Sheni: A Generative System for Decorative Pattern Design

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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 designers' requirements. Thus, graphic designers need a faster and easier system to create decorative patterns.
The purpose of this research is to build a decorative pattern generation system called "Sheni". This system analyzes decorative pattern of plants and formalizes classical styles into design representation by using stylistic analysis and shape grammar. This representation records in the system and will be Controlledled by graphic designers to create decorative patterns of one kind of or integrated style. The intention of this research is to produce the satisfied generating results for designer more efficient or make the results be the source material for follow-up design works.

1. Introduction

1.1 Background

Decorative patterns of craft have influenced the classification of classical style most. Especially there are so many decorative patterns of classical style used natural curve of plant and foliage motifs to present beauty of nature. These patterns have been widespreadly applied to artistic works, handicrafts and design form to the present.
So far, the manufactures of decorative patterns get into computational period. From making by hand to duplicate by printing, a computer program of today has been able to analysis and interpret how designer thinking and create patterns automatically. As a generative system integrated shape grammar applied to computer-aided-design, designers can set their concept and conditions of design to generate all the computing results which adapted to the rules they defined. Then designers can choose a satisfied one. Comparing with a traditional design process that designers merely rely on their intuitive and inspiration, this generation mechanism serves with an evaluative and selective way to solve time consuming in design processes.

1.2 Motivation

In order to solve the processing time of creating decorative pattern, graphic designers need a generative system which can creating decorative pattern of plant faster and easier.
A computational design way provides supports form computer system for designers to recognize the distinction of different style, and then they may select or develop one style they want.

1.3 Purpose

The intention of this research is to build a generative system for decorative pattern design of plant. We use a code, "Sheni", to be the name of the generative system. Graphic designers can operate Sheni to

create or modify decorative pattern to be the source material for follow-up design works.
This research also converts the stylistic factors of classical style to rules according to shape grammar and stores in Sheni. Graphic could use these picked out rules to create decorative patterns of one kind of or integrated style and arouse designers' inspiration when they are creating, and then produce a more satisfied works.

1.4 Design Problems

There are some situations at present when graphic designers in internal creating decorative patterns:

(1) There is no software to aid decorative patter design
(2) The existing source books of decorative patterns are usually unadoptable
(3) Creating decorative patterns is a time-consuming course.
(4) Designers are not familiar with classical style

According to the above reasons, this research defines the design problem as the lists below:

(1) How does Sheni make graphic designers create decorative patterns of plant faster and easier and facilitate them to do the modification and for follow-up design works
(2) How to use shape grammar to convert classical style to rules storing in Sheni, then make graphic designers get the support form Sheni when they are describing one style?

1.5 Research Scope

The points of this research merely discuss about decorative pattern of plant, and all kinds of decorative patterns and styles won't discuss in depth. Besides, the manufacturing process, material, and context of culture won't be concerned in this research either.

1.6 Overview

This research involves five chapters: Chapter 1 is an instruction, introduces the background, motivation, purpose, design problem and the scope of the research. Chapter 2 provides a comprehensive review of the literature. Chapter 3 describes research methods, including style describing system and label points, generation processes of shape grammar. Chapter 4 presents the implication of system according to the integration of analysis results and literature review. Finally, Chapter 5 is a research conclusion, providing the finding, contribution, and recommendation for future researchers.

2. Literature Review

In order to get enough analyzable information to construct shape grammar, the literature review aims at the classification and structure of classical decorative patterns of plant at beginning. But there is no suitable finding result able to construct shape grammar due to a limited time. The most classifications of style base on only the cultural context and background at the time, but not the form elements of stylistic factors with a systematic conclusion and summarization. For this reason, this research first focuses on the stylistic analysis theory and classification decorative pattern, and second surveys the relative research of shape grammar.

2.1 Decorative Pattern

The consists of pattern can be analyzed via some outward factors like shape, contour, facade, visible structure…and so on, or investigated according to the inward context like concept of creator, meaning of icon, cultural background...and so on.[12] For the instance of seeming form elements, these basic design elements may be mixed or matched in infinite variety. These are the designer's alphabet and he uses them to form his unique vocabulary to create essays in shape.[13]

The outline of form of one pattern may determine the use of decoration, these can mainly classify into these 5 categories [9]:

(1) Heraldry form:

Decorative patterns without limitations by outline of form.

Fig 3 A heraldry form pattern

(2) Suitable form

Decorative patterns within limitations by outline of form. The pattern must fill up the area in the boundary.

Fig 4 A suitable form pattern

(3) Partial form

Decorative patterns within limitations by outline of form. The pattern has not to completely fill up the area in the boundary.

Fig 5 A partial form pattern

(4) Corner form

Decorative patterns use for corners in one plane. It is usually with a right angle and triangle form.

Fig 6 A corner form pattern

(5) Fringe form

Decorative patterns surround the planes.

Fig 7 A fringe form pattern

The book "*Architectural Ironwork*" [13] provides many classical decorative ironworks, such as doors, signage, balustrade, and staircase with plant elements, and classifies them into systematic categories in terms of their composition and structure. There are mainly able to distribute into natural object and artificial object. Natural object involves floral decoration (like fleur-de-lis, rose, camellias…and so on that are popular in middle age), foliage (such as acanthus, palmette, and scroll used widely in Rome and Greece period), human face, seashell, fruit, animal, Imaginary creature…and so on. Here is the summarization list below:

(1) Curves
(2) Foliage and floral decoration
(3) Scroll
(4) Animal decoration
(5) Heraldry shapes
(6) Others

2.2 Stylistic Analysis

The definition of style from the aspect of fine art is the integration of peculiarity of creation, completeness of creation, and selfhood of creation. A style can be owned by one person, one group, one sect, or one period. The existing of style must be the result from comparing more than two categories of style.[7]

From the aspect of form, style is a clear and duplicable relationship of syntax in a collection of object.[16] A style can describe the characteristic feature of shape, structure, design. Every object has a form, and the style will be generated when this object has a characteristic feature. Moreover, the style needs a form to be the loader to present its visible externals.[2]

Chen has developed a system that can describe the feature of style called "Style Description Framework (SDF)."[2] This is a theory can represent a style by converting style into formal language, and it can record every factor composed the style completely. There are six main analyzable categories as the list below:

(1) Form elements
(2) Joining relationships
(3) Detail treatments
(4) Materials

(5) Color treatments
(6) Textures

The stylistic feature attributes can be converted to polar adjective pairs with a five-rank descriptive scale and use for describing each attribute. This is the most important contribution of this system for stylistic analysis. Every one polar adjective pair means one dimension in a style space. First using an estimated value (ev) to be a centric value, and confidence factor (cf) to adjust the range of the centric value. A style class with fewer salient attributes is likely to be at a higher level in the style hierarchy. On the other hand, a style with more boundaries becomes a specific one in the style space. A specific style is the subclass of a general one. There is a example in Fig7. A polar adjective pair is used to be an attribute respectively for “form elements”, “joining relationship”, and “detail treatments.” The estimated values of style Sy and Sx indicate the centric in a 0.0-1.0 hierarchy and the confidence factors define the range of each attribute in this style space. If Sy’s space contains the Sx’s, Sx is the subclass style of Sy.

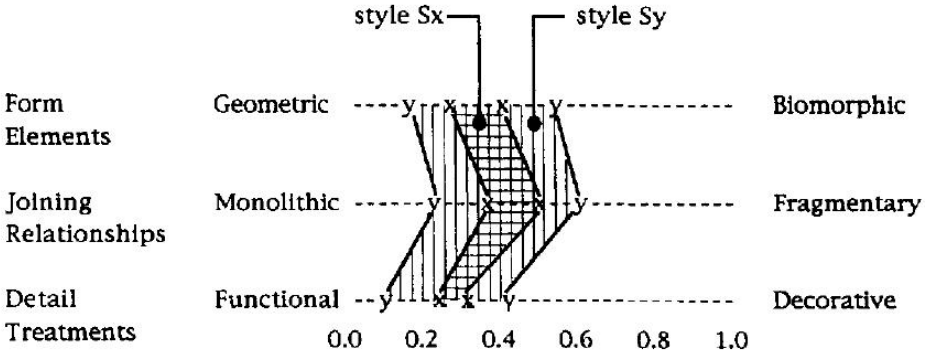

Fig 8 A SDF model with style Sx and Sy

Seven polar adjective pairs are included to describe the form elements representing distinguishable parts of an object:
(1) Harmonious-contrasting
(2) Homogeneous-heterogeneous
(3) Geometric-biomorphic
(4) Pure-impure
(5) Simple-complex
(6) Balanced-unstable
(7) Low cultural reference-high cultural reference

Polar adjective pairs are used here to describe the joining relationships among parts in three dimensions:
(1) Monolithic-fragmentary
(2) Self evident-hidden
(3) Static-dynamic

Four adjective pairs describe the detail treatments given an object:
(1) Uniform-multiform
(2) Angular-rounded
(3) Functional-decorative
(4) Subtle-bold

2.3 Shape Grammar

The development of shape grammar involves three parts. First is the theory and standard of shape grammar. Second part aims the generating design style, and this is applied most. The third part is

shaper grammar interpreter system [11] uses for implications on computer aided design domain. Designer can use the program of shape grammar to generate design.[3]
Stiny [17] defined 4 basic elements of shape grammar, and they are shape, label, rule, and initial shape. He also mentions 5 procedures of shape grammar for developing design language in Kindergarten grammars [18]:

(1) Vocabulary,
(2) Spatial relationship,
(3) Shape rule,
(4) Initial shape, and
(5) Shape grammar.

According to Knight [8], shape has different functions and attributes depend on the order of applying rules and number of selectable paths. There are six type of shape grammar with different orders of applying rules and format of rules:

(1) Basic grammar,
(2) Non-deterministic basic grammar ,
(3) Sequential grammar,
(4) Additive grammar,
(5) Deterministic grammar, and
(6) Unrestricted grammar,

3. Research Methods

After surveying the reference about structure of decorative patterns and stylistic analysis, there is an interview implemented with five graphic designers to conclude the procedure of creating or modifying decorative patterns at first. According to the results of interview, the needs of designers will confirm and be the principle for developing the user interface. Secondly, this research will integrate the theories of structure of decorative patterns and stylistic analysis to build a style description system for decorative pattern of plant. The collected decorative patterns of plant will be analyzed in terms of the standards system defined, and the outcomes are going to become style profile models and form elements database. Finally, shape grammar will be established to generate decorative patterns of plant.

3.1 Style Description System

In addition to “Color treatments”, “Materials”, and “Textures”, this research will focus on “Form elements”, “Joining relationships”, and “Detail treatments” form the categories of SDF. These are the main principles to build a style description system for describing the stylistic features of decorative patterns. Designers are able to define the characteristic of the patterns they are going to create.
The components of decorative pattern such as curves, outline of form, foliages, scroll, and other decorations belong to “Form elements.” The subordination of curves and relationship between form elements and curves are analyzed by “Joining relationships.” “Detail treatments” decides the type of lines.
This research selects these 7 classical styles and 20 representative decorative patterns for each style to analyze by style description system:

(1) Gothic
(2) Renaissance
(3) Baroque
(4) Rococo
(5) Neoclassicism
(6) Victorian
(7) Art Nouveau

Designer gets various visual elements to imitate different styles in terms of the condition “Form elements” gave. “Joining relationships” provides different rules to support designers to generate curves and “Detail treatments” choose different rules for various types of lines. These will describe detailedly in the later section.
The polar adjective pairs of “Form elements” that SDF gave:

Attribute (Code)	Polar Adjective Pairs	
Categrories of Parts (COP)	Harmonious	Contrasting
Form of Element (FOE)	Homogeneous	Heterogeneous
Consist of Element (COE)	Geometric	Biomorphic
Structure of Element (SOE)	Pure	Impure
Relationship of Element (ROE)	Balanced	Unstable
Context of Element (CXE)	Low cultural reference	High cultural reference

Table 3 Polar adjective pairs of “Form elements”

The polar adjective pairs of “Joining relationships” that SDF gave are not appropriate to describe the relationship of decorative pattern of plant. Here are the redefined ones list below:

Attribute (Code)	Polar Adjective Pairs

Curvature of Trunk (COT)	Straight	Winding
Curvature of Branch (COB)	Straight	Winding
Arrangement of Branch (AOB)	Regular	Irregular
Similarity of Branch (SOB)	Similar	Variational
Rank of Branch (ROB)	Single	Multiple
Arrangement of Leaf (AOL)	Regular	Irregular

Table 4 Polar adjective pairs of "Joining relationships"

The polar adjective pairs of "Detail treatments" that SDF gave:

Attribute (Code)	**Polar Adjective Pairs**	
Type of Line (TOL)	Uniform	Multiform
Edge of Curve (EOV)	Angular	Rounded
From of Curve (FOV)	Functional	Decorative
Shape of Curve (SOV)	Subtle	Bold

Table 5 Polar adjective pairs of "Detail treatments"

One style "st" can be represented as:

$$S(st) = \{st, \{ev, [a(1), ev(1)],[a(2), ev(2)],...[a(n), ev(n)]\}, \{cf, [a(1), cf(1)],[a(2), cf(2)],...[a(n), cf(n)]\}\}. \quad (1)$$

$$a(n) = \{COP, FOE, COE, SOE, ROE, CXE, COT, COB, AOB, SOB, ROB, AOL, TOL, EOV, FOV, SOV\}. \quad (2)$$

"a" means the class of attribute style description system defined, and "n" is the number of attribute. "ev" and "cf" are the identifiers for the estimated value and confidence factor respectively.

3.2 Shape grammar and Generation

3.2.1 Label Points

Name of Label	**Icon**
Start Node	
End Node	
Normal Node	
Controlled Node	
Branch Start Node	
Branch End Node	
Leaf Node	

Table 6 Icon of Labels

Start Node, Branch Start Node, End Node, Branch End Node, and Leaf Node have two common

attributes: coordinates and angle.
Normal Node and Controlled Node will become straight lines or curves depend on applying rules. One curve group involves one Controlled Node and two Normal Nodes, and Normal Nodes can be used collectively by another curve group.

3.2.2 Curve Group

A curve group constructs from two Normal Nodes and one Controlled Node and identifies one quadratic Bezier curve. The path of quadratic Bezier curve tracks by the function B(t) which hinges on P_0, P_2, and P_1 (represent two Normal Node and one Controlled Node respectively):

$$B(t) = (1-t)^2 P_0 + 2t(1-t)P_1 + t^2 P_2, t \in [0,1]. \quad (3)$$

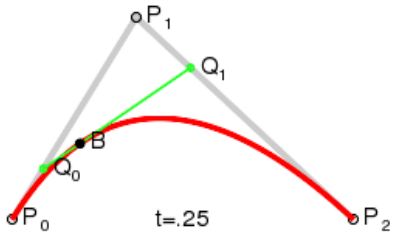

Fig 9 Construction of a quadratic Bezier curve

3.2.3 Generation process

First, a type of outline of form must be selected, and the Start Node is the “initial shape”. After choosing outline of form, the shape of frame will determine the rough external, symmetrical way, and the potential purpose of this pattern. Secondly, the Trunk, Branches, Leaves and other decoration motifs are “vocabularies.” At last, “Spatial relationship” contains the subordination of curves and relationship between form elements and curves, and these will be converted to parts of “shape rules.” All of the above are the basis to create “shape grammar.”
According to the orders of applying rules to generate curves and form elements are not sequential, and there are different paths able to chosen by designers, this research use “Unrestricted grammar” with least restrictions and most powerfully design language generation ability.
The generation process divides into six stages:

A. Choosing form of outline and setting the coordinate of Start Node;
B. Producing Trunk and modification; produce
C. Producing Branches and modification according to Trunk;
D. Producing Leaves and modification;
E. Detail treatments for Trunk, Branches, and Leaves;
F. Making all curves and nodes duplicate with symmetrical, reflectional, or rotational.

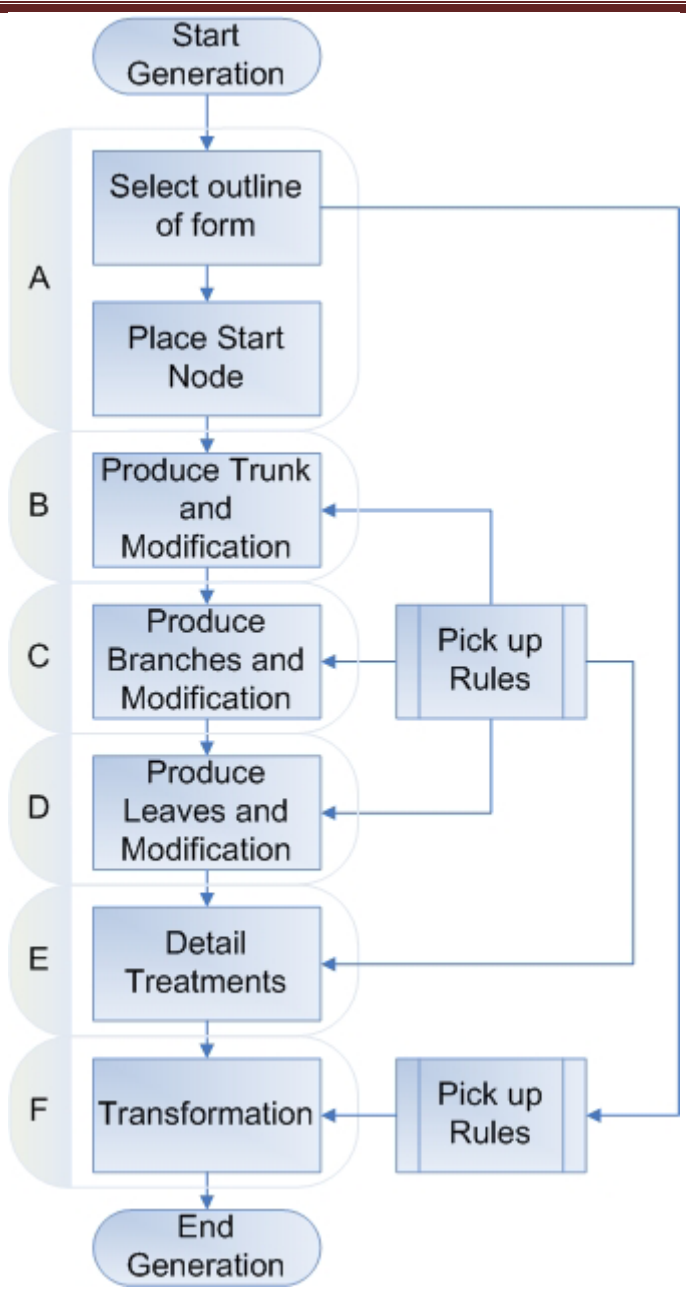

Fig 10 Generation process

(1) Stage A of Generation

Start Node is the initial shape. Depending on the selection of outline of form will effect upon the final result of generation. Here is an example of “partial form” without symmetry in the future.

Fig 11 Rules of Stage A

(2) Stage B of Generation

In order to generate the Trunk, designer first applies ruleB_1 on Start Node. End Node and one Controlled Node will be placed in the frame of initial shape. Start Node, End Node, and one Controlled Node construct a curve group. Then designer can apply ruleB_2 to increase the Trunk more complicated. There is a limitation that ruleB_2 can only apply on the curve with End Node to ensure the path of curve won’t be divisive. RuleB_3-4 is used for modify the curve. To maintain the

harmonizing of curves, the Controlled Node desire to move must be one point on the straight line construct by the collective Normal Nodes and the Controlled Nodes which use the collective Normal Nodes, and the Normal Node desire to move must be one point on the straight line construct by the Controlled Nodes which in the same curve group.

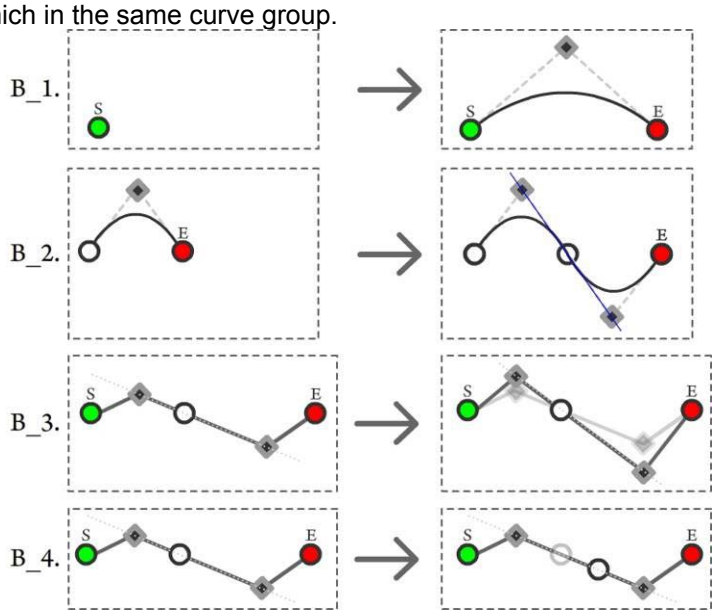

Fig 12 Rules of Stage B

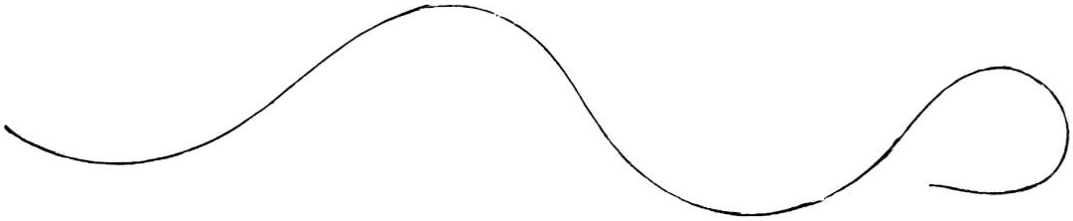

Fig 13 Trunk generated by Stage B

(3) Stage C of Generation

RuleC_1 is used to create a Branch Start Node on Trunk, and ruleC_1-2 are used to increase curve groups the same as ruleB_1-2. The new generation curves of Branches can also apply ruleC_4 to attach another new Branch Start Node, and the new node's rank value increase 1. The rank value is one of the attribute of Branch Start Node identify the level of this curve group of Branch. RuleC_5-6 are applied to modify the curves of Branches.

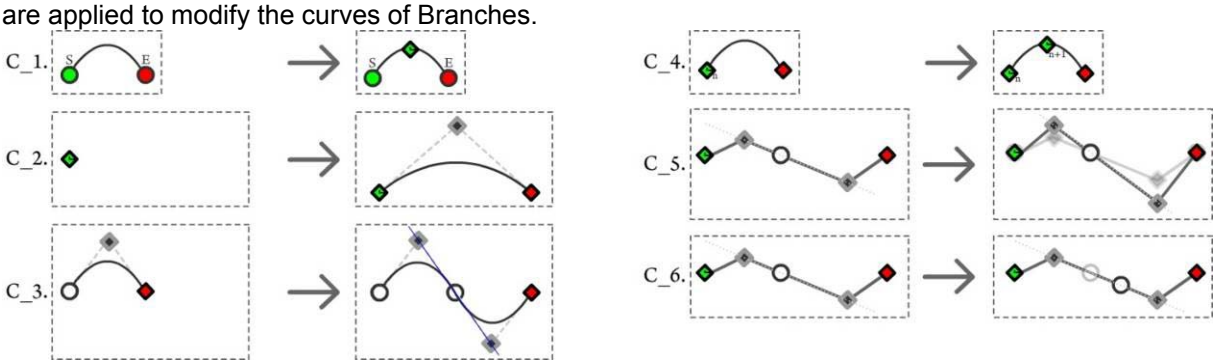

Fig 14 Rules of Stage C

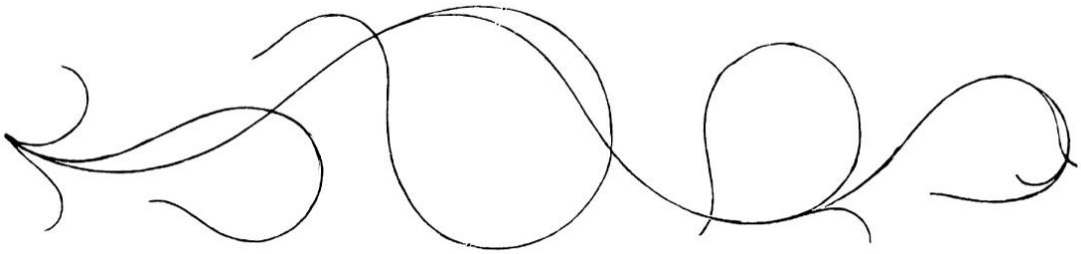

Fig 15 Branches generated by Stage C

Fig 16 More Branches generated by Stage C

(4) Stage D of Generation

Repeatedly applying ruleD_1 to attach Leaf Node to curve of Trunk and ruleD_2 to curves of Branches. Finally, applying ruled_5-7 to attach the form elements to replace the labels, and ruled_3-4 to remove the Normal Nodes and Controlled Nodes

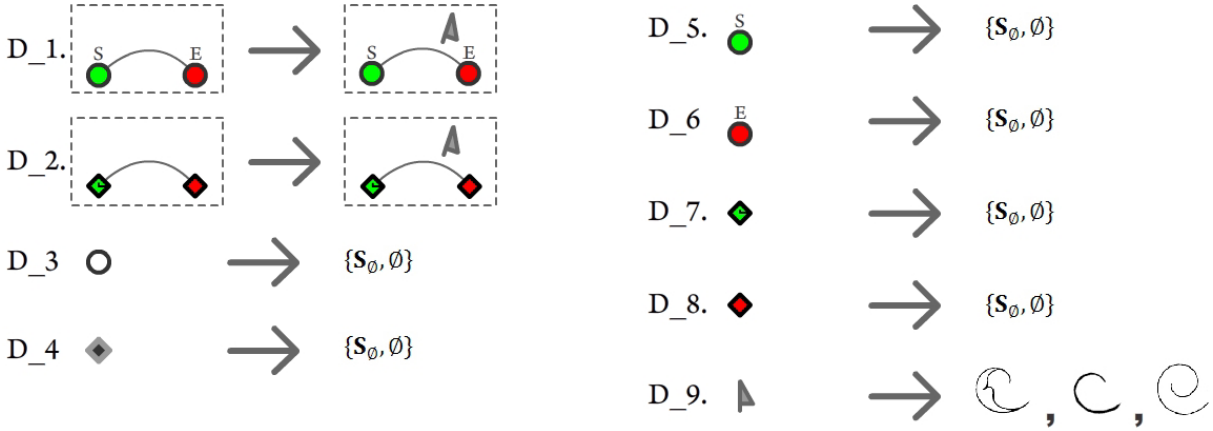

Fig 17 Rules of Stage D

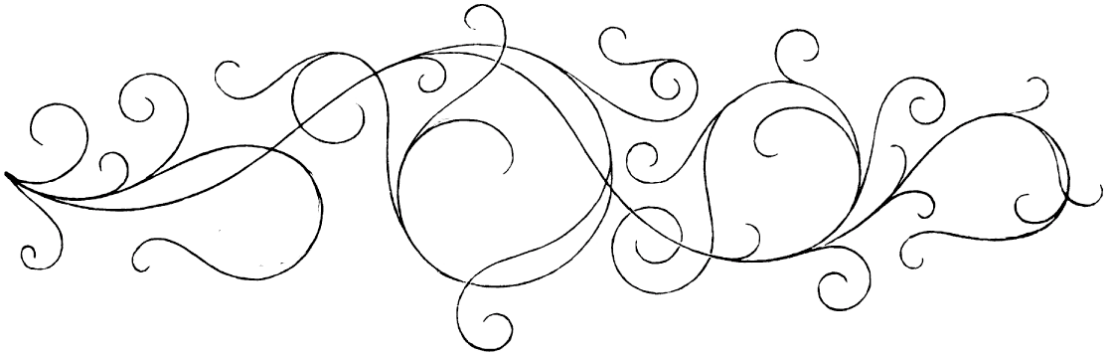

Fig 18 Leaves (scroll) generated by Stage D

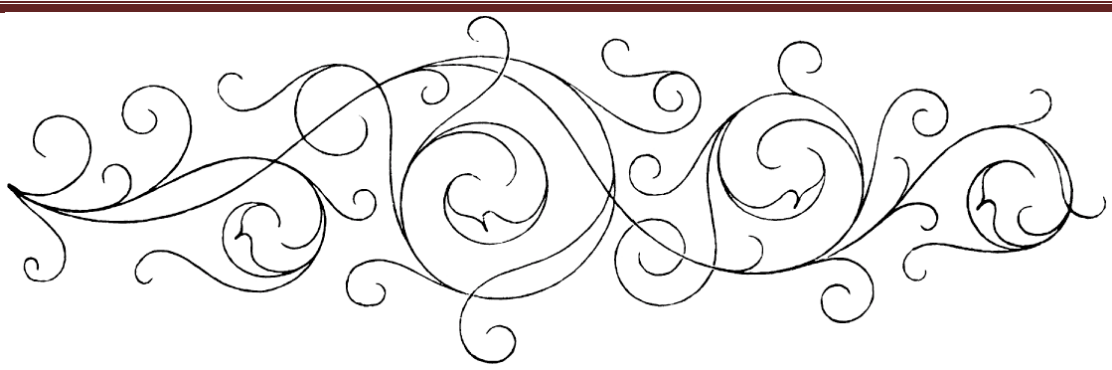

Fig 19 Leaves (scroll) generated by Stage D

4. Implication

The implication system, Sheni, will use Action Script 2.0 of Adobe FLASH to develop the user interface and use the program language of Active Server Page (ASP) to be the middleware connects with database. User can manipulate Sheni through internet by using browser and save the pattern results as files or the style profile models and step records.

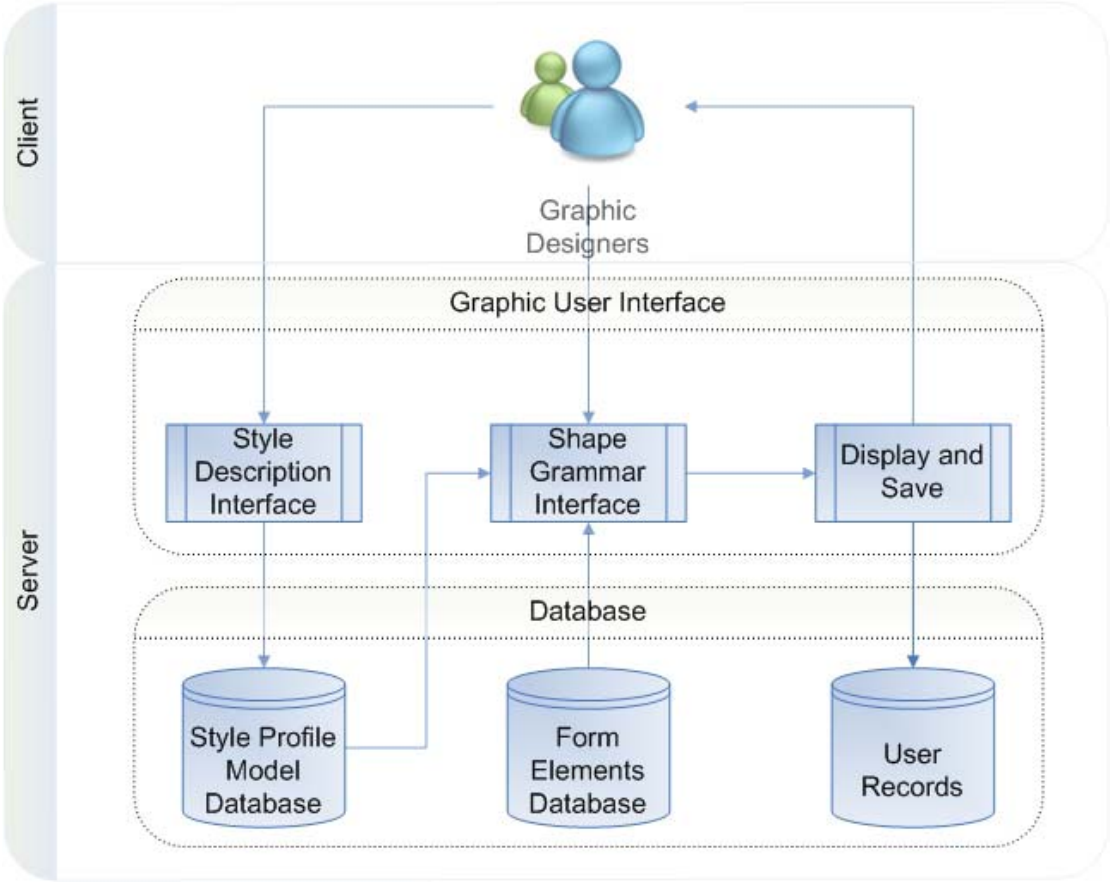

Fig 20 System architecture of Sheni

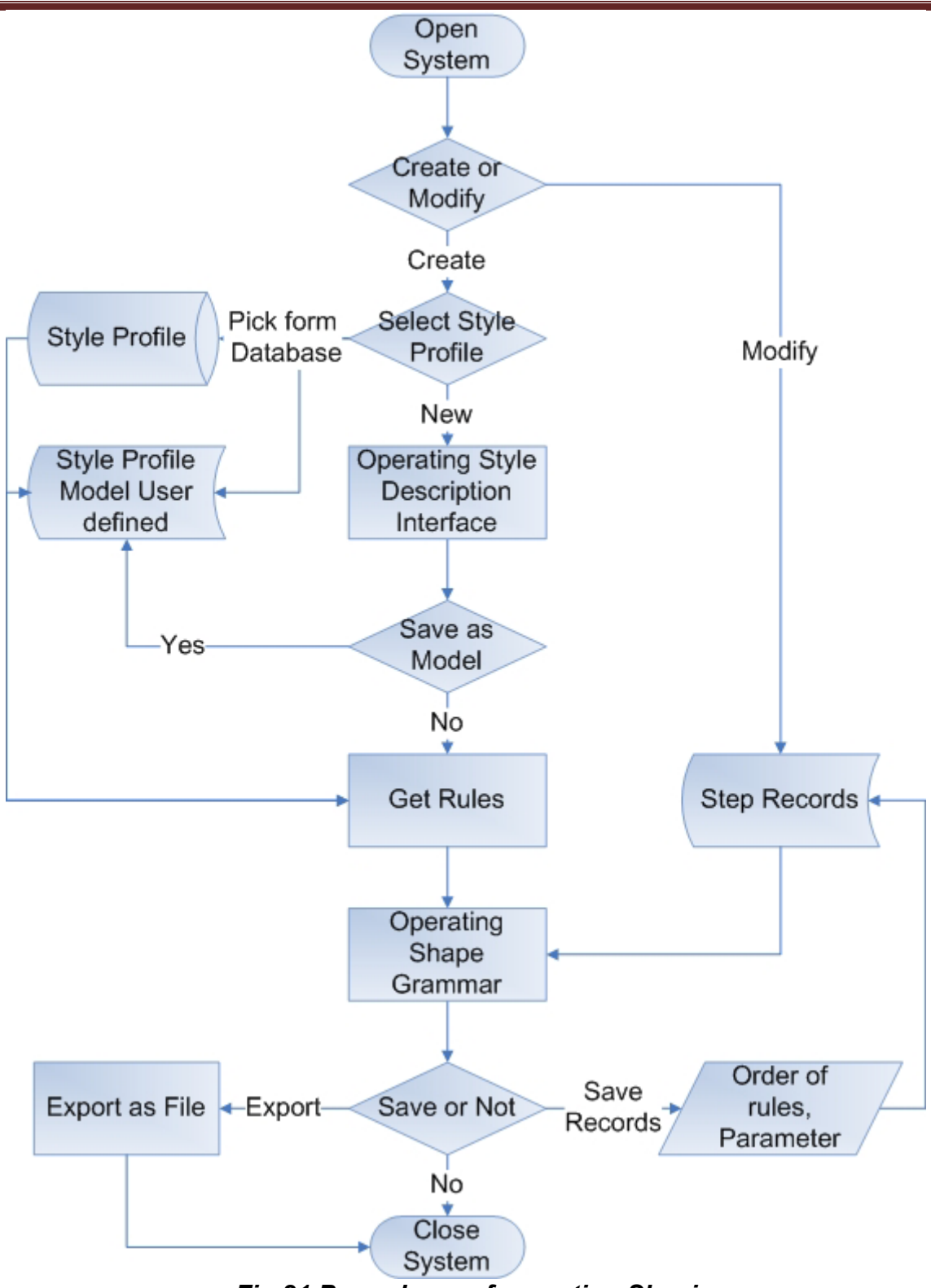

Fig 21 Procedures of operating Sheni

4.1 Style Description Interface

The interface of style description system. After designers defined the features of style which they are going to use to create decorative patterns, the interface connects to the style profile model database to choose the grammar to apply for designers.

4.2 Style Profile Model Database

Besides the seven classical style profiles, and the models defined by designers are saved here.

4.3 Form Element Database

According to the decorative patterns this research analyzed, there is a summarization of the simplest form elements with tags depend on the classification of structure of decorative patterns, and the form elements will be saved in the form element database. The style description system will set the message of tags to get the form elements designer needs.

5. Conclusion

5.1 Contribution

Sheni provides a object-oriented base system for generating decorative patterns of plant. Graphic designers can fast create or modify decorative patterns by manipulating shape grammar or step records.
Another reason is that designers usually not exactly so understand the characteristic features which constructed the style. They may use incorrect subjective judgments to describe a style, and this make the representation of style has deviations. The style description interface of Sheni makes designers know the classical style depend on the style profiles or understand how other designers think as they are creating patterns through style profile models defined by others.

5.2 Future Work

This research merely analyzes decorative patterns of plant of seven classical styles. The future research can focus on a more general classification to discuss and improve the shape grammar to gain more powerful generation ability.

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