Design of Japanese Kimono using Interactive Genetic Algorithm

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***Abstract*—These days, customer not only selects a yukata from marketed yukata, but she also orders a custom-made yukata. When customer orders a yukata, it is necessary to show her favorite yukata to a designer. But if she has ambiguous image for her favorite yukata, it is hard to show her favorite design. We propose a yukata design system using an Interactive Genetic Algorithm (IGA). The proposed system is for designing a yukata to suit user's taste. From the assessment experiment of the system it was found that the proposed system proved to be effective in the designing of a yukata. In addition, we proposed additional functions that allow obi color mutation partially in search for the solution. And further experiments were carried out for the verification. The results indicated the effectiveness of the additional functions.**

***Index Terms*—Optimization, Interactive Genetic Algorithm, Yukata design system, Color combination**

I. INTRODUCTION

Yukata is a traditional garment often worn during outings to traditional events in Japan, such as mid-summer night fireworks shows and festivals. While similar to kimono, yukata is thinner and lighter - a sort of cooler kimono. It is a special garment that comes with a distinctive Japanese flavor, and is especially popular among young women. Conventionally, designs of yukata were often fixed and traditional, but a variety of designs have become commercially available nowadays. And customer not only selects a yukata from marketed yukata, but she also orders a custom-made yukata. This is testament to the fact that people pay great attention to the design of a yukata.

For this reason, a system that designs a yukata to suit personal taste can be useful. "Adaptive Texture Alignment for Japanese Kimono Design"[1] and "Design Support System for Japanese Kimono"[2] are proposed as a system which designs a yukata. These sysytems design a yukata automatically by the way user decides cutting place of the yukata fabric. That is, these systems are used for a fixed design. If user has image for her favorite design of yukata, it is convenient that user can arrange yukata variously by using one design. If user has ambiguous image for her favorite design of yukata, it is unconvenient for user. Because it needs to prepare a design of yukata. It is desirable that any user can design favorite yukata. There is an Interactive Genetic Algorithm (IGA)[3] that serves as a method of reflecting such human sensibility. There are systems that employ this IGA, such as "3-D CG Lighting"[4], "Application of fashion design"[5] and "Design of Sign Sounds"[6].

However, there has yet been no research on the designing of yukata using IGA. For this reason, this study proposes a yukata design system that adopts IGA to create a yukata that accommodate user's taste. The proposed system supposes a scenario with ordinary users who would wear yukata and designers of yukata. There would be two usages for ordinary users. The first being custom-made yukata, where even users who have no design experience can make original yukata by printing out designs made with the system directly onto yukata fabric. The second being users purchasing a yukata close to their taste from those available on the market. The system can assist users find their preferred yukata through innumerable ones available to search for the yukata similar to one designed with the system. Meanwhile, by using the system a designer can come up with innovative designs like never before. In other words, the system will be able to help inspire designers.

II. YUKATA

Yukata[7][8] is a traditional Japanese garment often worn in mid-summer. Yukata is typically made from such fabrics as cotton or polyester. While resembling kimono, yukata is the thinner, lighter and cooler version of kimono. Yukata is shown in Fig. 1. Starting from 4000 yen, the price of yukata is affordable. It is worn for attending traditional events that take place in mid-summer, such as fireworks shows and festivals. For that reason, people have the opportunity to wear yukata about twice a year on average. In general, a Japanese people would own about three yukatas. There are shops that offer custom-made yukata service, and there is a high awareness of the design for these yukatas. To this end, we are proposing the yukata design system that makes designing yukata to user's taste possible.

III. INTERACTIVE GENETIC ALGORITHM

This study adopts IGA to bring out potential preferences and aims to build a computer-proposed design system to achieve yukata designs that will satisfy users and designers. An IGA is a Genetic Algorithm (GA) [9] which simulates evolution of organisms, where the evaluation part of the GA is handled subjectively by a human being. In problems which cannot be

Fig. 1. Yukata

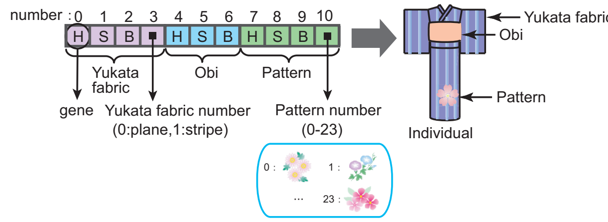

Fig. 2. Chromosome encoding.

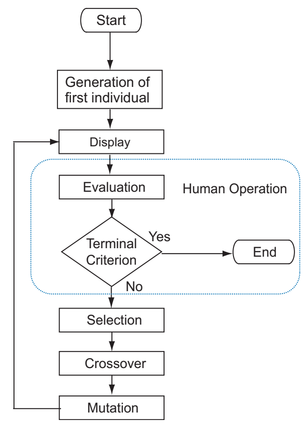

Fig. 3. Flow chart of yukata design system.

numerically quantified because they involve the impressions and tastes of human beings, optimization is done based on evaluation according to human sensibility.

IV. Yukata design system employing an IGA

A. *Chromosome representation of a Yukata*

In this section, we describe how the yukata is modeled in the proposed system.

- A yukata consists of three materials: a fabric, an obi (sash of yukata), and a pattern on the fabric. These parts are represented by various colors. Although there are many varieties of yukata fabric designs, in this research, we deal with two representative types of them — a plain color type and a striped one. Moreover, we prepared 24 varieties of patterns.
- For color representation, RGB and HSB color systems are often used. In this study we use the HSB [10], which is based on the human color perception, to represent the color of each part of the yukata. In the HSB model, the color is defined by "hue", "saturation" and "brightness". Hue describes red or blue color. And it is circularly represented by an angle between 0 and 360 degrees, and is called " hue circle." Saturation indicates the intensity of color with values between 0 and 100. Low saturation color would show grayish and murky tone. Brightness also varies between 0 and 100. When the value is 100, the color becomes white, while it shows black when its value is 0. In such cases the values of hue and saturation make no sense.
- One yukata represent as a chromosome. Yukata is encoded into a chromosome as shown in Fig. 2. Each gene carries numeral information concerning the HSB color values, the fabric design number, and pattern number of each material. This study uses normalized values between 0 and 1 for the saturation and brightness within the HSB color system. The fabric design number contains 0 and 1, where 0 indicates plain and 1 means stripes. As shown in Fig. 2, numbers are given to each pattern.

B. *The process of the yukata design system*

The process of the yukata design system with IGA is shown in Fig. 3. The process of each stage within Fig. 3 is as follows:

- Generation of first individual: Color of the yukata fabric, color of the obi, color of the pattern, fabric design, as well as type of design are randomly selected to create multiple individuals. Users and designers select their preferred individuals from these. The user interface to accommodate user selection of individuals is shown in Fig. 4. In our system the initial individuals are those selected by the user and new ones randomly created by the system.

Fig. 4. Userinterface for selection of first individuals.

- Presentation: 12 individuals are presented to the user through the user interface. Example presentations are given in Fig. 5.
- Evaluation: In response to each presented individual, the user is asked to use the buttons or slide bar provided to give evaluation based on the subjective view of the user. Evaluation by use of buttons requires the user to select points on a five-point scale, while evaluation by use of the slide bar asks the user to indicate the level of preference. The values of the evaluation will then be taken

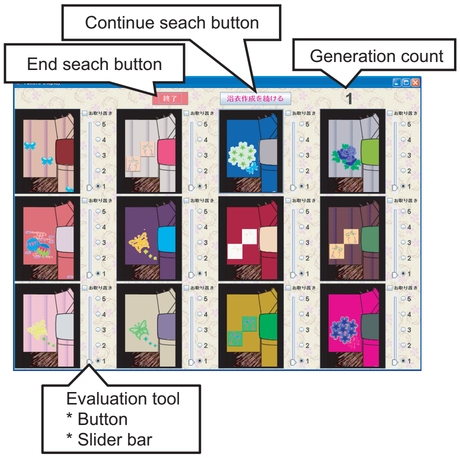

Fig. 5. Display.

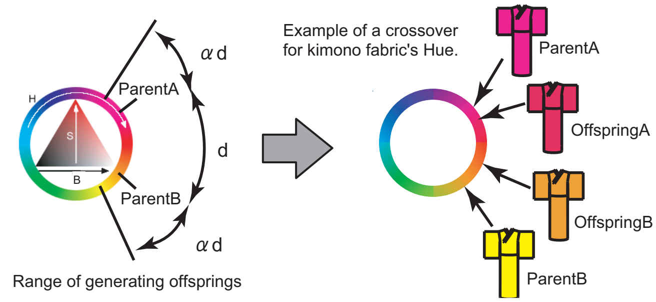

Fig. 6. Crossover.

as fitness values within the IGA. The user can freely chose whichever method to use for the evaluation. In addition, selecting the KEEP button will allow the user to keep any of the presented individuals completely for the next-generation. The individuals here are recognized as an Elite Individual within the IGA.

- Terminal criterion: The search for solution terminates once individuals preferred by the user are created.
- Selection: The system uses tournament selection and elitism. Tournament selection is a selection method where n numbers from the population are randomly selected, leaving only those with the highest fitness level. In this study, we suppose n=2 and that 12 individuals are selected from 12 times of application. Elitism is a method that unconditionally leaves only individuals selected as elite individuals.
- Crossover: This system uses BLX-α[11], which allows the creation of offspring individuals with colors closely resembling those of their parent individuals. BLX-α is a method where offspring individuals are created within the scope created with the plus and minus of α-times of the difference between the two parent individuals. The locus of 0, the example of crossover of yukata fabric hues, is indicated in Fig. 6. In Fig. 6, parent individual A is represented in reddish purple and B in yellow. From these parent individuals we get the red offspring individual A and the orange offspring individual B. In such system where colors are treated this way, the creation of colors close to the parent individuals is important. This system adopts BLX-α as a method that provides this functionality.
- Mutation: The gene values are altered at a certain probability rate. The altered values are randomly decided by the system within the design space. Through this we get changes in the color of the yukata fabric, the color of the obi, and the pattern.

V. Experimental evaluation of the proposed system

A. Experimental overview

Experiment is conducted in order to verify whether user-preferred yukata designs could be created using the proposed system. The proposed IGA system is compared with a manual design system. In the manual system, users create their favorite yukata by manually adjusting the design parameters as they like.

Subjects of this experiment are 18 men and women in their 20s. Experimental subjects create women's yukata, based on the design concept given for them. Male subjects design the yukata which suits women who go to see fireworks show, and females do to wear them for fireworks show. The concept is reflected in the interface of the systems by pasting the picture of fireworks on the background of the yukata displayed in the screen. To get used to the systems, the subjects design a yukata through 3 times for each system. In addition, the following questionnaires are given before and after the experiment, to verify the effectiveness of the proposed system:

1) Question 1 (Before the experiment)
How specifically can you image the features of yukata which suits the design concept?
2) Question 2 (After the experiment)
Were you able to design the yukata that fitted the design concept using this system?

B. Experimental results and analysis

Samples of final designs created by experiment subjects using these systems are shown in Fig. 7. From Fig. 7 we can see that the subjects were designing yukata with various types of design and colors.

The results of Question 1 are shown in Fig. 8, from which we can say that there were many subjects who, while not able to express in words, had a general image of what their preferred yukata should look like.

Next, the results of Question 2 are shown in Fig. 9. Fig. 9 shows a difference between the IGA system and the manual design system. It was shown that the differences were statistically significant (sign test, $P < 0.05$).

From the result, we can say that it is possible to design highly satisfactory yukata by using the IGA system. On the other hand, the yukata designed using the manual design

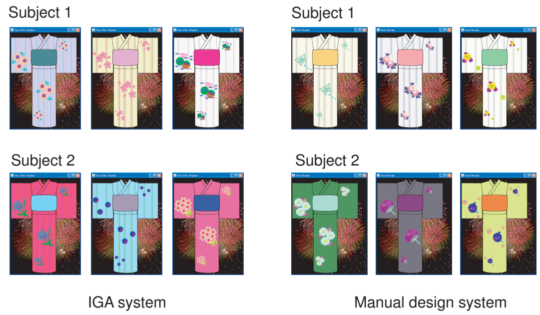

Fig. 7. Final designs.

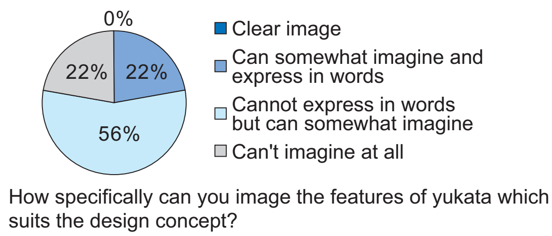

Fig. 8. Result of questionnaire item 1.

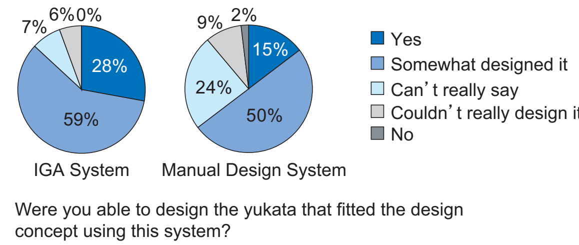

Fig. 9. Result of questionnaire item 2.

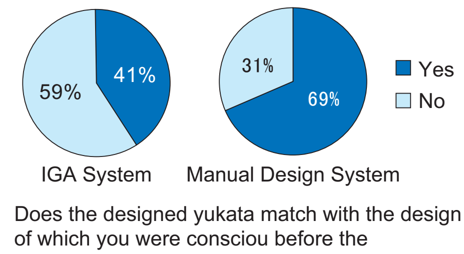

Fig. 10. Result of additional question.

system has a low degree of satisfaction compared with the IGA system. Since there are few subjects who have image of their favorite yukatas clearly, it is thought that the manual design system was difficult to indicate their favorite designs. This assumption was confirmed through the comments from the subjects.

Furthermore, the following question were carried out to the subject.

- Additional question
  Does the designed yukata match with the design of which you were consciou before the experiment?

The results of additional question are shown in Fig. 10. The difference of the result between the IGA system and the manual design system was statistically significant (binomial test, $P < 0.05$). The subjects designed their favorite yukatas of which they are conscious using the manual design system. On the other hand, using the IGA system, they created the favorite designs which had not been imagined before the experiment.

Therefore, we can say that the proposed system is effective to discover new preferences of the user, that is, it can be used as an idea generation support system. From the above discussion, the effectiveness of the proposed IGA system was shown.

Even users who have an ambiguous image of a favorite yukata can design a satisfied yukata using the IGA system. As mentioned above, we can say that the IGA system can help design yukatas that will satisfy users and designers by clarifying the potential images users and designers possess. It is effective to use IGA as the technique of designing a yukata.

Moreover, we were able to gain constructive opinions concerning the improvement of our system from the subjects. One is the request for an additional function to allow marginal changes in the color of the obi. It became clear that many subjects at the initial stage of the yukata design process tend to evaluate mainly the colors and patterns of the yukata fabric, and once these converge to some degree with the subjects preferred colors and patterns, they moved on to the color of the obi. From this perspective we have considered adding a function that can randomly change the color of the obi at any generation, whenever users may feel the wish to do so - that is, a function to allow obi color mutation.

VI. Verification of the Effectiveness of Additional Function

A. *Experimental overview*

In order to verify the effectiveness of the additional function mentioned in V-B, an experiment is conducted to compare the revised system having the additional function with the system that lacks it. The systems used in this experiment are as follows:

- Basic system (overall mutation system): a system where constant mutation occurs in all design variables.
- Improved system (overall/partial mutation system): a system with constant mutation, but also able to create mutation only in the design variables representing the obi color indicated by the user in any generation.

The improved system is the basic system with an added button to change obi color randomly. The user interface for when using this button is indicated in Fig. 11.

The button comes with the following features:

1) Create mutations in the obi color of only individuals that were stochastically selected.
2) The button can only be used in one generation of whatever the user wishes to use and can be used as often

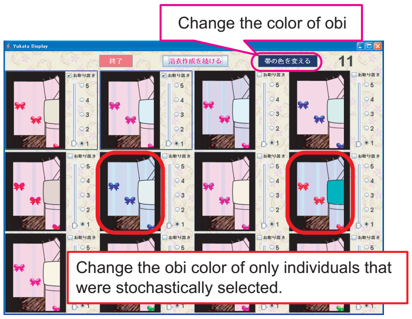

Fig. 11. Userinterface after action of the button.

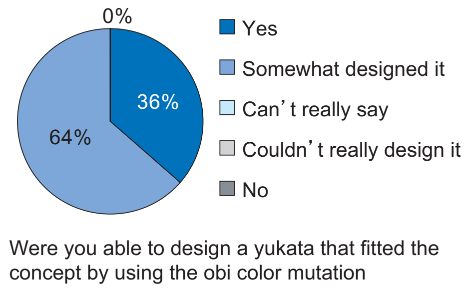

Fig. 12. Result of questionnaire item 3.

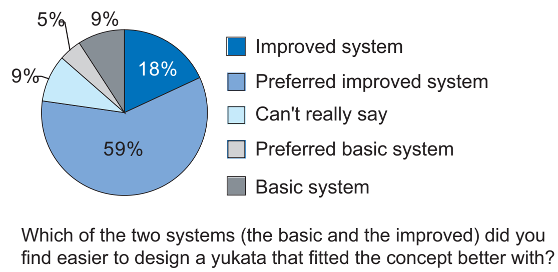

Fig. 13. Result of questionnaire item 4.

as desired within that generation. Once the button is used in a certain generation, it will not appear and be available for use in the window showing the next generation.

The reason behind the setting in feature 1) mentioned above was so that the following evaluation may be conducted: As mentioned in V-B, users and designers mainly evaluate the fabric and pattern of the yukata initially when designing yukata; and not without a certain degree of evaluation on the color of the obi. For this reason, it became vital to keep the format inherited up to the mutation of the obi color. From this we felt that it was important to create mutation in minority individuals stochastically selected, rather than in all individuals. Meanwhile, the reason for the setting in feature 2) can be explained as follows: Since the probability of selecting a mutated individual in our experiment was set to 0.3, by using the additional function twice or three times in any generation users will get obi color mutations in nearly all individuals. In such case, there is a possibility that the format of obi color inherited may vanish. For this reason, we limited the use of the additional function within only one generation.

Subjects of this experiment are 22 men and women in their 20s. The yukata design concept is also the same as that given in V-A. Subjects are asked to design yukata by using both the basic and the improved systems. After the experiment, the following questions are carried out to the subject.

- Question 3
  Were you able to design a yukata that fitted the concept by using the improved system?
- Question 4
  Which of the two systems (the basic and the improved) did you find easier to design a yukata that fitted the concept better with?

B. Experiment results and analysis

The results of Questions 3 are shown in Fig. 12, from which we are able to say that the improved system can also be used to create highly satisfactory yukata designs.

Next, the results of Questions 4 are shown in Fig. 13. In order to determine whether this difference is statistically significant or not, we have performed a sign test. This difference was significant($p < 0.05$). The result shows that the improved system was easier to use than the conventional system for creating yukata that fits the given concept.

The effectiveness of the additional function within this improved system, i.e. the system to force mutation of obi color, is verified. Therefore, we investigate of all subjects the elite individual selected after the mutation. Fig. 14 shows the presented individuals prior to the obi color mutation, as well as those after the mutation.

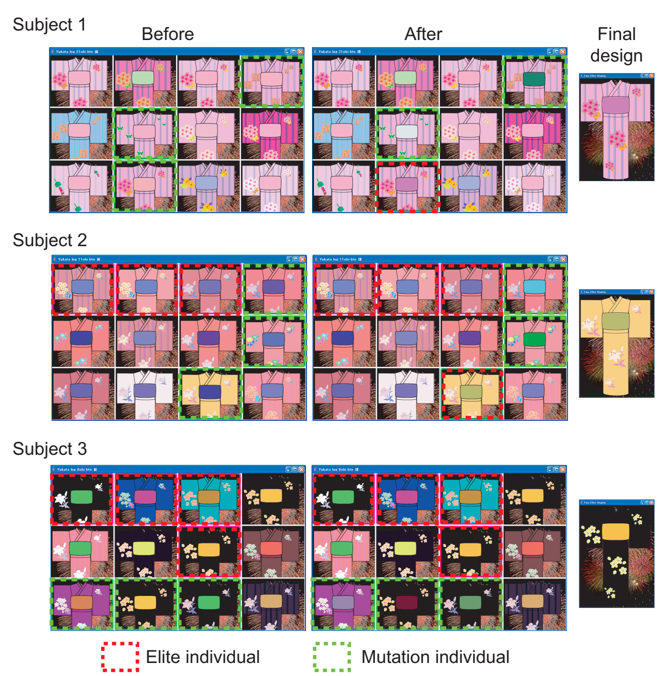

Fig. 14. The effect of the additional function.

The result of investigation, 13 subjects had chosen individuals with obi color mutation. The number of people who selected mutated individual was more than the number of people who didn't select mutated individual. However, the difference were not statistically significant (binomial test, $P < 0.05$). We found that the improved system requires further consideration of the following items:

- Generations where the button to change obi color randomly can be used
  The populations which are shown to subject 1 and 2 in Fig.2 before executing the mutation converged.I However, in the case of subject 3 it did not converge as much. We believe that the additional function would likely have been used in the latter part of the evolution process, though there were also subject users who used it in the first part of the process. From this we found that, while users could freely use the button to change obi color to change the color of the obi in any generation, the difficulty lies in the timing of the use.
- Mutating individuals
  Using the button to change obi color will bring mutation in stochastically selected individuals. That is, users have no knowledge of which individuals will mutate. From our experiment questionnaire we received the request for the ability to designate the individuals to mutate.

We will consider the suggestion and hope to further improve the system.

VII. Summary

This study proposed a yukata design system that uses IGA to design yukata to suit user's taste. From our experiment we found that our proposed system was able to effectively create highly satisfactory yukata. In addition, from interview surveys conducted during the experiment we received the suggestion to improve the system by allowing obi color change. To that end, we added a function that allowed obi color to mutate in any one generation as desired by the user while in search for the solution. From the result of experiment that we verify effectiveness of the additional function, the proposed additional function was indeed effective. We found that the proposed additional function was effective from the result of questionnaires about palatability and the ease of use through the experiment. However, we didn't establish the effectiveness through the selection history of elite individual. The detail of additional function needs further consideration.

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