

User Interface Providing Support for Creating Artistic Patterns

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SUMMARY

As design work using computer spreads, usage environments are appearing which have operations involving aesthetic sensibilities via the GUIs in a variety of graphics software and have the representational capacity to represent three-dimensional images and images with the feel of oil paintings. However, their operation still relies on the user's sensibilities and knowledge. In this paper, we propose a user interface for a user support system for creating artistic patterns. Its features are summarized by the following three points. First, the system has knowledge about designs. The result of design analysis provided the following knowledge. (1) The elements producing a design are the colors, shapes, and composition. (2) To turn an image into a pattern, the image is conceived of as a specific scene, then the pattern can be drawn by extracting the colors, shapes, and composition based on the scene by combining these elements. This knowledge is held in the system. Second, there is a user interface to easily transmit the image to the system. The media to convey kansei (affective information) are considered to be both linguistic and nonlinguistic. And an interface was designed to enable direct manipulation by pen or mouse to select from a list box of a three-level kansei language and to select from a pattern candidate group. Another user interface was designed which accounts for the inability of a person to grasp the kansei from the start to completion and allows repeating the kansei specification by the user and the presentation of patterns by the system. Third, there is a mechanism that automatically creates the pattern in response to the user's kansei. We designed an

algorithm to create a design by (1) using fuzzy logic to deduce the user's image and (2) creating the pattern by using the parameters needed to draw the pattern which were extracted from the deduced image. Furthermore, we developed a support system for creating artistic patterns that has the above functions, and had multiple testers test its operation to verify the system's effectiveness in application tests on real problems. © 2001 Scripta Technica, Syst Comp Jpn, 32(11): 20–37, 2001

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1. Introduction

Accompanying the rapid spread of the latest personal computers and workstations, design work on computers using graphics software is continuing to expand. Various graphics software enable operations involving the senses by means of a graphical user interface (GUI). The representational power of three-dimensional image representations and reproducing the ambience of oil paintings by using computer graphics (CG) technology has expanded and is making advanced environments available. However, in the current situation, these operations still rely on the senses and skills of the creator.

In most graphics software, a design can be created by selecting the buttons for primitive shapes such as circles, rectangles, and freehand curves from a palette and laying

them out in a window, then defining their colors and other attributes. But decisions like “what shape to use” and “where to place the shape and what color to make it” are left entirely to the user. To turn an image floating in one’s head into a particular design is a heavy burden to a user who lacks the sensibilities or specialized knowledge.

Thus, research on systems to support creating artistic patterns has advanced when the system can understand the user’s *kansei* (affective information) and support the operations until the user’s image becomes a pattern and eliminates most of the problems described above [1–4].

In this research, we report on a system for supporting the creation of the user’s designs that focuses on abstract designs of color two-dimensional geometric shapes of points, lines, and planes and infers the image the user wants to draw while the pattern is being conveyed between the user and the system.

Section 2 presents the approach taken in this research which analyzes previous research on idea support in image media and *kansei* information processing and summarizes the problems. Section 3 analyzes the knowledge needed to turn images into patterns and defines the knowledge the system should possess. Section 4 considers the necessary conditions in the user interface to support the operation to make the image floating in one’s head into a specific pattern and designs the user interface based on these conditions. Section 5 describes the algorithm that uses fuzzy logic to infer the design image the user wants to draw and the algorithm that automatically creates the pattern as the technique to implement the proposed system. Section 6 presents the system evaluation tests. Section 7 describes future issues. Section 8 summarizes the results.

2. Analysis of Previous Techniques and the Approach Taken in This Research

2.1. Research objective

Many people have amazing sensibilities, but a large gap exists between one’s strengths and weaknesses in grasping, understanding, and expressing these amazing sensibilities in an individual. Even if a computer could provide a little support in an activity involving the sensibilities in a person weak in this activity, it may be useful in the support of ideas and creativity, cultivating the hidden needs of users, and searching for information.

This research focuses on design as one issue in research on *kansei* information processing that handles image media and implements a system to support the creative activity of drawing designs. The objective is to support the task of representing the conceptual image of *happiness* or *sadness* as an abstract pattern of color two-dimensional

geometrical figures of points, lines, and planes (e.g., Fig. 4).

2.2. Existing research problems

References 5–8 and 34 discuss research on supporting designing on computers. In Ref. 34, the production of a multimedia product is supported by repeating the operation of the user specifying the concept or method, followed by the system presenting related design knowledge based on this specification. Reference 5 uses a genetic algorithm to create a layout plan and fuzzy logic to evaluate its impression to support the creation of posters. In Ref. 6, quantification method I, which is one type of multivariate statistical analysis, is used to build a *kansei* model to support the creation of written forms (arrangement or layout) from a questionnaire on impressions. Reference 7 proposes a conceptual model of the *kansei* synthesis processing of multimedia information handling image and sound information and creates a support system for creating the multimedia presentations. Reference 8 applies associative memory and fuzzy theory to study *kansei* data processing to support system kitchen design.

One advanced measure is a proposal [33] for design support that uses the system’s knowledge to perform criticism. This technique has been analyzed in research [36, 37]. Reference 35 presented existing research on the collaboration between people and computers and summarized the research approaches taken in this field.

Previous research on image media and *kansei* centered on research that adopted color as the theme [9–13]. This research analyzed the relationship between the colors and color scheme and their impression on people, and extracted, understood, analyzed, and represented the *kansei* information. For example, Ref. 10 proposes a technique to pick out the “conspicuous” colors from a picture and select the image colors of that picture. There has also been research on extracting composition elements other than color [15, 16]. For example, Ref. 15 extracts the impression given by the composition through image processing. Research [20] handling patterns and color builds a *kansei* model using fuzzy logic and evaluates handkerchief designs. Other research [21], which adopts composition and color, automatically creates scenic images from written descriptions of a scene. The research in Refs. 17–21 combines multiple elements connecting the *kansei* such as color to composition and color to pattern. There is abundant research [11–14] on handling *kansei* information as one technique for searching images. For example, the research on *kansei* databases and search systems [11–13] presents candidates in response to the input of *kansei* words such as adjectives based on the relationship between the *kansei*

words and the image data determined beforehand statistically.

As shown above, there is a great deal of research, but the problems summarized below become the research issues in the implementation of a support system for creating abstract two-dimensional patterns, which is our research objective.

(1) Insufficient knowledge in the system

To support the design work of a user not possessing the knowledge or sensibilities for design, support is not possible if the system cannot provide these elements. If the system does not possess the knowledge, it will not be able to understand the design the user wants to draw nor assist in the creative activity of drawing a design. To give the system the knowledge related to design, the elements which must be considered are what kinds of elements should form a design, which features produce the design of the image imagined by the person, and what elements are to be combined and how to combine the elements to represent the image as a design.

Research [9–13] dealing with color and research [14, 15] addressing composition merely handle only one kansei element. And research on color and pattern [20] or color and composition [21] adds one more element as a primary element but only handles two kansei elements. This research focuses on a portion of the kansei elements, but is limited to analyzing these elements individually and cannot comprehensively analyze the kansei knowledge of humans. In particular, the design knowledge used in existing techniques cannot be adequately applied to designs based on geometric figures, which are the targets of this research.

(2) Discussion of the user interface for conveying kansei

In tasks performed cooperatively by humans and computers, the mutual communication of their intentions greatly affects the task results. When conveying vague information such as the image underlying a design, more attention must be paid to this communication state. To enable an image to be conveyed by the easiest communication means to the user, based on the above consideration (1), what should be considered when conveying the design and image between the user and the system must be analyzed, and the user interface must be designed.

In research [5] on support for creating posters and research [6] on support for writing documents, the user only uses the words of the kansei language to convey his preferences to the system. Vague information such as a person's preferences or an image is difficult to convey by only using these words. We must be able to convey more of the artistic sense to the system.

The kansei language and impression language for expressing kansei which are used in Refs. 5–8 are merely

abstract, standard words such as *simple* or *lively*. Although the image you wish to draw may be abstract in this way, the vagueness of these words is irritating when the image is more clearly defined. Kansei and images cannot flexibly handle the feature of an expression in a variety of words by a person.

In particular, because the designs targeted in this research have a high degree of abstractness, and the gap between the design or image and the artistic work is large, a user interface which easily conveys kansei is sought.

(3) The lack of algorithms to automatically create designs

The user's image cannot be completely understood from only vague information about the design or image conveyed by the user to the system. Similar to the response of people to some words, the system must infer the user's kansei while supplementing associated information which provides different elements from the vague information.

Kansei is often involved when a person uses a pen to draw a picture on paper or canvas. For example, a person can draw a picture given a general description of "draw a rough line from the bottom to the top" on the drawing paper, but a computer cannot act like a person. A computer cannot draw a picture unless very detailed and specific items or actions such as "Draw an X centimeter-thick line in the direction of Y degrees to Z centimeters from the bottom of the drawing paper." In other words, we must consider how to create a design if some parameters are used in some way to create it. However, no one has proposed an algorithm to automatically create a color design composed of these types of geometrical figures.

2.3. Approach taken in this research

As solutions to these problems, our research advanced the approaches (i) to (iii) presented below for problems (1) to (3) described above.

(i) Analyze the relationship between the design and the kansei of people. If we analyze what elements are required to create the design and how to represent the image as a design if these required elements are used, the process for drawing a design will be understood. (See Section 3 for a detailed description.)

(ii) Study the necessary conditions for the user interface to support the task of creating a specific design from the image floating in one's head. Design an interface which considers what types of media to convey kansei and how people perceive and understand kansei. (See Section 4 for a detailed description.)

(iii) Study algorithms to infer the image thought of by the user from the vague kansei information conveyed to

the system by the user. And separately analyze the parameters needed to actually draw the design for each design element found in (i). Study algorithms to automatically create the design using these parameters. (See Section 5 for a detailed description.)

3. The Knowledge Required to Turn an Image into a Design

We analyze the knowledge of a designer to support the task of the system drawing a design from an image. The designs handled by this research consist of color geometrical figures.

- First, how a design is constructed from the elements to express the image must be clarified.
- How the image is related to the elements and how the elements can be combined to express a design must be analyzed.

Each factor is discussed below. For general remarks concerning analyzing kansei related to design, see Refs. 22–24 about algorithms that visually express a design.

3.1. Kansei elements in artistic patterns

First, we clarify what features of a design are connected to kansei. Many of the algorithms in previous research that handled images and kansei often constrained the targets to elements such as only color, only composition, or only color and composition. Using only these elements to build an entire design is inadequate.

The elements to build a design are colors, points, lines, planes, materials, composition, space, time, light, smells, heat, and sounds. Of these, we consider the ability to express the visual kansei based on the two-dimensional geometrical designs targeted in this research. Space and time are not included because there are two dimensions. Smells, heat, and sounds are not included because the expression is visual. Materials and light are not included because the elements are geometric. Based on the above studies and the analyses in Refs. 22 and 23, the elements required in the limited range of this research were the colors, points, lines, planes, and composition. The three structural elements in this research are color, composition, and shape, which is the general term referring to points, lines, and planes.

These three elements of the color, shape, and composition carry kansei information, and are probably the indispensable elements that visually appeal to people.

If designs are drawn from the same lines and shapes but in different colors, they have very different impressions

on people. For example, if a square box is black, it seems heavy, but if a light color, it seems light. Even if the colors are the same but the shapes differ, the impressions on people differ. For example, a square shape colored blue gives the impression of calmness, while a round shape having the same color gives the impression of flowing motion. The contents that can be expressed change with the placement of the shapes in a frame. Regularly aligned points seem static, while randomly placed points give the impression of motion.

If kansei is expressed by two-dimensional geometric designs, the three elements of color, shape, and composition (arrangement of the shapes and colors) are required to build the entire design. Not only does each element have independent kansei information, but each is connected to the others. There is also overall kansei information created from combinations of these elements.

3.2. Process to turn the image into a design

To express an image by a design, the color, shape, and composition must first be handled comprehensively. In this paper, we consider the kansei process until a specific design is produced from an image.

When an image is floating in your mind, it is not recalled in words, but is always recalled as specific situations and pictures called shapes and images. For example, consider the kansei of *happy* expressed as a design (Fig. 1). First, we imagine what kind of situation is *happy*. If this situation is put into words, a smiling face, palpitations, jumping, openness, cheering, exaggerated gestures, and a blushing face emerge. Next, the features of the elements (color, shape, composition) forming the design are discerned from these words. If the color is based on a smiling or a blushing face, features such as (1) a bright color and (2) yellow or red can be extracted. Because the shape jumps, is open, or is an exaggerated gesture, (1) an energetic shape, (2) open shape, (3) dynamic shape, and (4) round shape can be extracted. Because the composition palpitates and makes you cheer, (1) the repetition of similar shapes and (2) a rhythmic composition are considered. The features of the extracted elements become clues and are combined to embody the vague image.

3.3. Summary

The knowledge required to turn a design into an image is summarized below.

- The elements forming the design (of color geometrical shapes such as points, lines, and planes) are the colors, shapes, and composition. Since these elements are interrelated, the elements and

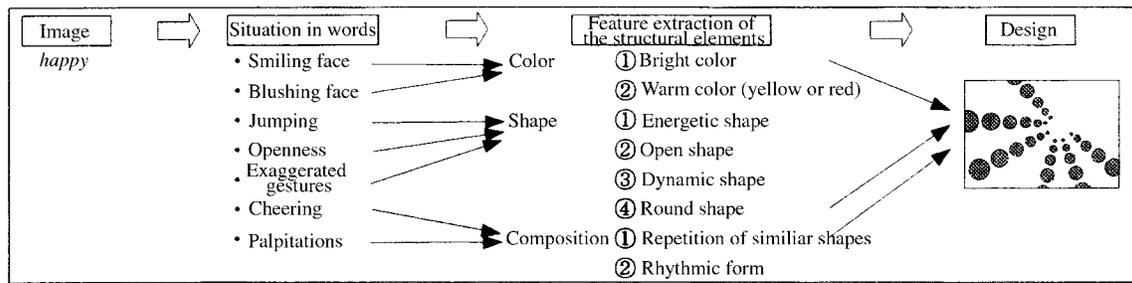


Fig. 1. An example of image materialization.

comprehensive knowledge about them are required.

- The process of turning an image into a design consists of describing in words the specific scene of the image → extracting the features of the colors, shapes, and composition based on the words → combining these features. Therefore, the knowledge to express the “image,” “specific scene,” and “feature of each element” and the knowledge to express the relationships among them must be provided.

4. User Interface Design

4.1. Conditions to be satisfied by the user interface

Kansei will always be a vague and obscure concept. Here, we consider the effect on the user conveying the kansei to the system, or the system to the user.

The problem becomes what form to convey objects which do not capture kansei. Table 1 lists the media for conveying kansei. They can be broadly divided into linguistic and nonlinguistic. If there is kansei which can be expressed in words, there is also kansei which cannot be

Table 1. Media to convey kansei

Linguistic
•Kansei with high degree of abstraction
•Kansei with low degree of abstraction
Nonlinguistic
•Illustrate similar creative work
•Actually draw and revise a design

expressed in words. The way to express kansei differs with the individual. If words are the medium, the expression can be divided into two classes. Kansei can be expressed with a high degree of abstraction, for example, “I want to draw an invigorating design.” And kansei can be expressed with a low degree of abstraction as in “something brought together in blue.” However, in the nonlinguistic case, the expressions can be divided into expressions which can convey the kansei by pointing to an object resembling the design you want to draw and indicating “a design similar to this,” and expressions where you actually draw on, add to, and revise some design presented to you.

Next, we must consider a common occurrence in which the person has difficulty understanding the kansei from the start to completion. This means that the kansei cannot be conveyed even once. There is also kansei which is understood at the outset. Although often the starting point is partial understanding, what is provoked by sight or sound gradually expands and clarifies the kansei you are searching for.

Thus, a system handling kansei to support drawing artistic patterns can use the form of kansei (linguistic or nonlinguistic) which is the easiest to convey to the user in order to convey as much of the user’s kansei as possible. The system must provide a function to reveal kansei which the user is not conscious of.

Furthermore, the knowledge required to express the image analyzed in the previous section as a design must be supported for the user interface. Based on this subsection and the previous section, the requirements of the user interface can be summarized in Table 2.

4.2. Interface design

Based on the analysis given in the previous subsection, we will design the interface for a system handling kansei.

Since the ways to convey kansei are not uniform and both linguistic and nonlinguistic forms are assumed, the

Table 2. Requirements

- | | |
|--|-----|
| •Elements forming the design: colors, shapes, composition | (1) |
| •Process to turn an image into a design:
Image → Specific scene → Element feature
→ Design
(High-order kansei) (Low-order kansei) | (2) |
| •Conveying the kansei | |
| •The form to express kansei is not uniform
Linguistic: Kansei having a high or low degree of abstraction | (3) |
| Nonlinguistic: Present a similar creative work | (4) |
| Actually draw and revise the design | (5) |
| •The kansei from the beginning to completion cannot be understood | (6) |

technique to convey the user's design and image to the system must allow inputs having both forms.

When the input is linguistic [(1), (2), and (3) in Table 2], the words to be input are freely expressed by the user or are selected from a specified frame. We adopt the latter in this research and use a mouse for input. Since several processes are performed until the image is expressed as a design [(2) in Table 2], the words expressing kansei can be divided into several levels and selected to match the process. From the analysis in Section 3.2, the words are divided into at least the three types of the most abstract words expressing the image, the words expressing a specific scene, and the most specific words to express the features of the design elements. From the analysis in Section 3.1 on the design elements, we found that the colors, shapes, and composition were required, and divided the words for each design element into three classes. The linguistic input based on the above designs an interface for selecting from a list box divided into abstraction levels (top of Fig. 2). Since the kansei of the user varies greatly, many expressions can be selected to closely approximate one's kansei from the three types of linguistic expressions. To convey the subtle kansei of the user when words are selected in the list box, a dialog box appears to set the degree of preference for those words. Then one adverb or adjective—*less*, *average*, or *more*—can be selected (bottom left in Fig. 2).

When the input is nonlinguistic, the two methods are a method to express the preference when presented an example of similar work and a method to express the preference by actually drawing the design [(4) and (5) in Table 2]. If an example of similar work is presented [(4) in Table 2], the preferred design is selected from the choices

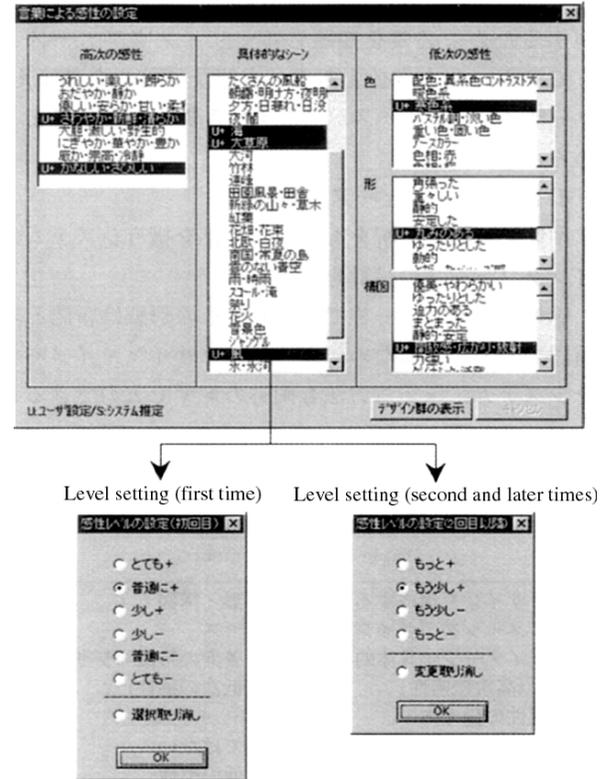


Fig. 2. Kansei indication in words.

of several designs presented by the system. The designs presented by the system are not randomly extracted designs, but are designs created by the system based on the kansei specifications of the user. Because the design is created based on the kansei specification of the user, the “selection of words from the list box” described above must occur once before the nonlinguistic input of the user according to this method. The interface was designed to select an example of similar work from a group of pattern candidates which reflect the user's preferences (Fig. 3). The user can select several candidates which are close to the image (check the boxes in Fig. 3).

If the preferences are expressed by actually drawing a design [(5) in Table 2], this research sets the drawing operations within a range that can be recognized by the system. In other words, the user is not allowed to draw freehand, but uses the user interface to revise the designs created by the system. For example, the basic operations are to reduce the diameter of a circle, thicken a line, and reset a color. By placing these restrictions, the system does not recognize the image, but can easily understand the kansei meaning of the user's revisions. The user revises only a portion of the design, and the user's kansei is conveyed to

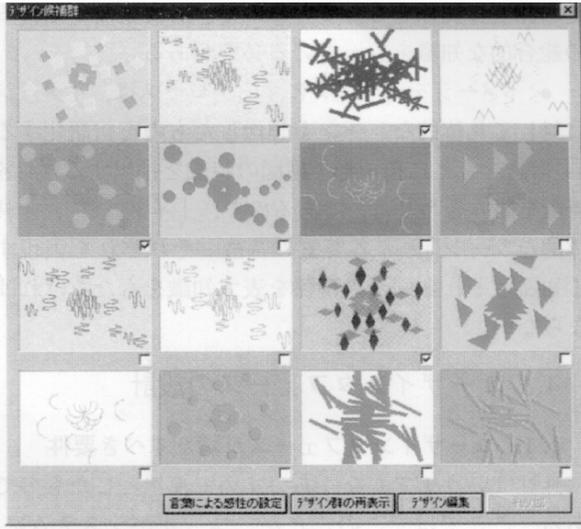


Fig. 3. Selections from a group of pattern candidates.

the system. Then the system can reflect this kansei information received from the user in the entire design. For example, if one of many circles is changed to a pastel color, then the inference is that the user has a strong image of *gentle* or *calm*. The colors of the other circles are similarly automatically changed to pastel colors. And the composition is changed to conform to this image. Thus, an interface that is directly manipulated by a pen or a mouse is designed (Fig. 4).

The property of not being able to understand kansei from the beginning until completion [(6) in Table 2] can be absorbed by repeating the feedback from the system when

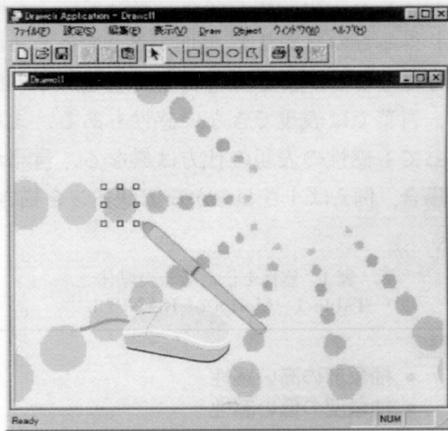


Fig. 4. Direct manipulation by a pen or a mouse.

the user indicates the kansei. The user looks at the designs presented by the system and can recognize kansei which he was not conscious of and further expand the new kansei. Based on the amplified kansei, the user can specify new kansei again. The image of the design the user wishes to draw can be clarified by repeating the operations of specifying the kansei and presenting the design. When the kansei is specified again in words after the group of candidate designs is presented, a dialog box appears to set the extent of the relative preference of the presented designs for the words which have been selected in the list box. The adverbs which can be selected are *more* and *a little more* (bottom right in Fig. 2).

5. System Implementation

5.1. Overview

From the results of the studies in Sections 3 and 4, the system must perform the process shown in Fig. 5.

The best combination of the image hidden by the user and the features of the design elements is inferred for the kansei partially specified multiple times by the user. Then the artistic pattern is created from the features of the elements. For example, if the user indicates *happy* (high-order kansei) and *springtime* (specific scene), the system makes the association to *calm* (high-order kansei), *bright color*, *round shape*, and *open composition* (low-order kansei). The *low-order kansei* found by inference is transformed into the *features of the design elements*. Then the *features of the design elements* are used to automatically create the actual *artistic pattern*.

The algorithm to infer the *high-order kansei*, *specific scene*, and *low-order kansei* hidden by the user and the algorithm to automatically create the *artistic pattern* from the *features of the design elements* are the most important elements in implementing the proposed system and are described below.

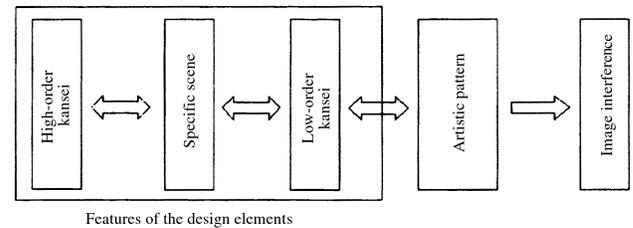


Fig. 5. Conceptual diagram of the system model.

5.2. Kansei inference algorithm

Here, we consider the data expression format. A user specifies the kansei by selecting words such as *happy* or *springtime*. The words used in this kansei specification do not have clear-cut meanings to separate them with the values 0, 1, and 2, but have ambiguous meanings. The extent of the preference is not given as “about 0.4,” but its preferred specification is in words like *very*. Although the vague meanings of these words and the extent indicated by these ambiguous words must be handled, currently, only fuzzy logic has a theoretical basis and is applied [5, 17, 20, 25–28].

The user selects the list box of words and specifies the extent of his preferences to merge with the kansei. Since the kansei specification from the user is partial, other words must be suggested from some words. Fuzzy rules are used to describe the rules to convert the kansei words into different kansei words in the next dimension. For example, vague rules can be described to associate *VERY happy* (high-order kansei) to *A LITTLE springtime* (specific scene). These rules are described by fuzzy sets (membership functions).

Proposal for a direct memory associative network for fuzzy rules

A fuzzy rule has the form of “If X is small, then Y is big,” but in the proposed system, the words specified by the user correspond to the antecedent and consequent of this fuzzy rule. Since the user simultaneously specifies multiple words in three levels, the activation values are input simultaneously to the antecedent and the consequent. In addition, since the words specified by a user are partial, there must be a function to associate the extent of the preferences for other words from this information. The associative architecture which satisfies this condition is considered next.

Fuzzy inference propagates to other activation values when all of the activation values are given to either the antecedent or consequent of a rule. In this system, since giving all of the activation values is impossible, because the user’s specification is partial, fuzzy inference cannot be applied.

A bidirectional associative memory is believed to compensate for the deficiencies of fuzzy inference. By using the associative function of neural networks [25], the processes that propagate the activation values from the antecedent to the consequent and from the consequent to the antecedent are fused. Repeating this propagation process has the feature of recalling the rules adapted to the conditions added to the antecedent or the consequent. Although FAMOUS [26, 27] and FAM [28] are applied research of the fuzzy paradigm to this method, these techniques cannot be applied in the proposed system because the images hidden from the partial specifications by

the user can be associated in a complementary manner, but the activation values cannot be simultaneously applied to the antecedent and the consequent.

Thus, the proposed system is based on a Hopfield network capable of complete coupling that arranges the antecedent and the consequent in the same level. The correlation between the antecedent and the consequent adds a rule node in which one node represents one rule in the level describing the antecedent and the consequent because the constraints which can be stored in the Hopfield network have been exceeded. In this case, the fuzzy rule is stored in the direct network. Therefore, an existing network was expanded by expressing the condition of the fuzzy rule represented by a fuzzy set as one node in the network. This new network is called a direct memory associative network for fuzzy rules. The direct memory associative network for fuzzy rules expresses the kansei knowledge by fuzzy rules to infer the user’s image. Next, the direct memory associative network for fuzzy rules is outlined.

Basic structure

Equation (1) is an example of the fuzzy rules to express kansei knowledge. For example, rule 1 has meaning such as “if the image is very *refreshing* but is not *busy*, then it is strongly associated with the *sea* but not with the *jungle*.” The two networks in Fig. 6 are built from this kind of rule.

- Rule 1: If x_1 is P and x_2 is N, then y_1 is P and y_2 is Z.
 Rule 2: If x_1 is Z and x_2 is P, then y_2 is P and y_3 is N.
 Rule 3: If y_1 is P and y_2 is P, then z_1 is N and z_3 is P.
- (1)

where

$$X = (x_1, x_2, \dots, x_n)$$

for x_i , a word having “high-order kansei” in Fig. 2

$$Y = (y_1, y_2, \dots, y_m)$$

for y_i , a word of the “specific scene” in Fig. 2

$$Z = (z_1, z_2, \dots, z_l)$$

for z_i , a word having “low-order kansei” in Fig. 2

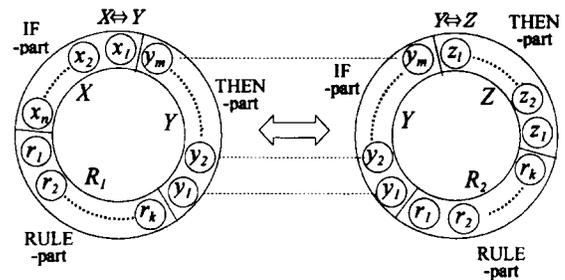


Fig. 6. Networked fuzzy rules.

P: Positive
 N: Negative
 Z: Zero

} : trapezoidal membership function

Each one is an associative memory. They are network $X \Leftrightarrow Y$ that associates X , the high-order kansei, to Y , the specific scene, and network $Y \Leftrightarrow Z$ that associates Y , the specific scene, to Z , the low-order kansei. Each associative memory consists of the antecedent (IF part), consequent (THEN part), and fuzzy rule part (RULE part) of the fuzzy rule. The nodes in the memory represent the membership functions in each part. The value of a node is described by a real number, and the rule to be stored is described using a fuzzy set.

Convergence

The two associative memories update the node values while maintaining their mutual correlation. The THEN part of associative memory $X \Leftrightarrow Y$ and the IF part of $Y \Leftrightarrow Z$ are a set of words expressing the same Y . The associative memory $X \Leftrightarrow Y$ updates the node values once by Eq. (2). The node values of the updated Y are set as the initial values of Y in associative memory $Y \Leftrightarrow Z$. Next, associative memory $Y \Leftrightarrow Z$ updates the node values once by Eq. (2). Then the node values of the updated Y are set as the next initial values of Y in associative memory $X \Leftrightarrow Y$. When this operation is repeated and both associative memories successively converge, the network enters the converged state.

Update

The initial value of each node n ($n \in [-1, 1]$) is randomly assigned a value to the other nodes based on the selection level for the kansei words selected by the user. This assignment of random numbers can generate designs which differ from one kansei specification by the user. In other words, a different convergence value can be found.

Each node has a parameter α ($\alpha \in [0, 1]$) to represent the strength of the user's specification for the kansei word held by the node. If the user made the first selection, $\alpha = 1.0$. If nothing was selected, $\alpha = 0.0$. The node is updated by Eq. (2) using the node value calculated from the associative memory and α . The α value is updated each time kansei is specified. When the convergence to the same kansei expression is repeated, the α corresponding to that kansei expression increases and updating becomes difficult.

$$n = \alpha n_{old} + (1.0 - \alpha) n_{net} \quad (2)$$

where

n_{old} : node value before updating (initial value for the first time)

n_{net} : value calculated by the associative memory with n_{old} as the input value

If the pattern candidate group is presented once, the user specifies the kansei again. The system makes new associations and infers the user's kansei again. For each specification, the values of node n assigned to the network for the next associative process and parameter α are updated.

The above inference algorithm is used to find the degree of the user's preference for the "high-order kansei," "specific scene," and "low-order kansei."

This algorithm is summarized in Table 3.

5.3. Automatic pattern generation algorithm

The features of the design elements related to low-order kansei, such as color, shape, and composition, from the associative network of the previous section can be introduced. This section shows the algorithm to automatically generate the artistic patterns using these parameters.

The color uses the hue and tone system because of their importance to human senses [29, 30]. There are 120 colors expressed by 10 hues and 12 tones, such as gaudy, bright, subdued, and dark, and 10 grayscales to produce a total of 130 colors. The hue, for example, warm colors like red and yellow, corresponds to a passionate image. A cool color like blue corresponds to an image of calm or purity. The unchanged tones represent the image. The image also greatly changes with the combination of the colors of the backgrounds and patterns (shapes). The color scheme for the backgrounds and patterns uses the parameters of *identical*, *similar*, *contrasting*, and *colorful*.

The shapes are restricted to the geometric figures in this system. However, the images differ for the three general shapes of the angular shapes composed of obtuse angles, round shapes, and tapered shapes composed of acute angles which have the images of quiet and stable, calm and smooth, and fast and jumping, respectively. These shapes are further subdivided into three or four shapes for a total of 11 types. Furthermore, an aspect ratio parameter for the shape is also needed because the types of round shape like a circle, an ellipse extending vertically, or an ellipse extend-

Table 3. Features of kansei estimation algorithm

1. Use fuzzy logic to express the kansei information.
2. Use "direct memory associative network for fuzzy rules" to associate the kansei hidden by the user.
3. Introduce "parameter α " to reflect each kansei specification by the user.

ing horizontally have different images of a stable feeling, a rising feeling, and a level feeling.

The composition handles 11 basic composition techniques. Each composition has reference lines represented by functions for placing the shapes and places the patterns along these reference lines. In addition, a reference line has parameters which differ with the composition. For exam-

ple, the composition of *diffuse* is a composition technique capable of expressing an open feeling by drawing the shape in radiating lines. But the reference lines for this composition are determined by the number of radiating lines related to the degree of openness, and either straight or curved radiating lines (to represent hardness with straight lines and suppleness with curved lines). The *size*, *motion rate*,

Table 4. Parameters required to create patterns

Color	Hue	10 levels		
	Tone	12 levels (gaudy, bright, subdued, dark)		
	Grayscale	10 levels => Total 130 colors		
	Color scheme	Same, similar, contrasting, colorful		
Shape	Type	Angular shape	Square, cross, horizontal line, vertical line	
		Round shape	Circle, wavy line, arc	
		Sharp shape	Triangle, diamond shape, W shape, V shape	
	Aspect ratio	Degree of vertical and horizontal stretching of the shape		
Composition	Type	Triangular shape		
		Diffuse	Number of radiating lines	lines
			Type of radiating line	Straight line, Curved line
		Horizontal lines	Number of reference lines	lines
			Placement position of the reference line	Top, Center, Bottom
			Placement of shape	On the reference line, Random
		Vertical lines	Placement method of reference line	Equally spaced, Random
			Degree of sparseness or density	%
		Diagonal lines	Number of reference lines	lines
		S-shaped curved lines	Number of reference lines	lines
			Degree of curvature	Small, Moderate, Large
		Cross	Number of reference lines	lines
		Oblique intersection	Number of reference lines	lines
		Symmetry	Direction of symmetry	Top-to-bottom, Left-to-right
	Uniform placement	Degree of density or sparseness	%	
	Centripetal			
	Shape size	Area		
	Motion rate of shape	% Moves randomly, No motion		
	Amount of rotation of shape	Angle		
Magnification of shape	% Randomly magnified, No magnification			

amount of rotation, and magnification of the shapes to be placed on the reference lines in each composition affect the image. If a shape is large, its image has a feeling of power, and if small, a feeling of coherence. The motion rate, amount of rotation, and magnification of a shape are the variation rates of the entire pattern. If the variation is large, a rhythmic feeling can be expressed, and the opposite feeling results for a small variation. If this type of variation is random, the feeling of coherence decreases.

Table 4 lists the parameters needed to create artistic patterns. The features of the design elements in Fig. 5 found in the previous section are transformed into the parameters in Table 4 (Step 1 in Table 5). The patterns are created as described below when these parameters are input.

First, the colors for the backgrounds and patterns (shapes) to be used are set while thinking about color harmony (Step 2 in Table 5). Basically, this system creates a pattern in three colors: foreground color 1, foreground color 2, and background color. Foreground color 1 is the first basic color of the shape to be drawn. Foreground color 2 is the second basic color of the shape. These two colors are alternately used to draw the shapes along the reference lines. The background color is the color of the background. One color is determined from the hue and tone parameters and is set to foreground color 1. With foreground color 1 set as the basic color, foreground color 2 and background color are determined based on the parameters of the basic color and the color scheme. A table is created to assign a total of three colors consisting of two other colors in each color scheme for the one basic color. The table uses Refs. 29–32 to select the colors having color harmony with the basic color and registers a total of 260 items where each item is a group of three colors. If the color harmony is identical to one basic color, the foreground colors 1 and 2

are the same color. If the harmony is similar, two similar colors as the basic color are set to foreground color 1 and background color. If the harmony is contrasting, two contrasting colors to the basic color are set for the foreground color 2 and the background color. If the harmony is colorful, a color harmonized with the basic color is set to the background color, and the foreground color has its hue changed by several gradations. Only in this case, the colors used are multicolored. Thus, the colors of the background and shapes are determined. Then the background color is first painted over the entire drawing region (Step 3 in Table 5).

Next, the shapes along the reference lines are drawn by alternately using foreground color 1 and foreground color 2. However, it is important to know where to place the shapes in the drawing area, what sizes to draw, what horizontal and vertical lengths to use, and how much to incline when drawing while rotating a shape. The size (area) of the shape drawn the first time is set to the value of the shape size parameter. The area for the second and later times is the product of the magnification parameter multiplied by the area of the previous drawing (Step 4 in Table 5). When the area is determined, it is used with the aspect ratio parameter to determine the vertical and horizontal lengths of the shape to actually be drawn (Step 5 in Table 5). If the shape is drawn while being rotated, the angle of rotation the first time is set to 0°. The product of the rotation rate parameter multiplied by the rotation angle of the shape drawn the previous time is set to the rotation angle for the next drawing (Step 6 in Table 5). For the first time, the placement position for the shape sets the center coordinate of the drawing position by using the starting point of the function having the reference line parameter and the vertical and horizontal lengths. For the second and later times, the movement rate parameter and the vertical and horizontal lengths are used to calculate the amount of motion from the position of the previously drawn shape to determine the center coordinate (Step 7 in Table 5). By proceeding in this manner, the shape is drawn until the last point of the function is drawn (Steps 8 and 9 in Table 5).

The algorithm to create artistic patterns is summarized below.

Table 5. Algorithm for creating patterns

-
- Step 1. Calculate the parameters needed to create the artistic pattern.
 - Step 2. Determine foreground color 1, foreground color 2, and background color.
 - Step 3. Paint the background color.
 - Step 4. Determine the shape's size.
 - Step 5. Find the vertical and horizontal lengths of the shape.
 - Step 6. Determine the rotation angle of the shape.
 - Step 7. Determine the drawing position of the shape.
 - Step 8. Draw the shape.
 - Step 9. Repeat Steps 4 to 8 while able to draw the shape on the reference lines in the composition.
-

6. Evaluation Tests

We developed and evaluated a prototype system to verify the effectiveness of the proposed system.

6.1. Test conditions

(1) Stored rules

The rules representing the know-how for creating artistic patterns were created by the following method. One rule has one design image and describes the connection of

Table 6. Rule examples

• $X \Leftrightarrow Y$ associative memory rule

If

- “happy or enjoyable” is P,
- “calm or quiet” is P,
- “gentle or tranquil” is p,
- “refreshing or fresh” is Z,
- “sad or sorrowful” is N
- ⋮

Then

- “summer” is p,
- “winter” is N,
- “sun” is p,
- “morning haze, dawn, or daybreak” is P,
- “night or darkness” is N,
- “sea” is Z,
- “mountains of budding leaves or plants” is P,
- “wind” is n,
- ⋮

• $Y \Leftrightarrow Z$ associative memory rule

If

If part is the same as the Then part of $X \Leftrightarrow Y$

Then

- Color Rules
 - “color harmony: bright” is p,
 - “color harmony: dark” is N,
 - “colorful” is Z,
 - “same color” is P,
 - “warm color” is P,
 - “cold color” is N,
 - “hue: red” is N,
 - “hue: orange” is P,
 - ⋮
- Shape Rules
 - “angular” is N,
 - “stable” is N,
 - “rounded” is P,
 - “moving” is P,
 - “pointed or sharp feeling” is N,
 - ⋮
- Composition Rules
 - “calm or quiet” is P,
 - “open feeling, widening, or radiating” is p,
 - “dynamic or active” is n,
 - “no motion or restrained” is N,
 - “rhythmical” is p,
 - “feeling of height” is N,
 - “feeling of moving sideways or distant feeling” is N,
 - ⋮

the image to each node of the network by membership functions. There are 15 stored rules because 15 images resulted from extracting only the basic images (high-order kansei).

One rule combines both a rule of the $X \Leftrightarrow Y$ associative memory and a rule of the $Y \Leftrightarrow Z$ associative memory. Table 6 shows one actual rule. In words, this rule represents the image with the “light feeling in sunlight on a gentle spring day.” P (Positive), p (a little positive), Z (Zero), n (a little Negative), and N (Negative) in this rule correspond to their respective membership functions (Fig. 7).

(2) Associative network

The size of an associative network for storing the rules in (1) were set to 8 X nodes and 33 Y nodes in the $X \Leftrightarrow Y$ associative network, and 15 rules were stored. Thirty-three Y nodes and 55 Z nodes were set for the $Y \Leftrightarrow Z$ associative network.

(3) User interface

The number of display panels of the pattern plan was set once to 16.

6.2. Test 1: Verification of the basic functions

In test 1, the designed user interface, the mechanism of the associative memory for estimating the kansei, and the automatic pattern creation mechanism are verified as operating appropriately. With the desired initial design image to draw set to have a “gentle soft feeling,” the designer uses this system to design, and analyzes and evaluates the operation.

System interaction mode

First, we present a history of interaction with the system (Fig. 8).

First, words close to the desired design image to be drawn were selected. For the idea approximating the “gentle soft feeling,” *happy or enjoyable* and *gentle or tranquil* in the *high-order kansei* list box are set in the *average* level, and *spring* from the *specific scene* list box in the *very* level,

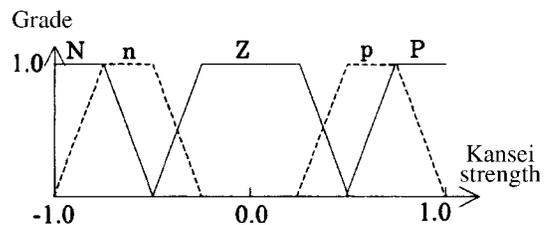
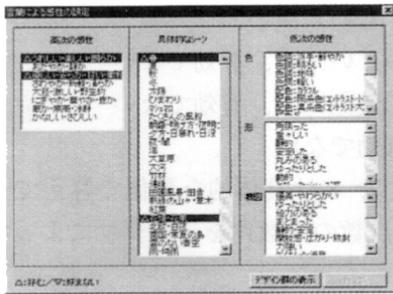


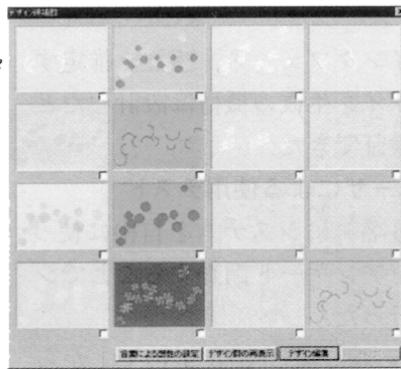
Fig. 7. Membership functions of the rules.

①



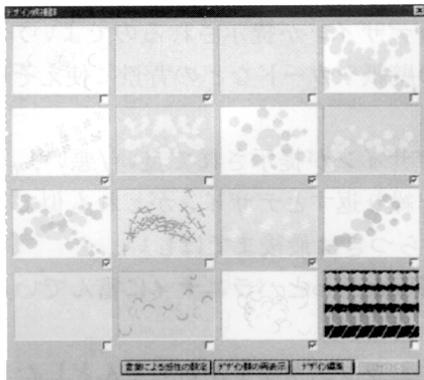
[User]
 • High-order kansei
happy or enjoyable-average
gentle or tranquil-average
 • Specific scene
spring-very
flower garden-average

⑤



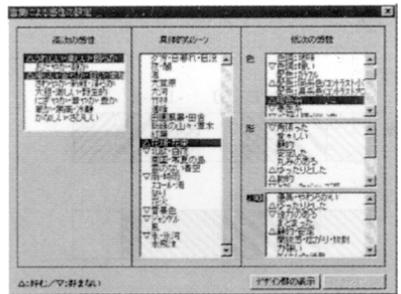
[System]
 • Presents the candidate pattern group.

②



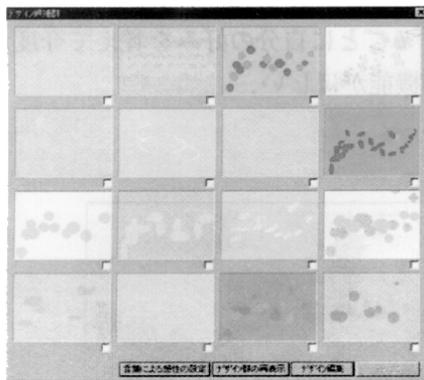
[System]
 • Presents the pattern candidate graphics.
 [User]
 • Selects patterns
 2, 5, 7, 8, 9, 11, and 15.

⑥



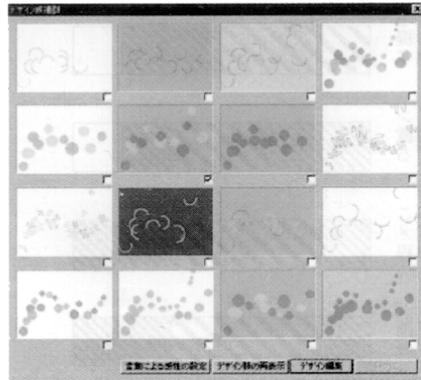
[User]
 • Low-order kansei
warm color-more

③



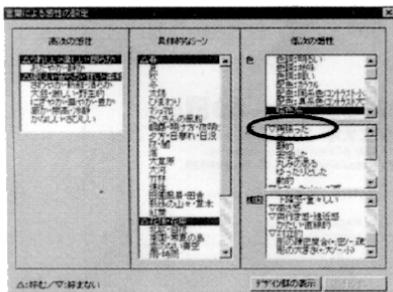
[System]
 • Presents the candidate pattern group.

⑦



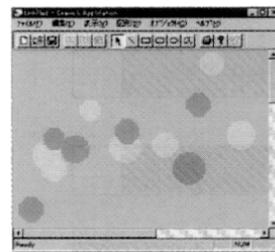
[System]
 • Selects pattern 6.

④



[User]
 • Low-order kansei
warm color-a
little more

⑧



[User]
 [System]
 • Done

Fig. 8. An example of creating a pattern.

and *flower garden* in the *average* level. The color, shape, and composition were not specified at all in the *low-order kansei* (Fig. 8 ①).

The candidate group of the 16 patterns estimated the first time by the associative network gives an overall gentle impression and nearly matches the specified kansei. In addition, the patterns are not uniform, but have some degree of variation.

Next, patterns 2, 5, 7, 8, 9, 11, and 15 were selected from the presented pattern group (checked items in the list box), and the preferences were specified to the system (Fig. 8 ②). The selections were pale yellow, yellow green, and beige for the colors; round for the shape; and no regularity in the selected pattern for the composition.

The results of the next estimate based on this kansei specification are presented (Fig. 8 ③). The resulting pale yellow green color and round shape strongly reflected the features of the selected pattern.

Then a pattern group having little variation was examined. We thought the pattern should be drawn to have a slightly warmer color than yellow green or green. This was specified by the words *warm color* and *a little more* (Fig. 8 ④). The small Δ and ∇ displayed to the left of the words in each list box of Fig. 8 ④ show the states where the convergence values of the nodes exceed some threshold in the estimation results. In other words, the kansei representing these nodes shows the estimates strongly imagined or not imagined by the user. In this example, an *angular* shape displays the ∇ which is not strongly imagined. The estimate is correct and the generated pattern is appropriate.

The result (Fig. 8 ⑤) of the estimate based on this specification does not use a warm color at all and appears to not change much from the previous candidate group. The reason is even if a *warm color* is specified before finishing, because it does not immediately match the intent, the previous specification by the user is recalled.

Therefore, *more* was specified for *warm color* (Fig. 8 ⑥). The estimate based on this (Fig. 8 ⑦) changed all the colors to warm colors. The shape and composition changed a little.

Finally, a pattern having a warm color and a round shape was selected and one pattern close to the image (Fig. 8 ⑧) was generated.

Internal processing associated with the image hidden by the user

Next, the system estimates the user's kansei and analyzes the process to associate the hidden image.

A pattern like the one in Fig. 8 ② was generated based on the estimate for the initial kansei specification. The specifications of the initial words were set to *happy or enjoyable* and *gentle or tranquil* for the *high-order kansei*, and *spring* and *flower garden* for the *specific scene*. The *low-order kansei* was not specified. The system estimated

the user's preferences from words not specified in the input information based on estimation. In Fig. 8 ②, nearly all of the 15 stored rules converged to 3—rules 1, 2, and 3—from the convergence values of the rule nodes in the associative memory. Rule 1 is strongly associated with *happy* and *calm* of the *high-order kansei*. Rule 2 is strongly associated with *happy* and *refreshing*. Rule 3 is strongly associated with *calm* and *gentle*. Patterns 3, 11, and 13 that converged to rule 1 are associated with colors having the orange, yellow, and yellow green hues, a round relaxed shape, and *elegant* and *soft* composition. Patterns 1, 4, 5, 7, 9, 12, and 15 that converged to rule 2 are associated with gaudy or bright colors having the yellow green, green, and blue green hues and an open or dynamic composition. Patterns 2, 6, 8, and 14 that converged to rule 3 are associated with colors having red, orange, yellow, and yellow green hues, a quiet stable square shape, and a calm composition. Based on these results, the structural elements of the candidate pattern group in Fig. 8 ② were generated. We see from the above that this system can estimate the kansei hidden by the user.

Next, we will explain the second estimate corresponding to Fig. 8 ③. The input information becomes both the specification of the four words given initially and the seven patterns selected in Fig. 8 ②. Based on this input, the system estimated the user's preferences similar to the first estimation and created the patterns.

Later, the user's preferences are estimated in the same way. The user's input information increases as the trials accumulate. The degree of reliability of the system's estimation of the preferences also improves.

Thus, the user interface, the mechanism of the associative memory to estimate kansei, and the mechanism for creating patterns were verified for a task like designing.

6.3. Test 2: Usage test with ordinary users

Ordinary users (six testers) had unrestricted use of the system. The system was qualitatively evaluated based on a questionnaire of their feelings when using the system.

The questionnaire was answered in a seven-stage evaluation of questions 1 to 11 in Fig. 9 for the system.

- +3: Very effective
- +2: Sufficiently effective in practice
- +1: Fairly effective
- 0: Neither
- -1: Fairly ineffective
- -2: Not effective in practice
- -3: Not very effective

Questions 7 and 8 were answered with specific numbers. The results were shown in band graphs of the ratios of the number of people at each score.

The following comments were given when the users were free to express their opinions about the system.

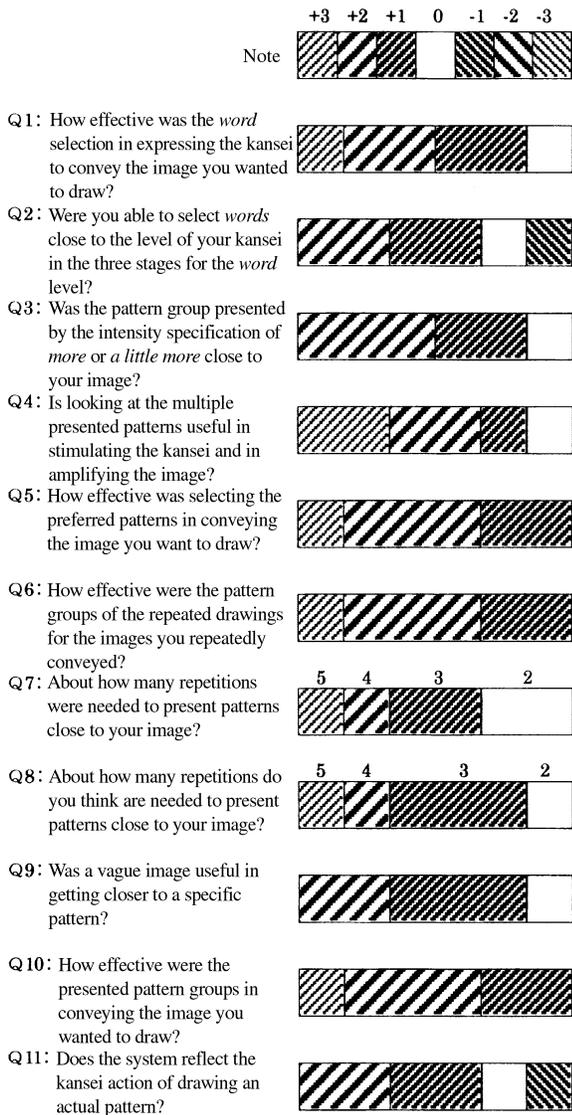


Fig. 9. Questionnaire questions and results.

C1: It's good that different patterns are always presented.

C2: These could be used as backgrounds for wallpaper in PCs and as greeting cards.

C3: Better/worse patterns than expected were displayed.

C4: As the kansei specification is repeated, all the patterns became similar. I would like to see some degree of variation until the end.

C5: Greater variety in the types of colors and images is good.

C6: It would be good to have a function to create exact patterns from suitably drawn rough sketches.

C7: I would like to see a function that remembers your preferences each time you use the system and reflects them in the next session.

C8: Selecting the words for kansei is difficult. Wouldn't it be better to use your own preferred words?

C9: I want to draw a specific image, not abstract geometrical figures. The expression *specific scene* tends to give the impression of creating an actual scenic image.

C10: When resetting the *kansei word setting* screen, it would be easier to reset if the value of the estimate for each word was displayed.

C11: The *low-order kansei* in the *kansei word setting* screen is difficult to set. Selection would be easy if the actual shape and composition were displayed in the picture.

From Q1, Q2, and Q3, the kansei specification in words is an effective function. However, from people giving an evaluation of 0 or -1 and C8, C10, and C11, we can infer that finding the words applicable to one's kansei from the word divided into three types is not a simple task to the users. We must reconsider the kansei words to be used and the function to allow the user to freely specify words.

From Q4, Q5, C1, and C3, the kansei specification by example was shown to be effective. The kansei can be conveyed to the system to illustrate some pattern. And the kansei can be amplified by looking at new patterns. On the other hand, the system must have diversity in the colors and shapes until completion (C5) since the multiple displayed patterns tend to an extreme during the operation (C4).

Q6, Q7, and Q8 show the importance of interactive operation. Now, after the user specifies the kansei once, the system needs at least one minute to redisplay the patterns. Although the system's execution speed may change somewhat, the user demands a pattern close to his image in three or four interactions with the system.

From Q9, Q10, and Q11, the system can support the user in kansei-related activities like designing an image. While this system is limited to geometrical figures, based on C6 and C9, it is possible to further stimulate the user's kansei by using specific pictures.

6.4. Test 3: Application to real problems

This system was used to create an actual pattern. The problem was to create a poster for the 1998 Human Interface Symposium having the theme of *human-machine coexistence*. The stored knowledge is for expressing the 15 basic images used in tests 1 and 2 of this section. Because this is inadequate, a pattern cannot be created directly from the words "human-machine coexistence." Therefore, the patterns are created by replacing *human-machine coexistence* with the words *fresh*, *advanced*, *refreshing*, (*high-order kansei*), *unusual colors* (*low-order kansei*), and *dynamic composition* (*low-order kansei*) which are words



Fig. 10. Poster: “human-machine coexistence.”

the system can understand. Figure 10 shows this poster. The background image is the pattern created by this system.

From the above tests 1, 2, and 3, the novelty and effectiveness of support for creating patterns by the proposed algorithm can be verified. This system expands the user’s kansei, and supports the operation until the image becomes a pattern.

7. Future Issues

Through evaluation tests, we verified the validity of the method. However, we are uncovering problems and are tackling them as current problems. The four major points are described below.

(1) Function to explain the system’s operation to the user

From the evaluation tests, questions like “Why did the system display that pattern?” and “How do I convey my intentions?” show the confusion users have about specifying kansei. This agrees with research which found that users always needed reasons and explanations when a system makes estimates and supports the user [33]. A mechanism is needed to explain to the user what kind of design knowledge is the basis for creating a pattern. We are now studying ways to output descriptive text based on the converged state of the associative memory network.

(2) Function to learn the user’s kansei

The proposed system provides support to the user to create patterns based on rules about the mutual relationships among the *kansei words* stored in the system. To further support the user, a function to automatically learn the kansei of individual users from the history of interaction is important and studies on knowledge acquisition techniques will be pursued. This would reduce the work maintaining the system.

(3) Function to feed back user pen information

A user interface was designed to convey the kansei information of the person thinking about the design image. However, the prototype system does not implement direct manipulation of the pattern by pen or mouse. This would allow the user to more freely and effectively convey the design image he wants to draw.

(4) Verifying the fuzzy associative memory

In the current stage, we only demonstrated the effectiveness of the system by simple evaluation tests, but we do not understand the principle, application range, and generality. If the parameters such as the items in the associative memory and the membership functions of the fuzzy expressions are determined heuristically, comparative tests of their effects on the system and their effectiveness must be verified.

8. Conclusion

We proposed a system to support drawing patterns by estimating the user’s kansei. First, to support drawing the patterns, the connection was analyzed between the patterns and the kansei of humans. Based on this analysis, the necessary conditions to convey the kansei information of the design image of the user to the system and from the system to the user were examined to design the user interface. In addition, the parameters and algorithms needed for a computer to actually draw patterns were examined.

Tests verified the novelty of support for creating patterns and the effectiveness of the interface and pattern creation algorithm of the proposed system. Furthermore, excellent results were obtained from qualitative evaluations by users.

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