

# Grammar Representations to Facilitate Style Innovation

## An Example From Mobile Phone Design

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*Previous research in generative design has suggested that shape grammar transformations could be used for developing new design styles by the systematic modification of grammars that encode existing styles. Our research explores how such grammar transformations can be facilitated to be responsive to changes in design style requirements. For this it is important to consider the structure and organization of rules, as well as the description of the styles of designs generated by a grammar. Using an example of mobile phone design, we outline the development of a flexible grammar structure that is conducive to transformations. The grammar is augmented with a style description scheme based on the concept of semantic differential to map the style characteristics of grammar components. These measures could be significant for driving purposeful grammar transformations for style adaptation and innovation.*

**Keywords:** Design grammars; style; product design; generative design

## Introduction

The notion of style is of special relevance in contemporary design and architecture due to its relationship with identity and image making, as it signifies a distinct design language unique to a particular architect, place or source, with specific characteristics that distinguish it from other designs.

It has been a common practice in design fields such as architecture to develop new design styles by adapting previous ones. In particular, product design domains such as those of mobile phone design and automobile design require frequent and periodic changes in design style in order to meet market competition. For the sake of consistency in product image, it is often a vital design objective that new design styles are based on previous ones. Thus, improvement on existing designs and design styles is

regarded as a significant strategy of design innovation in product design (Baxter, 1995).

Such needs of style adaptation and innovation may be addressed by making use of the method of grammar transformations, which allow the adaptive reuse of previous design styles encoded by grammar rules (Knight, 1994). Grammar transformations are also significant since they make possible the use of grammars beyond a single application. The objective of our research is to explore how such grammar transformations may be facilitated as a response to changes in design style objectives and criteria.

## Grammar transformations for style synthesis

Shape grammars provide a generative construct for encoding design styles. Previous work in using shape

grammars for capturing design styles encompasses domains of architecture, engineering and product design (McCormack et al., 2004).

Knight developed a formal model for grammar transformation that made use of rule addition, deletion or modification based on changes in grammar primitives and spatial relations. One of the primary advantages of the grammar transformation model is that it makes possible the reuse of design information in extant grammars for the generation of new design languages. Grammar transformations have thus been used to analyze relationships between various styles of design (Knight, 1994) and to adapt preexisting styles of designs into new ones (Colakoglu, 2005).

Although previous works recognize the utility of grammar transformation for the reuse of design style information, they do not give an explicit description of the rationale for transformations (Chase and Liew, 2001) and do not provide mechanisms for the comparison and evaluation of design styles generated by various grammars. This work seeks to address such issues by developing a flexible grammar structure by organizing grammar rules; and to develop a method to represent the styles generated by grammars. The role of the former is to assist designers in authoring grammars that are conducive to transformations, while the latter would allow designers to interpret and compare styles generated by various grammars.

## Method Overview

This study views design style from the perspective of the design product that is, as a vocabulary of formal elements composed by a syntax (Ackerman, 1963). Stylistic change may thus be understood as changes in a style's constituent design elements and their interrelationships.

We make use of an example of mobile phone designs. A grammar is authored by translating key design elements into shapes and their interrelationships into spatial relations. A standard format is developed for representing grammar rules. Sub-

designs in grammar rules are expressed as instances of shapes linked to each other through instances of spatial relations, thus giving an explicit description of their style constituents (Figure 1). This concept is similar to previous works that propose the separation of 'element' and 'structure' in designs (Carlson and Woodbury, 1992). This facilitates style exploration by rule modification based on changes in either shapes or spatial relationships.

The organization of rules is critical for their retrieval and adaptation in rule based systems (Seebomh and Wallace, 1998). Hence, grammar rules are decomposed into their most basic form and are organized in a hierarchy, differentiating sub-rules and their variations in distinct function based sets. This makes possible the addition, deletion or replacement of rules at various levels of complexity. Furthermore, such an organization gives a modular nature to the grammar making possible transformation by replacement of given rule sets with other sets that achieve the same functional objective. State change controls and object constraints controls play an important part here in ensuring syntactically correct designs upon grammar transformation.

In order to facilitate transformations, it is also important to consider the interdependencies in grammar components, as modification of one rule may affect other rules and leave them obsolete. In order to address this, a rule dependency graph is used (Figure 2). Such a graph elucidates the relationships between grammar rules, and informs designers of the branch or branches of dependent grammar rules that might need to be transformed if a given rule is changed. This helps in preventing redundancy in rules when the grammar is transformed.

The second part of our work deals with the development of a description scheme (Stiny, 1981) to describe the style or styles generated by a grammar by mapping the style characteristics of grammar components. We make use of the method of the semantic differential which has been used to characterize styles in product design (Chen and Owen, 1997). The style description scheme comprises of a

set of style attributes that are linked to every grammar component. A set of opposing adjectival pairs are selected for the description of these style attributes for each grammar component (Table 1). These are quantified by incorporating user defined values on a numeric scale of -5 to 5, and the data generated is then analyzed. We are looking at a number of analytical measures, one of which is described here. We define the style generated by a grammar as a range within which a number of design styles might be interpreted. The style range of a grammar is represented by mapping the maximum and the minimum attribute values of grammar components.

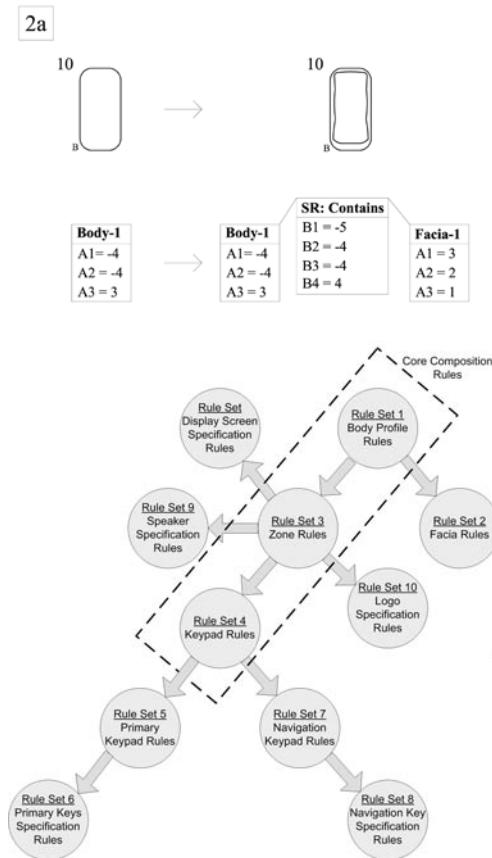


Figure 3 shows the style range generated by the mobile phone grammar.

Such a method of mapping the style attributes of grammar components could be used to assist designers in assembling grammars in selecting appropriate shapes, spatial relations and rules that have desired characteristics. It could also be used to guide grammar transformations by making strategic changes to specific grammar components.

## Discussion

In this paper we outlined the development of a flexible grammar structure for the purpose of facilitating grammar transformation by organization of rules into modular function based rule sets. Furthermore, we proposed the development of a style description scheme for a pertinent description of the style or styles generated by a design grammar.

Figure 1.  
Representation of grammar rules.

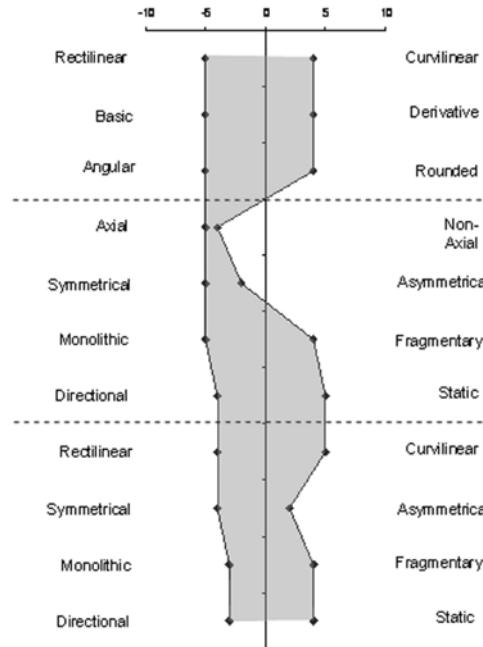


Figure 2.  
Mapping dependencies in rule sets

Figure 3.  
Mapping style range of the grammar

Table 1.  
List of adjectival descriptors

Grammar Component		Adjectival pair	
<b>Shape</b>			
Boundary	A1	<i>Rectilinear</i>	<i>Curvilinear</i>
	A2	<i>Basic</i>	<i>Derivative</i>
Corners	A3	<i>Angular</i>	<i>Rounded</i>
	<b>Spatial Relationship</b>		
Organisation	B1	<i>Axial</i>	<i>Non-axial</i>
	B2	<i>Symmetrical</i>	<i>Asymmetrical</i>
	B3	<i>Monolithic</i>	<i>Fragmentary</i>
	B4	<i>Directional</i>	<i>Stable</i>
<b>Shape group</b>			
Arrangement	C1	<i>Rectilinear</i>	<i>Curvilinear</i>
	C2	<i>Symmetrical</i>	<i>Assymetrical</i>
	C3	<i>Monolithic</i>	<i>Fragmentary</i>
	C4	<i>Directional</i>	<i>Stable</i>

The grammar representation method as described here facilitates grammar transformations based on addition, deletion and modifications in shapes and spatial relations, and allows replacement of rule sets without leaving parts of the grammar obsolete. Furthermore, the development of the style description scheme makes possible evaluation and comparison of styles generated by various grammars.

In a style reuse scenario, the comparison of the new or altered style brief with the style range generated by the existing grammar could prompt goal directed transformations to the grammar for the development of styles of design that correspond to the altered brief. Such a method could particularly be of use in the domain of product design, where design style criteria are continually undergoing change for the same product.

This work is based on the designer's interpretation and thus the style description method as described here would include the designer's bias. We aim to explore the use of empirical methods and mathematical measures to quantify style characteristics of grammar components. We also aim to make use of weighting mechanisms in order to account for dominant style characteristics. Grammar structuring as described here facilitates transformations that essentially have the same form-function decomposition. We acknowledge that in order to allow a creative exploration of style, the representation should

make possible the recognition of alternative groupings of design components as well as their emergent properties. These are relevant issues that are directions for further research.

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