Fuzzy Set-based Multistage Associative Inference and Its Application to Kansei Design Support System

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Abstract: As the personal computers and the workstations are widely used, the design-work supported by the drawing software is getting popular. However, the software does not assist the creative work, but provide users with the convenient tool only for drawing. Our final goal is to realize the supporting systems for the artistic pattern drawings. We have analyzed the process of the creative work and designed the user interface that supports and expands the user's creative activities. In this paper, we propose the inference method for our kansei design support system. First we summarize the special features that are indispensable for the inference method. Second we propose the new inference method, called the Fuzzy Set-based Multistage Associative Inference, to cope with the requirements. Thirdly, we analyze the characteristics of the proposed inference mechanism. Finally we demonstrate the effectiveness of the inference method through the actual design processes.

1. Introduction

Recently, the multi media technology and the network technology enable us freely to access various multi media information spread in the world [6]. It seems that we are now in the second era of an information-oriented society. However, people is tied up in front of a small CRT screen, such as 19 inches or 21 inches, and the input modalities to the computer are also limited to a keyboard and a mouse. These sever limitations on the personal computing environment prevent the novice users from the full utilization of the computing power, which the personal computer brings us.

We proposed the new design concept of the next generation user interface, called RVI-concept, which is an acronym of the real virtual intelligent user interface concept [1]. Through the development of the RVI-based systems, we found that it was indispensable deeply to combine the symbolic and computational processing in order to realize a software architecture for the next generation user interface [2]. Now we believe that fuzzy methodologies play an important role to combine the symbolic and computational processing due to the inherent nature of fuzzy theory.

In this paper, we demonstrate the application of the fuzzy theory to the kansei design support system.

As the personal computers and the workstations are widely used, the design-work supported by the drawing software is getting popular. However, the software does not assist the creative work, but provide users with the convenient tool only for drawing. Our final goal is to realize the supporting systems for the artistic pattern drawings. We have analyzed the process of the creative work and designed the user interface that supports and expands user's creative activities.

In the following section, the user interface of the kansei design support system is briefly explained. In the section 3, the software architecture is shown and the fuzzy associative inference and the fuzzy relational inference are addressed. In the section 4, the fuzzy set-based multistage associative inference is explained in detail. In the section 5, we demonstrate the effectiveness of the inference method through the actual design process. In the last section, the summary is given.

2. User Interface of Design Support System

The final goal of our system is to support the artistic pattern drawings, which consist of the geometrical patterns such as lines, triangles, rectangles, circles, and so on. Based on the analysis of the artistic pattern drawings, we designed the user interface of the system [3, 4, 5]. Table 1 summarizes the characteristics of the artistic pattern drawings that we found and focused on when we designed the user interface.

Table 1 Characteristics of Design Process

(1) Basic elements of the design:
Color, Shape and Pictorial composition   ...①
(2) Design Process:
Feeling⇒Scenes⇒Fundamental features⇒Drawings
(Abstract)   (Perceptual)   ...②
(3) Representation of Feeling
• No unique representation
Language : abstract/perceptual   ...③
Nonverbal: Show examples   ...④
Directly draw and modify   ...⑤
• No complete representation in advance   ...⑥

To meet the requirements ①, ②, and ③, we designed the 3-layered "List Box" shown in Fig.1. The three layers correspond to the abstract feeling (the left column in Fig.1), the concrete scene (the center column) and the fundamental features (right column) respectively. Each layer has the word lists from which the user can select the suitable words as shown the upper part of Fig.1 or can modify the strength of the words in the absolute or relative way as shown in the lower part of Fig.1.

The layer for the fundamental features is divided into three types of the word list, i.e., the color, the shape and the pictorial composition, which are the basic elements to define the drawings.
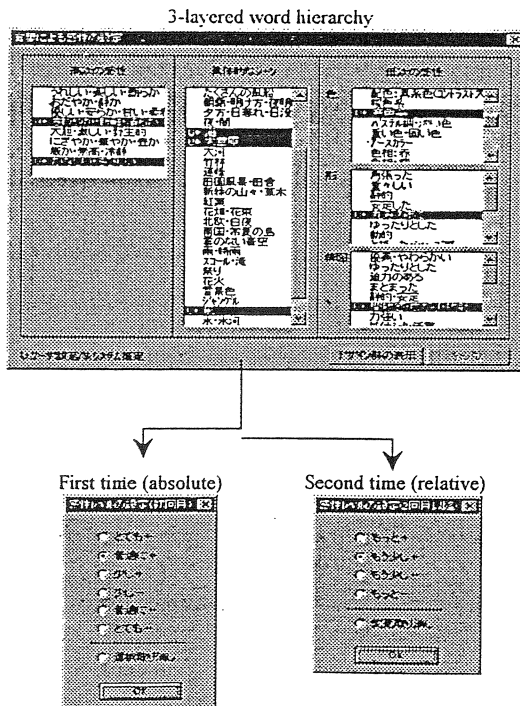

Fig. 1 User Interface in 3-layered List Box

To meet the requirement ④, we added the user interface function to select the desired drawings from the design candidates (shown in Fig.2).
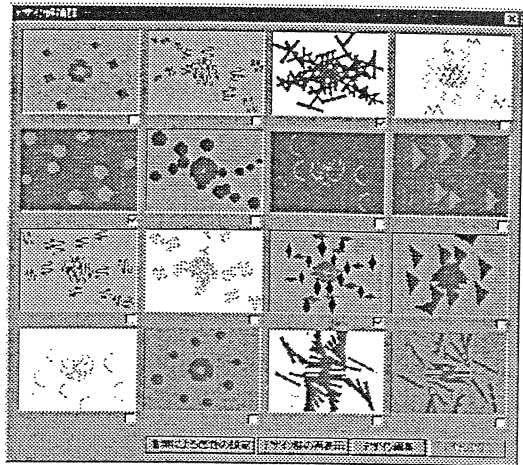

Fig. 2 Selection from design candidates

Concerning ⑤, the user can directly draw and modify the drawings through the mouse and the pen operation (shown in Fig.3)
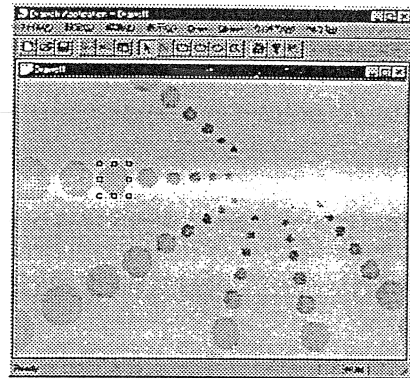

Fig. 3 Direct modification by user

Concerning ⑥, the users can indicate the words to show the feeling, see the drawings that the system produced, select the most preferable candidates as many times as they want. Through this iteration, they gradually understand what they really want to draw.

3. System Architecture

To tell the system about the feeling of the design that the users want to draw, they select the words from the 3-layered "List Box", select the preferable drawings from the drawings that the system produced, and modify them by hands. The user's

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instruction is partial and imprecise. The interaction continues until the preferred drawing is produced. The system must produce the design candidates based on the user's partial and imprecise instruction.

Our system is realized by the software architecture shown in Fig.4. The three left blocks correspond to the 3-layered "List Box" in Fig. 1. Since the user's instructions are partial and imprecise as mentioned above, we use the fuzzy associative inference mechanism instead of the fuzzy inference. In the rest part of this paper, the fuzzy associative inference will be explained in detail.

The results of the fuzzy associative inference are represented by the combination of three types of perceptual words (i.e., the color, the shape and the pictorial composition). Then they are directly converted by the fuzzy relational inference into the parameters to draw a design.
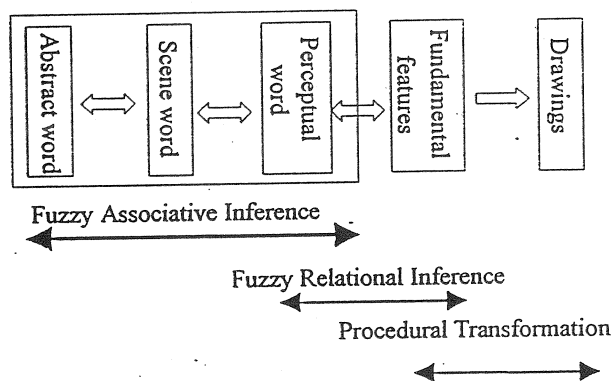

Fig. 4 System Architecture

4. Fuzzy Set-based Associative Inference

4.1 Requirements and Basic Approach

Because the words in the 3-layered "List Box" have the fuzzy nature, we use the grade value [-1, +1] to show the strength of the words. The value −1 means the complete negative feeling and +1 is the complete positive feeling.

The relations between the abstract words and the scene words can be represented in the conventional fuzzy rules. For example, "if word-x is very positive, word-y is more or less negative then word-z is slightly positive." Also the relations between the scene words and the perceptual words can be represented in the same way.

Due to the partiality and the impreciseness of the

user's instructions, however, it is impossible to infer in one direction such as the direction from the abstract layer to the perceptual layer or from the perceptual layer to the abstract layer. This is the reason why we do not use the conventional fuzzy reasoning or the bi-directional fuzzy associative memory such as FAM [7, 8, 9].

To satisfy the requirements analyzed above, we have developed the new associative inference algorithm based on the well-known Hopfield neural network.

4.2 Fuzzy Set-based Multistage Fuzzy Associative Inference

4.2.1 Data Representation

The grade value [-1, +1] and the fuzzy set are represented in a uniform format $<a, b, c, d>$ based on the following rectangular notation on the range [-1, +1].
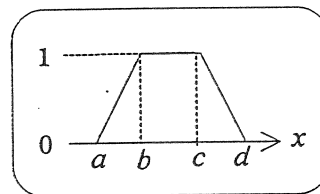

Fig. 5 Fuzzy Set Representation

The user's input to the system is represented by the real number [-1, +1]. The other data are represented by a fuzzy rule with a fuzzy set or the fuzzy number. For example, a relation rule among the 3-layer "List Box" is given by a fuzzy rule with the fuzzy predicates shown in Fig.6. Moreover the coefficients of the associative matrix are the fuzzy numbers.
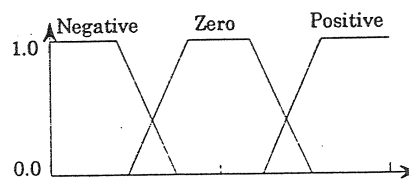

Fig. 6 Standard Fuzzy Sets

4.2.2 Network Structure

The fuzzy rule represents the relation among the 3-layer "List Box". Lets use the variable X, Y and Z

for the abstract word, the scene word and the perceptual word. We need two types of rules. One shows the relation between Xs and Ys, the other is for between Ys and Zs. Examples are given below.

Rule1 : If x_1 is P, x_2 is N then y_1 is P, y_2 is Z.

Rule2 : If x_1 is Z, x_2 is P then y_2 is P, y_3 is N.

Rule3 : If y_1 is P, y_2 is P then z_1 is N, z_3 is P.

P : Positive, N : Negative, Z : Zero

Then the fuzzy associative neural network is composed of the two fully connected neural networks. Each fully connected neural network can be seen as a fuzzily extended Hopfield neural network.
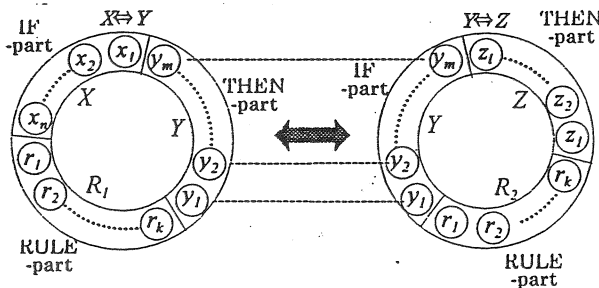

Fig. 7 Multistage Fuzzy Associative Network

Note that r_i is the node to represent each rule. They are useful to check the active rules and to improve the capacity of the associative memory.

4.2.3 Learning Algorithm

There is no difference between the traditional learning algorithm and ours except that we use the association matrix based on the fuzzy number.

Let denote the memorized pattern as $U_1, U_2, ..., U_P$, such that $U = (u_1, u_2, \cdots, u_n)$, u_i is a fuzzy set in Xs, Ys or Zs.

Then the fuzzy set-based associative matrix M is given by;

$$M = \sum_{i=1}^{P} U_i U_i^T .$$

Note that the coefficients in M are the fuzzy number represented by <a, b, c, d> as shown in Fig. 5.

4.2.4 Associative Inference Algorithm

Basically, according to the usual associative inference algorithm, the status of the network, U(t) is updated as;

$$U(t+1) = \phi(MU(t)),$$

where ϕ is a sigmoid function such as;

$$OUT_i = \frac{2}{1 + \exp^{-NET_i / TEMP}} + 1 .$$

Our neural network is composed of two networks, which have the common nodes of Ys. We update each neural network at each cycle repeatedly rather than converge one network and the other independently. This is because that Xs, Ys, and Zs have the close relationship each other. But we have to point out that it causes the instability of the convergence.

The users usually modify their input to the system after they look at and evaluate the dozens of drawing that the system produced according to the users' instruction. Then the system must reproduce the drawing candidates again. It is very important that the system does not forget the past instruction. In other words, the system must keep in mind of the result of the past processing in some extent.

To resolve this problem, we introduce the parameter α to show the mobility of the node. The parameter $\alpha = 1$ means that the mobility is zero and $\alpha = 0$ means the full mobility. So the status of each node is updated as follow.

$$n_{new} = \alpha n_{old} + (1.0 - \alpha) n_{net}$$

In case $\alpha = 1$, actually, no update occurs. When $\alpha = 0$, the status is completely updated, independent to the past status.

Each node has its own parameter α and the value itself is also updated through the iteration of the interaction with the user.
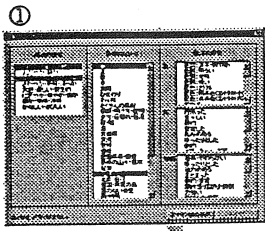
Usually, α is updated as follow.

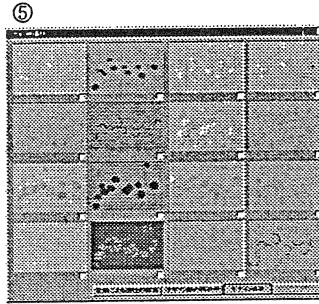$$\alpha = \alpha_{old} + (1.0 - s.d.)$$

$$s.d. = \sqrt{\frac{\sum_{i=1}^{S} (n_{show-i} - mean)^2}{S}}$$
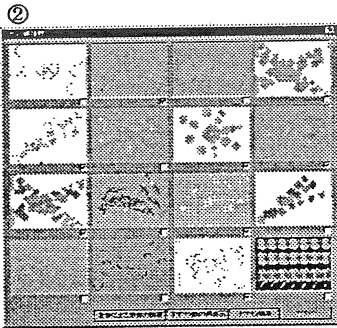
$$mean = \frac{\sum_{i=1}^{S} n_{show-i}}{S}$$

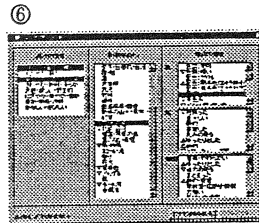n_{show} : last convergent status of the node

① 【User】
• Abstract words
"lovely—normal"
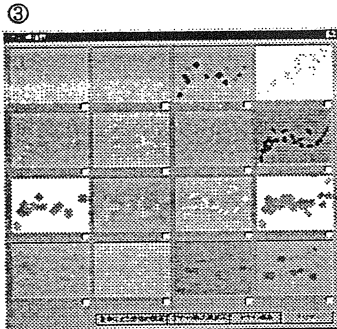"sweet—normal"
• Scene words
"spring—very"
"flower garden— normal"

② 【System】
• Show the drawings.
【User】
• Select 2,5,7,8,9,11,15.

③ 【System】
• Reproduce and show
  the new drawings.

④ 【User】
• Perceptual words
"warm color— more"

⑤ 【System】
• Reproduce and show
  the new drawings.

⑥ 【User】
• Perceptual words
"warm color— more"
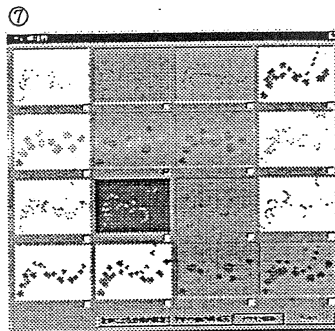
⑦ 【System】
• Select the 6th drawing.
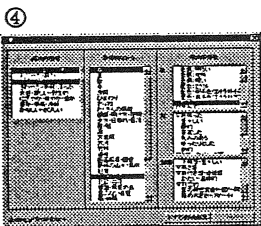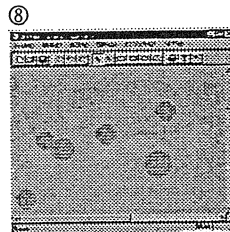
⑧ 【User】
【System】
• Drawing is completed.

Fig. 8 Example of Design Process

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4.3 Characteristics of Fuzzy Set-based Multistage Fuzzy Associative Inference

(1) Knowledge Acquisition

The knowledge for the kanseiful drawing can be easily represented by the fuzzy rule rather than the vector of the strength of the words in the 3-layered "List Box". This means that the fuzzy rule corresponds to a number of the vector data. It is extremely effective in the knowledge acquisition.

(2) Learning

Similarly to the effectiveness in the knowledge acquisition, the learning phase is also improved by the adoption of the fuzzy set-based associative matrix M.

(3) Associative Inference

Due to the coupled network and the mixed convergence algorithm, the conference can not be guaranteed. But the drawback is easily resolved by the limitation of the iteration.

5. Evaluation

We have evaluated the effectiveness of the inference method through the actual design processes. Here one typical design flow is demonstrated in Fig. 8.

According to the qualitative evaluation through the interview with the testers, they showed the positive evaluation for the user interface and the quality of the produced drawings. However someone complained that the convergence was so fast that the system failed to produce the wide range of the candidates.

6. Summary

We have analyzed the process of the creative work and designed the user interface that supports and expands the user's creative activities. Based on the analysis, we proposed the inference method for our kansei design support system. We summarized the special features that are indispensable for the inference method.

Then we proposed the new inference method, called the Fuzzy Set-based Multistage Associative Inference, which uses the associative matrix with fuzzy numbers. We analyzed the characteristics of the proposed inference mechanism from the viewpoints of the knowledge acquisition, the learning speed and the associative inference. For the evaluation, we demonstrated the successful actual design processes.

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