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VINE GRAMMAR GENERATIVE SYSTEM

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Abstract. Graphic designers always take both time and efforts when they are creating a decorative pattern with complicated curves and a great deal of motifs. Although there are many sourcebooks of decorative patterns, the satisfaction of the results couldn't accomplish with designer's requirements. Thus, graphic designers need a faster and easier system to create decorative patterns in classical style. There are a few effiencient methods to analysis curves and surfaces in the development of shape grammars. The purpose of this research is to develop *Vine Grammar* based on shape grammars. The vine grammar analyses principles hidden in the language of deisgn works to create the order, then generates design by using Bézier curves. This research also presents the development of a decorative pattern generative system called *Shlishi* by using FLASH Action Script 2.0. The grammar can be applied with computers and to verify rules quickly by *Shlishi*. The intention of this research is to make graphic designers to use these rules to create decorative patterns of plants in classic style and to produce satisfactory results for designer more efficiently or to make the results the source materials for the follow-up design works.

Keywords. Vine; *Shlishi;* decorative patterns; shape grammar; generative design system.

1. Introduction

The manufacturing of decorative patterns gets into computational period. From making by hand to duplicating by printing, a computer program of today has been able to analyse and interpret how designer think and create patterns automatically. With a generative design system, designers can set their concepts and conditions of design to generate all the computing results which adapted to the rules they defined. Then designers can choose a satisfactory one. Comparing with a traditional design process that designers merely rely on their intuitive inspiration, this generation mechanism serves with an evaluative and selective way for designers to solve their time consuming in design processes.

Graphic designers always take both time and efforts when they are creating a decorative pattern with complicated curves and a great deal of motifs. Although there are many sourcebooks of decorative patterns, the satisfaction of the results couldn't accomplish with designer's requirements. Probably designers are unfamiliar with one style and couldn't describe the framework with the right concept. Even they make their works become skin-deep ones.

Shape grammars have the great power in generating language in the architecture and industrial design domains. But there are few efficiency methods to analysis or generate curves and surfaces since shape grammar being developed in 1972 (Gips, 1999).

This research makes use of shape grammars, which have great power in generating composition of lines, to develop "Vine Grammar". It analyses principles hidden in the language of design works in order to get criterions, then creates decorative pattern design of plant with curve elements by rules of the vine grammar.

Finally, the research develops a shape grammar interpreter uses a code, *Shlishi,* to be the name of system. The word *Shlishi* is number 3 in Hebrew, and God creating flowers and plants on the third day in world of Genesis. Graphic designers can operate *Shlishi* to create or modify decorative pattern in computational way to be the source materials for follow-up design works.

2. Shape grammar

Shape grammar is a computational design method by calculating shape in limitative conditions. Shape grammar has multiple capabilities like emergence, parameterisation, descriptions, labeling, weights, multiple drawings, and so on. A grammar is used to get the hypothesis of prediction and correct the grammar by elevating the style (Li and Lau, 2004).

A shape grammar interpreter can be separated into two main parts: determinism and indeterminism. A deterministic system generates automatically and an indeterministic (non-determinism) system is operated by designers. An automatic generating system sets the initial shape and terminal condition, and then the system will decide which rule to be applied automatically. An indeterministic interpreter usually has a user interface to consign the decision of ordering rules to designers. And, the results of generation will mainly depend on the designer's free mind.

3. Curves

A curve can identify an infinite number of points that are conformed to the definition of shape by Stiny (1980a), and the conception can extend to maximal lines and sub-shapes with collinear with not only a node but also the class of nodes that construct the curve.

In the past ten years, the development of shape grammar mainly aims at designs with straight line. There are few relative researches about analysing or producing curves or surfaces in shape grammars (Gips, 1999).

Stiny (2006) mentioned that there is a possible variation of generating curves without detailed examples. There are only predictions which a closed curve is able to change its forms by shape transformation.

Jowers (2010) uses a sub-shape idea to analyse curves. By applying shape algorithms which provide the mechanisms necessary to implement a shape grammar interpreter for shapes composed of parametric curves in two- or three-dimensional space.

There are sets of shape grammar for generating Chinese traditional patterns with curve elements. Unfortunately most of them are decided by the outline generated by rules, and then by replacing the straight line with curve elements. These grammars don't have a sub-shape, and they might belong to symbolic grammars. Design works generated by these grammars have less variation and have to increase the generative power by adding or replacing rules by human.

A parametric shape grammar of Hepplewhite-style chair-back design has been developed by Knight (1980). The constraints determining the design of a chair-back can be more succinctly rigorously expressed by triangles which generated by parametric shape grammar. At the final stage, a procedure for replacing straight lines with curves in any previously generated rectilinear design.

The intention of symbolic grammars is to attempt all compositions between elements. By replaying a single element to a composite element, rules can raise the diversity of design. There is a difference between shape grammars and symbolic grammars. The symbols are all human have to combine, and they can't change itself when they're put in place (Stiny, 2006). Language generated by shape grammars not only get the result from re-arranging symbols, but also change the form or attributes of element which blend the idea of designers. By manipulating the parameters and applying the ordering of rules, it make design varied.

4. Vine grammar

The vine grammar can use equations to replace polygons into curves. This study uses quadratic Bézier curve for an instance. According to the composition of the spatial relationships between Bézier polygons, the grammar could create various Bézier curves.

Polygons in the space have to be arranged in a specific way. In vine grammar, limited numbers of spatial relationships between polygons keep curves harmonious, and rules can produce these spatial relationships.

The vine grammar doesn't use a grid system to define a basic unit. Chinese lattice generation of Ice-ray grammar (Stiny, 1977) and axis of Palladian grammar (Sass, 2007; Stiny and Mitchell, 1978b) both use a grid system to define the parameter of distance in the space. Thus design that the vine grammar generates are decided by manipulating the apex of Bézier polygons.

4.1. SPATIAL RELATIONSHIPS

The goal of vine grammar rules is to produce new relationships of Bézier polygons. The left-hand shape (LHS) of one rule could be one labelled Bézier triangle or multiple triangles with specific relationships. And, the right-hand shape could be more Bézier triangles with more complex relationships.

As the vine grammar desires to generate one harmonious curve, there are two kinds of common relationships, C-type and S-type. As the vine grammar desires to generate a multiple curve with branches, there is also a Y-type relationship. And they are defined as below:

1. A Bézier triangle constructs from two locative-vertices and one controlled-vertex. A Bézier curve passes by these two locative-vertices. The controlled-vertex affects the value of curvature.
2. Two Bézier triangles only contact with a single point, a shared locative-vertex. This share locative-vertex is collinear with the other two unshared locative-vertices of Bézier triangles, and these vertices construct an axis.
3. As the figure shown below, two Bézier triangles both locate at the same side of the axis, one C-type curve could be generated.

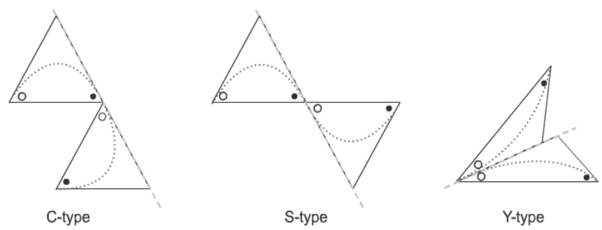

Figure 1. Spatial relationships and curves (a) C-type; (b) S-type; (c) Y-type.

4. In other words, when there are two Bézier triangles located at the different sides of axis, one S-type curve could be generated.
5. As the figure shown below, when shared vertex is collinear with controlled-vertex of both triangles, one Y-type curve could be generated.

4.2. GENERATION

The initial shape roughly decides the border and tendency of the generating result. Rules mentioned here produce Bézier triangles according as the scope of the initial shape. There are labels used to control application times and target shape which is going to apply rules. There are three stages of generative procedure: *trunk*, *branches*, and *leaves.*

4.2.1. The generating and modifying of trunk

Trunk is the main body of one decorative pattern of the plant. After defining scope and location of the initial shape, rules are defined to turn a single quadratic Bézier curve into multiple quadratic Bézier curve. And, specific spatial relationships are used to generate S-type or C-type curves shown in figure 2 below.

Rule r1 is applied to the initial shape and generates three Bézier triangles contacted with S-type relationship. And, the procedures of these three triangles apply rule r2 respectively as shown in figure 3.

4.2.2. Producing "branches" and modifications according to trunk

A Branch is a division of the Trunk, or division of other Branches. After two Bézier triangles are contacted with C-type relationship by applying rule r3, a new Bézier triangle with a right-angle label will be produced. And, rule r4 and r5 extend the result of rule r3 to generate C-type curves as shows in figure 4.

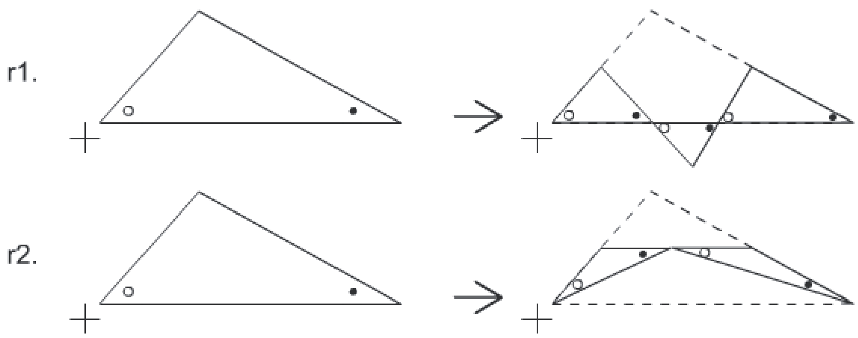

Figure 2. Rules which can generate trunk

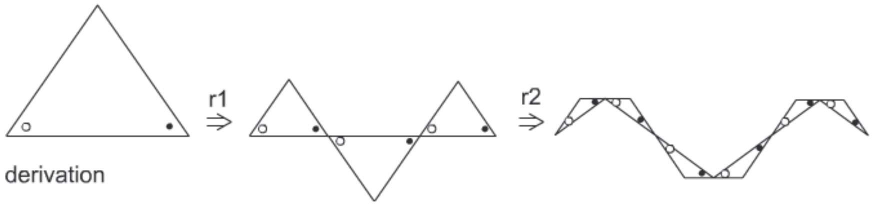

Figure 3. Derivation of generating trunk.

According to the generating result of the above derivation from last procedure, each set of Bézier triangles with C-type relationship apply rules r3 and r4 repeatedly to generate spiral curves. The derivation is shown in figure 5.

4.2.3. Producing "leaves" and modifications

After finishing generating trunk and branches, a rough framework of the decorative pattern is formed. Then, any one Bézier triangle applies rule r6 to generate a new Bézier triangle with a label of letters by using a Y-type relationship. A Bézier triangle with the label of a specific letter could be placed into a form element by applying rule r7. Rules r8 and r9 are used to erasing right-angles or equal-line labels. Rule r10 turn the labels of Bézier triangle into the same arrangement of the initial shape. Finally, rule r10 replaces all Bézier triangles into curves. The result is shown in figure 7 below:

4.3. INITIAL SHAPE

In order to generate a vine design repetitively or symmetrically, an initial shape could have multiple Bézier triangles. With the same ordering of rules being applied to Bézier triangles, curves reflecting each other.

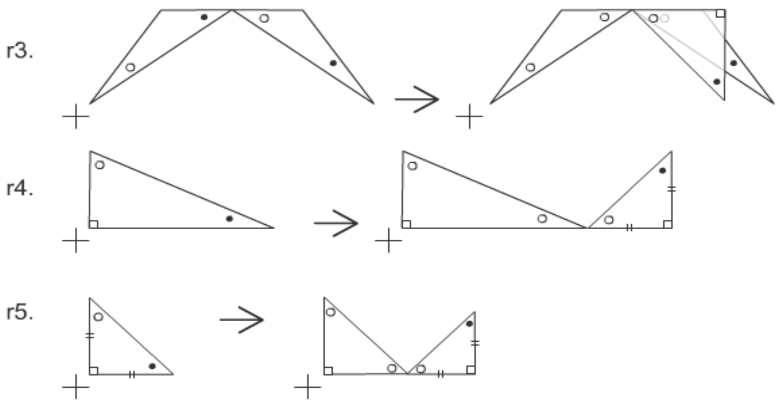

Figure 4. Rules which can generate branches.

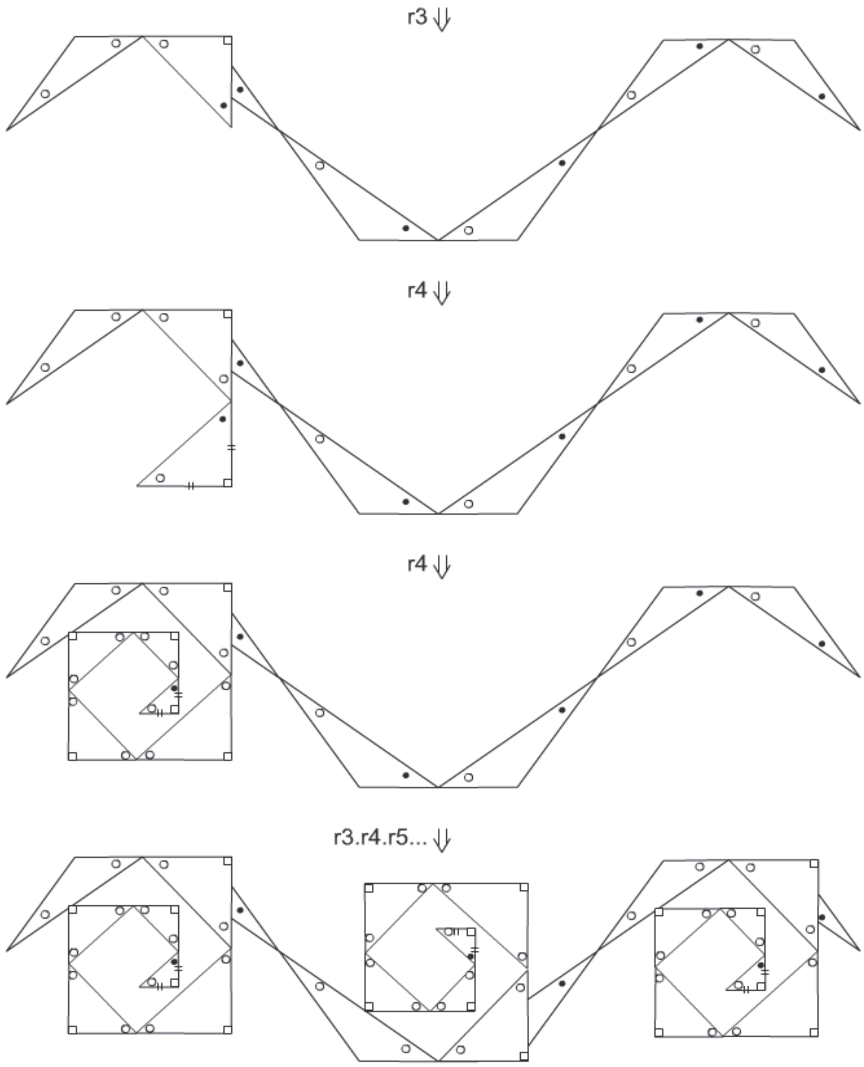

Figure 5. Derivation of generating branches by using rules r3, r4, and r5.

5. Discussion

This research studied the vine grammar based on shape grammars. A shape grammar study usually focuses on design works of straight line. According to the vine grammar, design works with curve could be generated. Rules of the vine grammar generate new spatial relationships of polygons, and then place the polygons into curves.

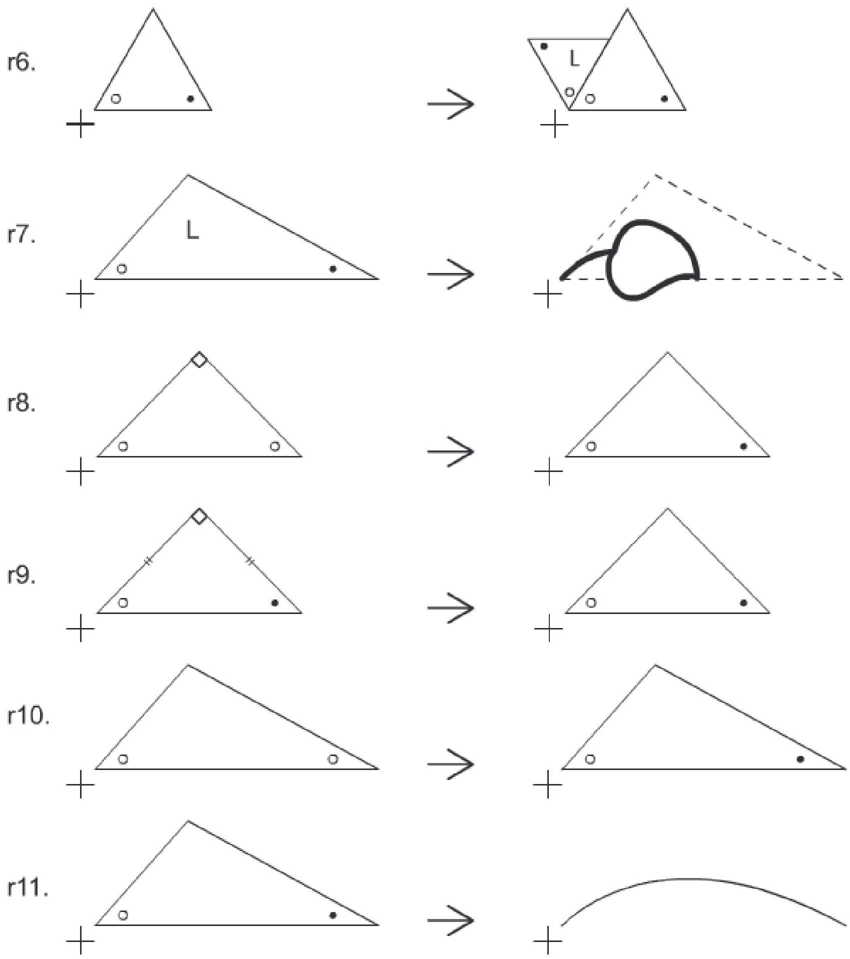

Figure 6. Rules for producing leaves and curves.

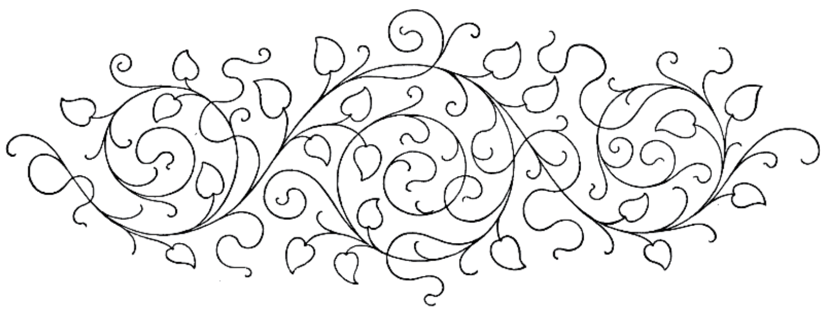

Figure 7. Decorative pattern generated after applying the rules repeatedly.

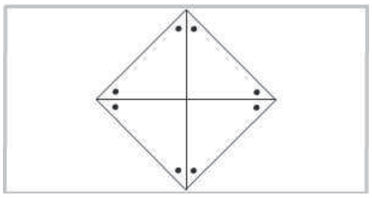

Figure 8. An initial shape with Bézier triangles arranged symmetrically.

Finally, *Shlishi*, a grammar interpreter system, provides an environment for testing rules for generating decorative patterns of plants. Graphic designers can quickly create or modify decorative patterns by manipulating the vine grammar.

In rules applying derivation, this research observes that indeterminism or determinism of shape grammars is decided by using designer's free mind or not being in a design process. For example, if someone operates on a set of determinative rules, the generating results will belong to the same style according to the ordering of applying the rules, format of the rules, or other restrictions. On the other hand, the various compositions of language are generated according to how the designer operates a set of non-determinative rules.

Free mind is defined as a designer's requirement and the notion for this design at the moment, and it contains creativity, knowledge, and experience of the designer. How do we get the balance between free mind and the restrictions of grammar? That will be another problem worth to confer.

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