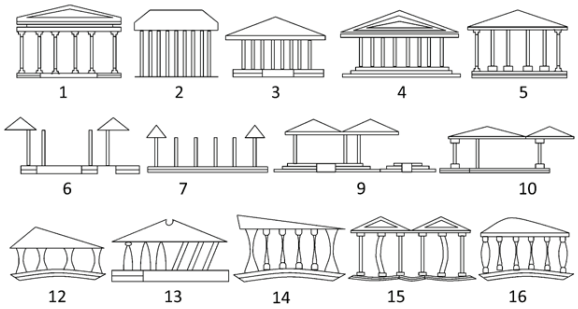

Figure 3. Examples of designs generated from the rule base.

4. A description scheme to define design type

A type description scheme was developed by modifying the style description scheme developed earlier in (Ahmad 2009) by retaining only the spatial characteristics of grammar elements. Verbal descriptions were assigned that described spatial relationship (in case of composition rules) or the design element (in case of specification rules) in the rule. Figure 4 shows an overview of the type descriptors chosen for the composition rules, specification rules and designs. For the purpose of this pilot study, straightforward binary descriptors were chosen and ascribed to grammar elements.

Based on the rules and the aforementioned descriptors augment to them, definitions were developed to describe design type in the language of a grammar. For the purpose of this work, only the description based on form-based and component-based classification of type has been attempted. These are described in the following sections.

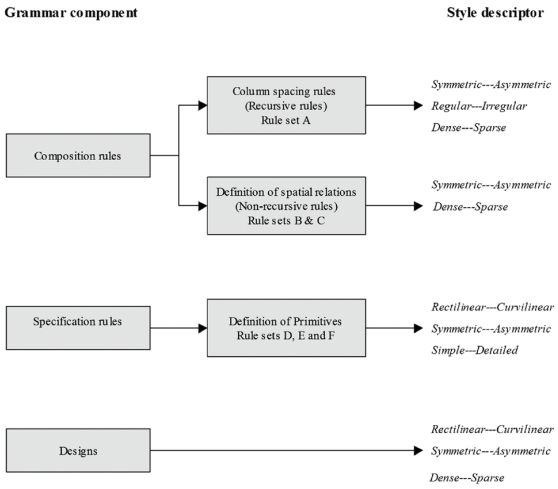

Figure 4. List of type descriptors.

4.1. COMPONENT BASED CLASSIFICATION

Firstly, component based classification of type may be defined using the rules present in the derivation of designs. For instance, T_1, a design type based on the double pediment roof type may be defined as the set of all designs that are generated using rules C2 and E7. Thus,

$$T_1 = \{D_d : d \ni (C2 \cup E7)\} \quad (1)$$

where D_d are designs with derivation d,

and C2 and E7 are rules in the rule base.

Designs 1, 3 and 4 fit this description.

Another example of this definition is T_2, a design type with a curved base. T_2 is defined as the set of all designs which are generated using rules B1 and D16. Thus,

$$T_2 = \{D_d : d \ni (B1 \cup D16)\} \quad (2)$$

where D_d are designs with derivation d,

and B1 and D16 are rules in the rule base.

Designs 12, 14 and 16 fall under this description.

Secondly, component based classification of type can also be defined using the primitive descriptor ranks augmented to the rules. For instance,

$$T_2 = \{D \ni PD_1 : PD_1 = -1\} \quad (3)$$

where D is designs generated by the grammar

and PD_1 is primitive descriptor 1 "*rectilinear---curvilinear*"

Designs 1, 3, 4 and 5 fall under this description.

4.2. FORM BASED CLASSIFICATION

Form based classification of design type may be defined in the following manner:

$$T_3 = \{D_d : d \ni (C5 \cup E1 \cup (F1x\ x))\} \quad (4)$$

where D_d are designs with derivation d,

C5, E1, E2 and F1 are rules in the rule base,

and x is the number of times a rule is repeated.

Designs 6 and 7 fall under this description.

Another type T_4 may be defined such:

$$T_4 = \{D_d : d \ni (A1.1 \cup A1.2 \cup C7 \cup (E3\ x\ 2) \cup (F1\ x\ x))\} \quad (5)$$

where D_d are designs with derivation d,

A1.1, A1.2, C7, E3 and F1 are rules in the rule base,

and x is the number of times a rule is repeated.

Designs 9 and 10 fall under this description.

Finally, form-based classification of type can also be defined using the spatial relation descriptor ranks augmented to the rules. For instance,

$$T_2 = \{ D \ni SR_3 : SR_3=1 \} \quad (6)$$

where D are all designs with spatial relation descriptor 3

and SR_3 is spatial relation descriptor 3 "*Dense—Sparse*".

Designs 6, 7, 9 and 10 fall under this description.

5. Discussion

This paper presented a possible method for the formal definition of design type in grammars. Three kinds of descriptors were developed to describe grammar elements: primitive descriptors, spatial relation descriptors and design descriptors. For the purpose of this pilot study, polar adjectival pairs with simple semantics were used for the description of three basic design elements. It is acknowledged that a complete description of design requires descriptors with greater detail. The purpose of the descriptors is to make explicit the qualities which are otherwise ambiguous in designs. Since the design problem was a fairly straightforward one, the use of simple semantics for the description risked stating the obvious. It is concluded that this method would be more suit-

able for larger grammars with greater number of rules. Further work includes a deeper study for selecting descriptors with a range of values and augmenting them to grammar primitives, as well as a case study with a larger grammar with greater number of rules. The study presented in this paper made use of set grammars that employ atomic primitive elements and limits emergent shapes. It is conceded that an ideal system would allow the development of emergent shapes and have a method that supports their description.

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