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A Design Support System for Kaga-Yuzen Kimono Pattern by Means of L-System

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Abstract. This paper proposes a support tool for designing kimono patterns. Kimono patterns are controlled by two rules, "flow" and "hierarchy"; the rule of "flow" controls the pattern arrangement, and the rule of "layered structure" manages the layer structure of pattern. The proposed system supports design of kimono patterns, considering these two rules. The system also applies L-System to express ornamental patterns of plants to appear in kimonos semi-automatically. It is possible for people who do not have good design skills to obtain an intended kimono pattern easily by using this system.

1. Introduction

This paper proposes a support tool for designing kimono patterns. This section describes the background of the research, the overview of kimono patterns, and related works.

1.1. Background

There are various types of stunning, unique and colorful patterns in Japanese traditional kimono, and they attract our attention. The kimono patterns are in the limelight in recent years, and have appeared on Western clothes and accessories. Needless to say, it is very hard for amateurs to design an elegant kimono pattern; they have to consider the balance, layout, and design for the elements of kimono patterns.

The main objective of this research is to provide an interactive support tool for designing kimono patterns, by the application of some design rules.

1.2. Overview of Kaga-Yuzen

The scope of this research is to design patterns which appear on tomesode kimono; a tomesode is a formal kimono with designs along the bottom of the skirt, worn by married women on ceremonial occasions. This paper selected Kaga-Yuzen as a case study for designing tomesode patterns. The designs of Kaga-Yuzen depict natural beauty; flowers, birds, and landscapes are drawn in minute detail with a special paste which prevents the

Fig. 1. Kaga-Yuzen tomesode.

colors from running together (KAGA-ZOME PROMOTION COOPERATIVE ASSOCIATION, 2000). Figure 1 shows an example of Kaga-Yuzen tomesode. As shown in this photo, there are printed patterns mainly along the bottom of the cloth. This research focuses on designing the major motif of Kaga-Yuzen, that is, plants.

1.3. Related works

There are two main research topics in design support tools; algorithms for pattern generation, and the user interface for pattern design.

(1) Algorithms for pattern generation

WONG *et al*. (1998) have reported an algorithmic design method for traditional floral ornamental patterns. They introduce the idea of "adaptive clip art," which encapsulates the rules for creating a specific pattern. The user can design a variety of floral ornamental patterns by arranging the adaptive clip art. This method automatically fills the specified area with a floral ornamental pattern. However, it is not suitable for designing kimono patterns, because kimono pattern is designed in layered structure, and is not arranged homogeneously.

There are many research studies for generation of various three dimensional plants based on L-system. L-system was proposed as a rewriting concept of plant development, and it is widely applied for defining complex objects in computer graphics, not only plants (PRUSINKIEWICZ and LINDENMAYER, 1990; PRUSINKIEWICZ *et al*., 2001; LUKASIK and HUDYMA, 2005) but also urban road networks (PARISH and MÜLLER, 2001) and buildings (WONKA *et al*., 2003; MÜLLER *et al*., 2006). These modeling methods aim to generate realistic-looking objects. Therefore, they are not suitable for designing kimono patterns, because the shapes in kimono are exaggerated.

(2) User interface for pattern design

One of the most popular design tools is *Adobe Illustrator*. This software is widely used to create artwork, including graphics for print, web, and motion design. The user interface of this software is designed for creators, therefore, it is rather hard for novice users to draw even a simple tree.

On the other hand, IJIRI *et al*. (2005) have presented an interactive modeling tool for three dimensional flowers. This method allows even novice users to define various flower models easily and quickly with a simple user interface. This research focuses on creating biologically plausible flower models, not on drawing two dimensional patterns.

Our goal is to provide an easy-to-use interface for designing kimono patterns, while allowing users to design a variety of kimono patterns algorithmically. In our system, users specify the outline for the intended kimono pattern, and then the system generates the details automatically.

2. Layout Rules for Kimono Patterns

Prior to designing the system architecture, we interviewed professional craftsmen of Kaga-Yuzen about designing kimono patterns. The following summarizes the interviews;

I1) The flow of the pattern is determined before drawing.

I2) Types of flowers are not restricted. A variety of flowers are used to design a pattern.

I3) Pattern drawing is started from a main part of a design.

I4) Main flowers are larger than the other surrounding flowers.

In addition to the interviews, the following two rules were observed from the reference book (KAGA-YUZEN ARTWORKS COLLECTION, 1986); kimono patterns have flows and layered structure.

2.1. Pattern flow

Figure 2 shows the extracted flow in the three regions of kimono pattern. To extract the flow, ten samples are selected randomly from the reference book (KAGA-YUZEN ARTWORKS COLLECTION, 1986). The three regions of the pattern are separated into the top, middle, and bottom regions. The flow in each region has the following rules;

Top region: There are two major peaks; large peak on the left side and small peak on the right side of the flow. The flow descends from the left peak to the right side gradually.

Middle region: The pattern flows from the top left to the bottom right gradually.

Bottom region: The flow of pattern forms “U” or “L” shape; the flow descends from the top left, glides horizontally, and then ascends the right side.

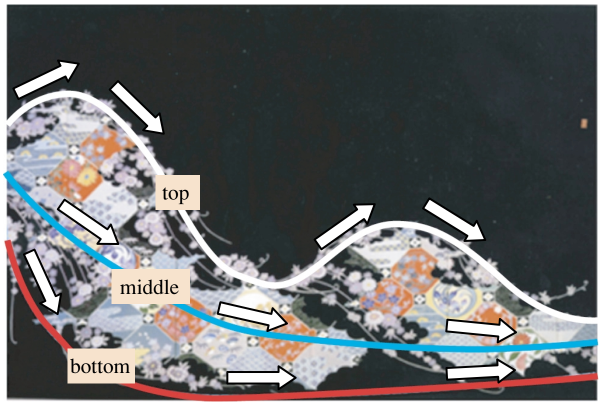
These rules correspond to the interview results with craftsmen, I1, and these are the primary guidelines for designing kimono patterns.

2.2. Layered structure

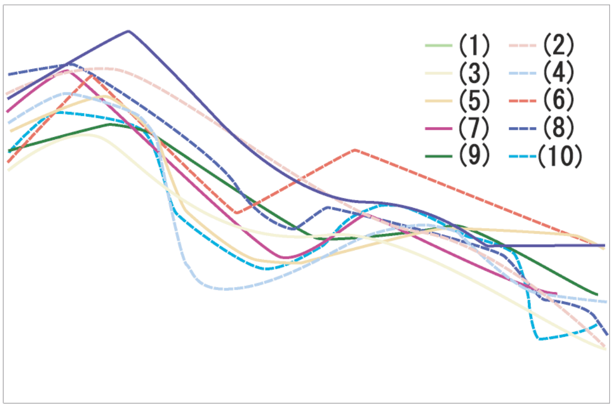
Another rule found in kimono patterns is a layered structure. Figure 3 shows an example of a layered structure. The number in Fig. 3 indicates the depth of the layer. Each layer contains the same motif. This layered structure reflects the drawing procedure of craftsmen, and gives a sense of depth to the viewer.

3. Algorithm for Generating Kimono Patterns

This section describes about the algorithm for generating kimono patterns by means of L-system.



(a) Kimono Sample



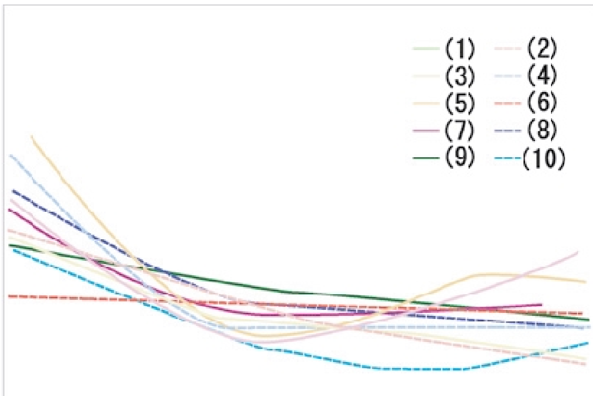
(b) Top Flow

Fig. 2. Rules of pattern flow.

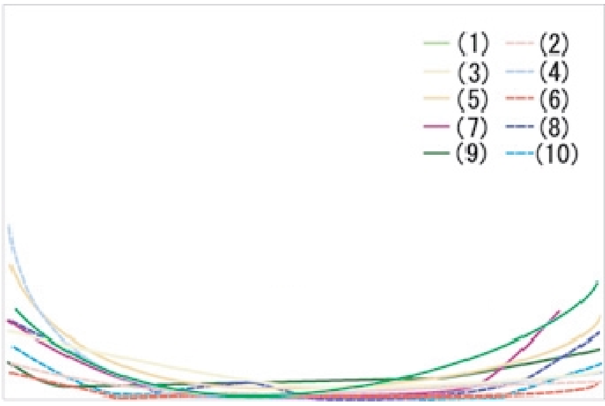
3.1. Plant pattern generation using L-system

L-system is a procedural modeling method to obtain two/three dimensional plant shapes (PRUSINKIEWICZ and LINDENMAYER, 1990). This paper applies this procedural modeling method to generate complex plant patterns in kimono. Figure 4 shows an example of plant shape generation by means of L-system. Figure 4(a) is an initial pattern, and Fig. 4(b) shows a production rule. Figure 4(c) is generated by applying the production rule five times recursively for each segment of the initial pattern.

Our system provides seven types of production rules to generate plant patterns as shown in Fig. 5. These rules have been designed based on the examples in the reference book of Kaga-Yuzen (KAGA-YUZEN ARTWORKS COLLECTION, 1986). The parameters for



(c) Middle Flow



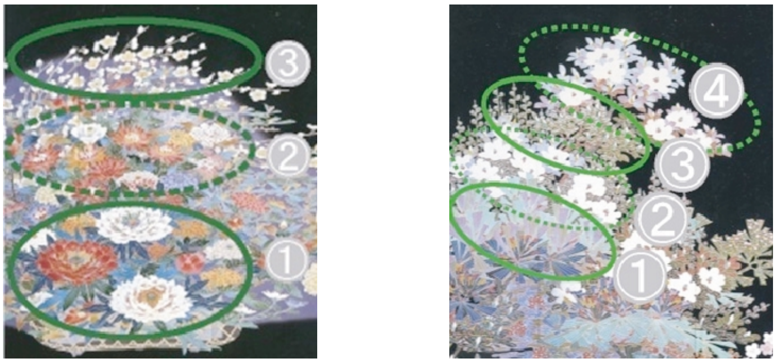
(d) Bottom Flow

Fig. 2. (continued).

generating patterns, such as branching angle and growth ratio of twig, can be specified by a user. Some restriction conditions should be applied to form a group of plant patterns, otherwise the pattern would grows infinitely. The system controls the growth of plants, so as not to exceed a boundary curve as shown in Fig. 6. If a new node extends beyond a boundary curve, the segment that connects the new node and the current one is not drawn; therefore, only the black segments in Fig. 6 are drawn.

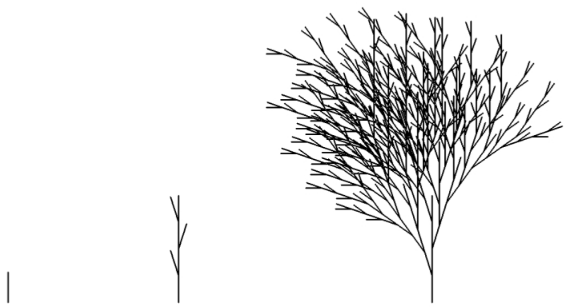
3.2. Rendering method for plant patterns

The method described in Subsec. 3.1 only treats structural patterns. To represent the generated structural pattern as a kimono pattern, some rendering methods are required.



(a) Sample #1 (b) Sample #2

Fig. 3. Examples of layered structure.



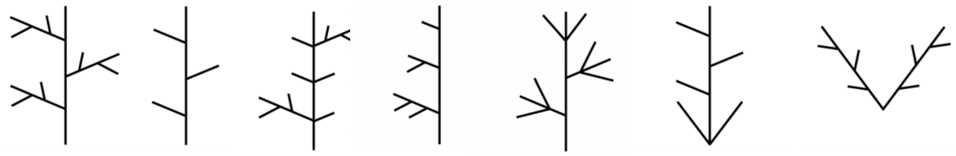
(a) Initial Pattern (b) Production Rule (c) Result

Fig. 4. Example of L-system.

3.2.1 Bending

A bending operation for branches is applied to exaggerate the expression of a kimono pattern. Each corner and twig is rounded by the bending operation, as shown in Fig. 7. The cubic Bezier curve is applied for a segment connecting two nodes, *seg-b* in Fig. 7, and Spline curve is applied for a series of segments consisting of three or more nodes, *seg-s* in Fig. 7, respectively. For Spline curve, all nodes in a segment are control points. For Bezier curve, two control points, P_a and P_b as shown in Fig. 8(a), are given as follows;

$$\overrightarrow{P_a} = \frac{2}{3}\overrightarrow{P_r} + \frac{1}{3}\overrightarrow{P_t} + \vec{n} \tag{1}$$



(a) rule #1 (b) rule #2 (c) rule #3 (d) rule #4 (e) rule #5 (f) rule #6 (g) rule #7

Fig. 5. Production rules.

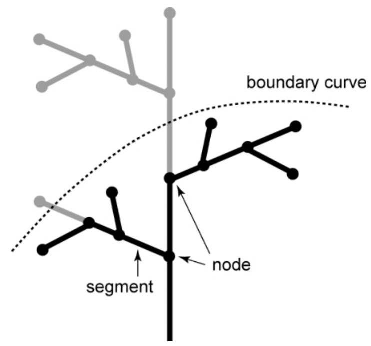


Fig. 6. Restriction condition.

$$\overrightarrow{P_b} = \frac{1}{3}\overrightarrow{P_r} + \frac{2}{3}\overrightarrow{P_t} + \vec{n} \tag{2}$$

$$\vec{n} = w \cdot \text{perpendicular}\left(\left(\overrightarrow{P_t} - \overrightarrow{P_r}\right) \Big/ \left\|\overrightarrow{P_t} - \overrightarrow{P_r}\right\|\right). \tag{3}$$

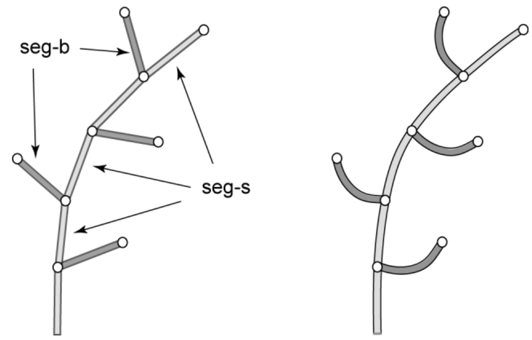
Here, P_r is a node on stem side and P_t is a node on branch apex. The function perpendicular ($\vec{v}$) returns a perpendicular vector for $\vec{v}$ whose direction is downward. The parameter w is a user-specified bending value. Bezier curve is defined with four control points, P_r, P_a, P_b, and P_t.

3.2.2 Tapering

To make a pattern more expressive, tapering operation is applied for stems and branches. The tapering operation decreases the diameter of stem/branch along its axis linearly, as shown in Fig. 9. The ratio for tapering is specified by user.

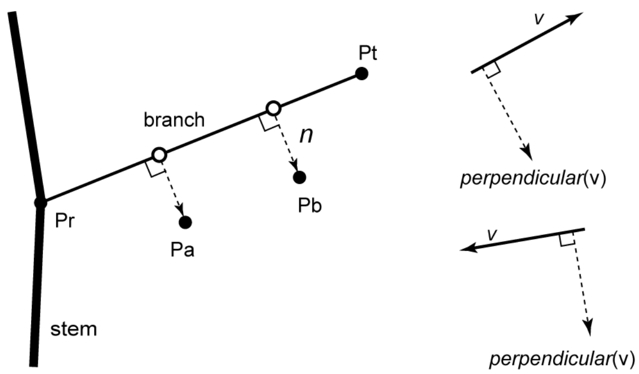
3.2.3 Decoration

To decorate a plant pattern, the following three processes are applied; flowering, leafing and texturing. Flowering process arranges pre-defined flower shapes at each branch apex. Users can select their intended shapes manually in a design interface. Our method provides two types of leafing; leafing around each flower, as shown in Fig. 10(a), and



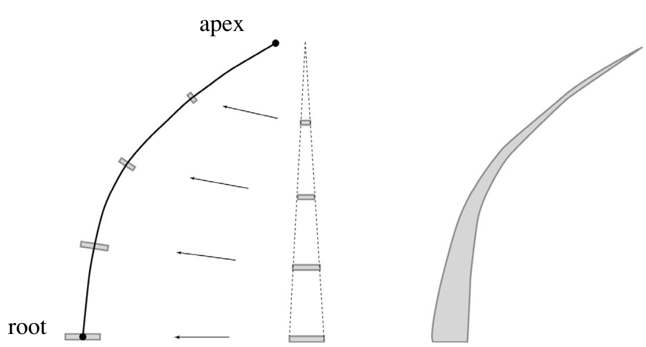
(a) Before Bending (b) After Bending

Fig. 7. Bending operation.



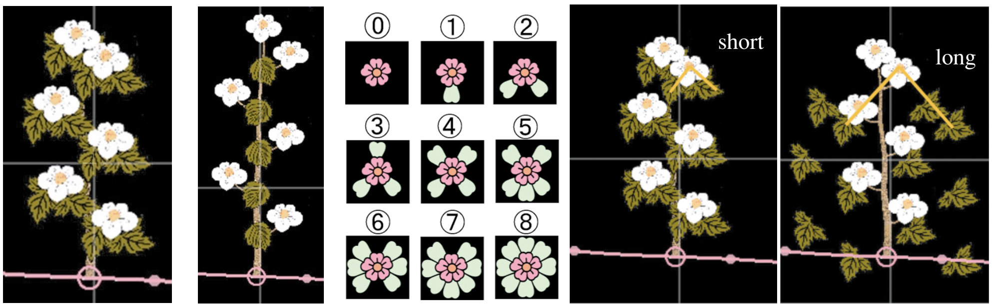
(a) Control Points for Bezier Curve (b) Perpendicular Vector

Fig. 8. Bezier curve for bending operation.



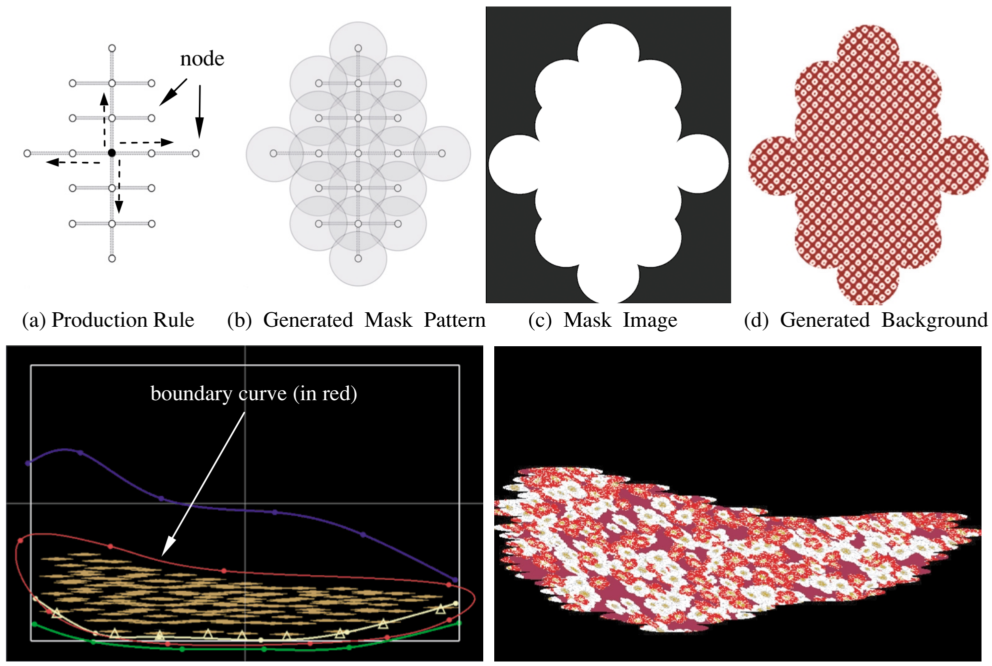
(a) Tapering operation (b) Result

Fig. 9. Tapering operation.



(a) Leafing around flower (b) Leafing at fork (c) Number of Leaves (d) Leafing Distance

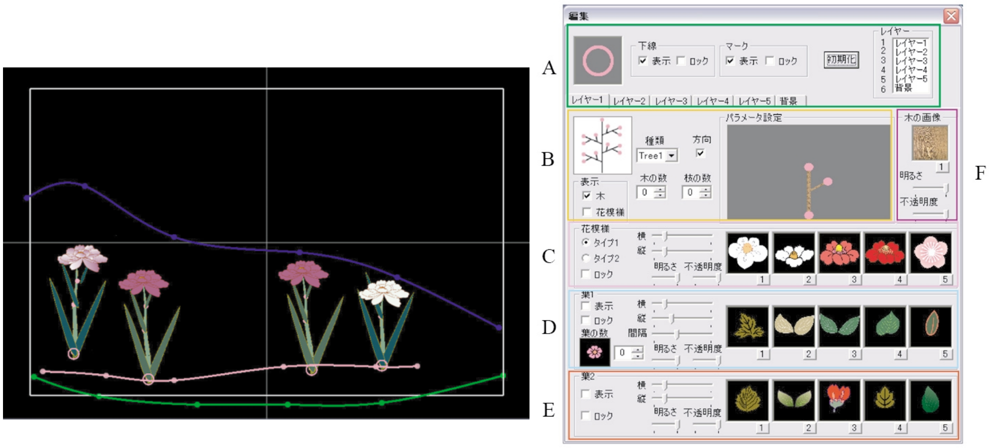
Fig. 10. Decoration.



(e) Example #1 (f) Example #2

Fig. 11. Background image.

leafing at each fork of a branch, as shown in Fig. 10(b). The number of leaves and the distance between flower and leaf, as shown in Figs. 10(c) and (d) respectively, are specified manually with a check-box or slider. Moreover, the stems and branches are textured with user-specified images, as shown in Figs. 10(a), (b) and (d).



(a) Working Area (b) Toolbox

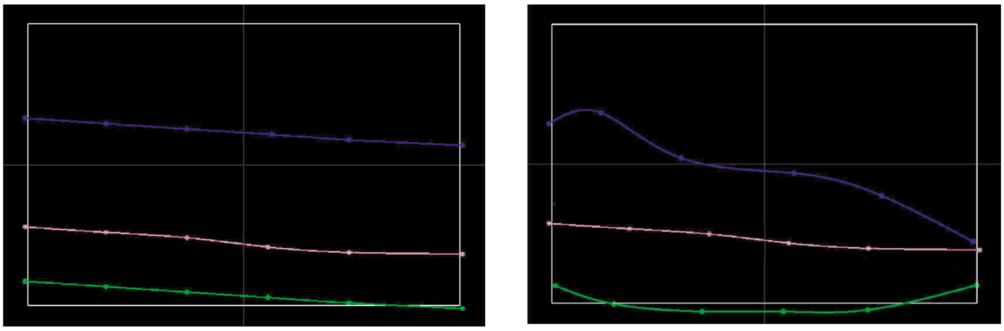
Fig. 12. Design tool.

1. Design upper and lower boundary curves
2. Specify plant figure for each layer
   a. Design base curve
   b. Parameter setting for plant
   c. Selection of flower and leaves
3. Adjust and modify

Fig. 13. Design process.

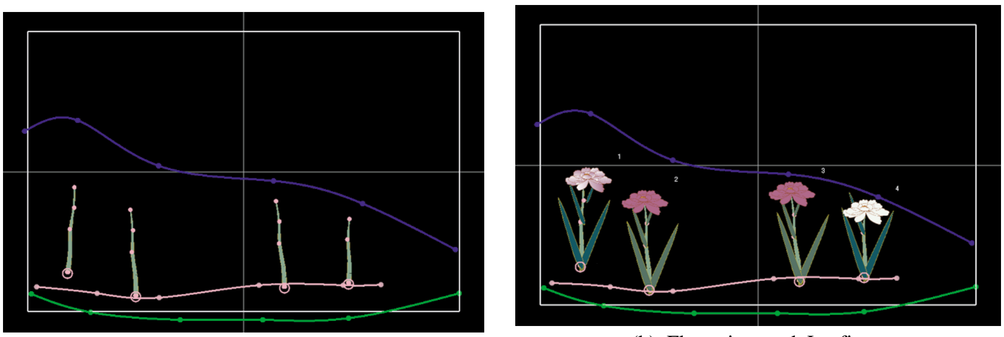
3.3. Rendering method for background image

Background patterns, such as clouds and ground, are also generated by means of L-system, in the same manner as generating plant patterns. There is only one production rule for mask pattern as shown in Fig. 11(a), and the pattern expands its branches in all directions. The boundary curve is specified as shown in Fig. 11(e). A mask image is obtained by replacing each node with masking primitive, as shown in Fig. 11(b). In this case, circles are used as masking primitive. And then, the mask image is obtained by filling the masking primitives with white and the background with black. Finally, the background image is generated by filling the white region of mask image with the specified background pattern, as shown in Fig. 11(d). Figures 11(e) and (f) show examples generated by changing the masking primitive and node distance.



(a) Initial Boundary Curves (b) Designed Boundary Curves

Fig. 14. Designing upper and lower boundary curves.



(a) Base Curve and Placement of Plant (b) Flowering and Leafing

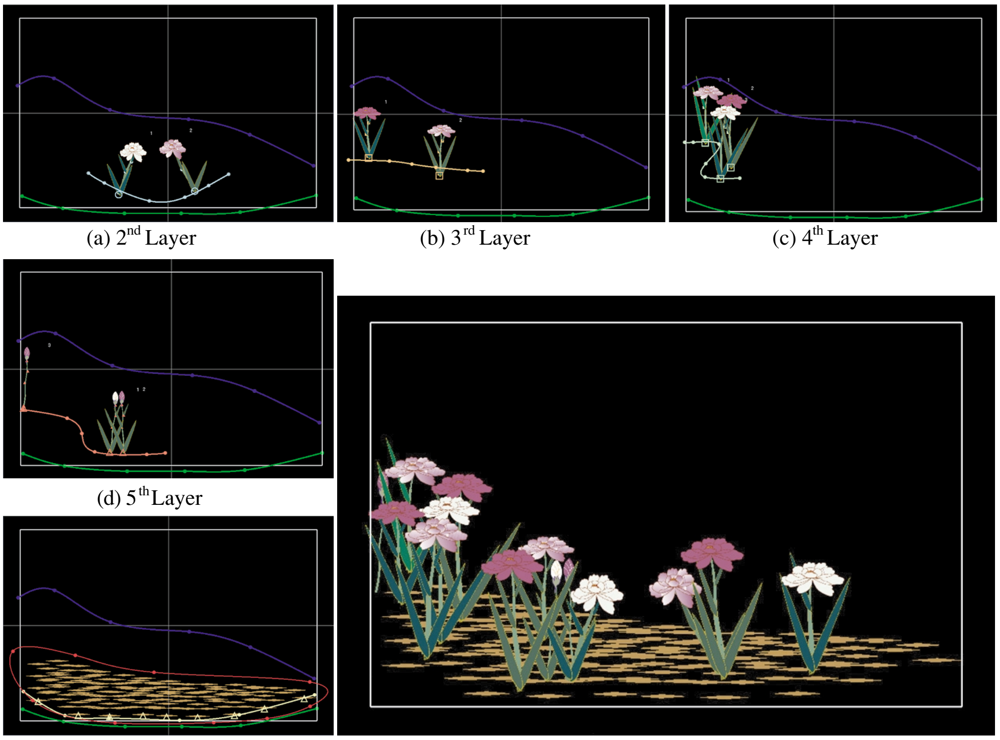
Fig. 15. Design in each layer.

4. Design Tool

This chapter describes the design tool for Kaga-yuzen, based on the algorithm for generating kimono patterns described in Sec. 3, and explains the design process in detail.

4.1. System overview

Kimono patterns are created with the following interactive design tool. Figure 12 shows the screen shot of the design tool; In the working area, as shown in Fig. 12(a), the user defines upper/lower boundary curves, and specifies base curve for each layer. As shown in Fig. 12(b), the target layer for design (A), the parameters for generating plant shapes (B), images of flowers and leaves (C–E), and texture for stem and branch (F), are specified separately as shown in the toolbox.



(a) 2nd Layer (b) 3rd Layer (c) 4th Layer

(d) 5th Layer

(e) Backgound Layer (f) Final Pattern

Fig. 16. Multi-layer design for kimono pattern.

4.2. Design process

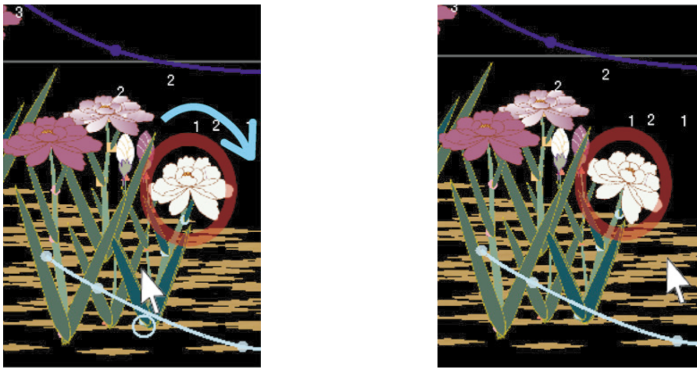
The design process consists of three main procedures, as shown in Fig. 13. First, the user designs an outline of kimono pattern by defining upper and lower boundary curves. And then, the user specifies plant figures for each layer. In this process, the user designs a base curve, specifies parameters for generating plants, and selects images of flowers and leaves. Finally, all the layers are merged, and the user adjusts and modifies the curves and parameters if necessary.

4.2.1 Designing upper and lower boundary curves

First, the user designs an outline of a kimono pattern by defining upper and lower boundary curves as shown in Fig. 14. The boundary curves are defined as Spline curves, and are modified by adjusting the control points. The user can also design the boundary curves by referring to the templates, which have been extracted from the artworks of skilled craftsmen.

4.2.2 Specifying plant shapes for each layer

In this system, the kimono pattern is designed with multi-layer structure. After the boundary curves design process, the user specifies plant shapes for each layer. In this



(a) Before Adjustment (b) After Adjustment

Fig. 17. Adjustment and modification.

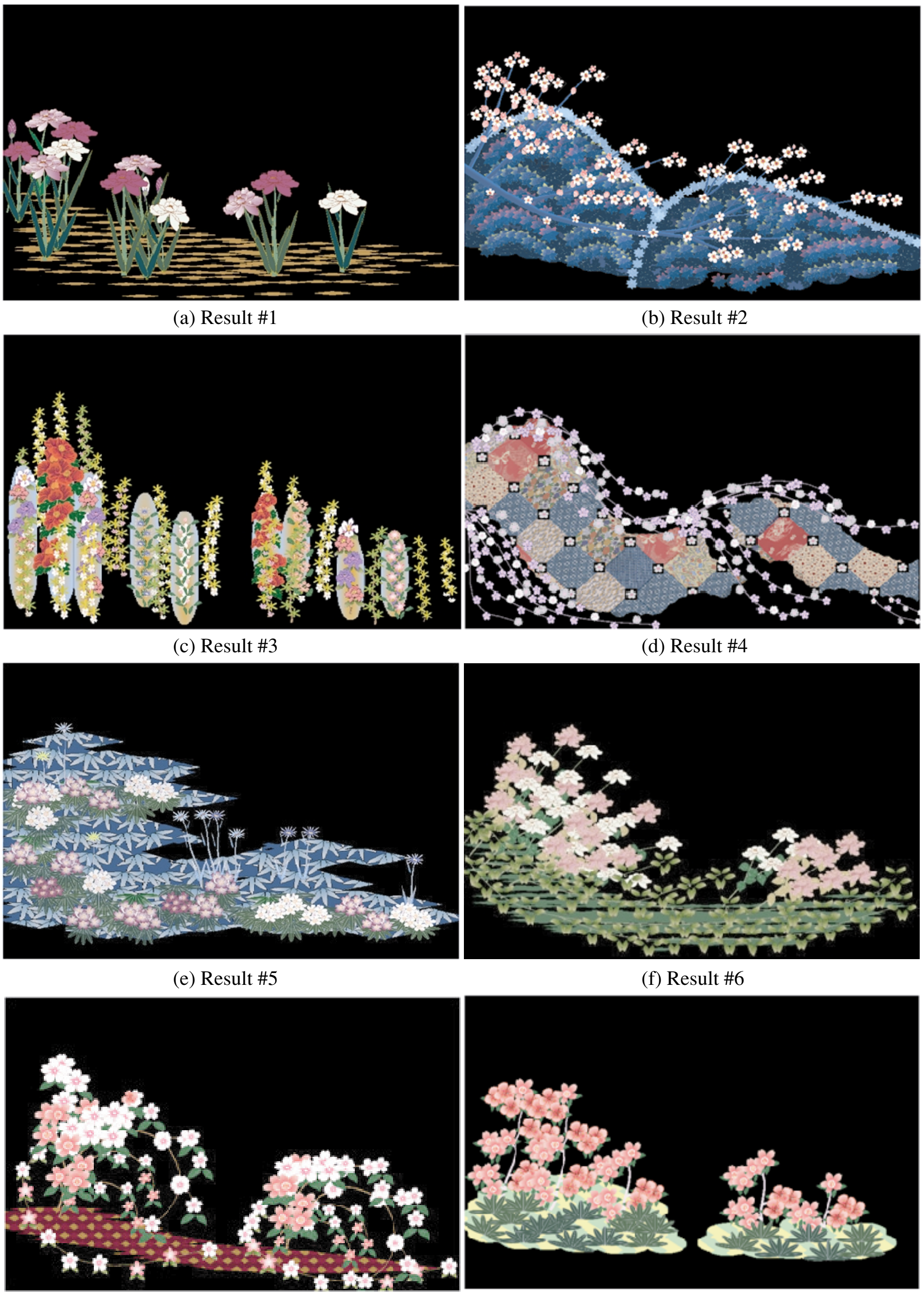
design process, the user specifies a base curve for the root of the plant pattern as shown in Fig. 15(a), in the same manner as designing boundary curves. The plant type, number of plants to be placed along the base curve, number of branches, and other parameters to generate plant pattern are specified in the toolbox as shown in Fig. 12(b). The plants are automatically spaced along the base curve uniformly at the default setting. And then, the plant patterns are decorated by flowering and leafing as shown in Fig. 15(b). Figure 16 shows the design process for each layer; the first layer is Fig. 15(b), and the final pattern consists of six layers including background layer.

4.2.3 Adjusting and modifying pattern

Finally, all the layers are merged, and the user adjusts and modifies the curves, locations of plants, parameters for generating patterns and so on, if necessary. Figure 17 shows an example of the adjustment and modification process. All objects, such as boundary curves and plants, are selectable by mouse in the system. In this case, the flower encircled by a red line is rotated clockwise by mouse operation. The user also can change the location and size of plants manually.

5. Results

This section shows eight examples designed by the proposed system. Figures 18(a)–(f) are practice examples inspired by the examples in the reference book (KAGA-YUZEN ARTWORKS COLLECTION, 1986), and Figs. 18(g) and (h) are original patterns. It took about forty to sixty minutes to design patterns from scratch. By combining the manual design process and computer aided pattern generation module, the user can design an attractive kimono pattern interactively and easily using the system. The multi-layered structure, which is generally used in design tools, makes it easy to design a complicated kimono pattern. We had the following comments from craftsmen on these results; “The examples are, on the whole, well drawn but rather unsophisticated.”



(a) Result #1
(b) Result #2
(c) Result #3
(d) Result #4
(e) Result #5
(f) Result #6
(g) Result #7
(h) Result #8

Fig. 18. Design results.

6. Conclusions

We have presented a method for creating a kimono pattern interactively. The proposed system applies the rules for designing kimono patterns, “flow” and “layered structure”, which have been extracted from the examples of Kaga-yuzen and the knowledge of craftsmen.

In this design support system, the user designs an outline of a pattern and specifies plant types to be drawn, and then the system generates kimono patterns automatically in detail. As a result, the user can design patterns comparable to professional artworks efficiently.

In the future, we would like to improve this system by investigating color harmonization, balance in size of flowers and leaves, and contrast in patterns. We also would like to refine the user interface to shorten the design process. For example, the system should place the plants on the curves semi-automatically, by referring to the positioning data based on the artwork of skilled craftsmen.

We hope the proposed method will contribute to archiving the knowledge of craftsmen in kimono design, and to creating a database and corpus for kimono patterns. We also hope to extend its application to other areas of design.

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