A Study on Sensitivity Analysis by Fuzzy Inference Rules Using Color and Location Information

Kwang-Baek Kim, Young-Woon Woo, *Members, KIMICS*

***Abstract*—**Human beings can represent state of mind such as psychological state, personality or emotional trouble by the pictures painted on one's own initiative. But in general, it is hard to understand a consulter's unconscious state through one's objective and intentional descriptions only. So one's psychological state and emotional trouble can be understood and cured by color and location information of objects drawn in one's picture. By this reason, a consultant can help and settle a consulter's growth stages of life and emotional trouble through treatment by pictures. In this paper, we proposed a method to find out state of sensitivity by analysis of color and location information represented in a picture and fuzzy inference rules. We applied the proposed method to the states of sensitivity from color information proposed by Alschuler and Hattwick and the psychological states from location information proposed by Grunwald. In the experimental results by the two applications, we verified the proposed sensitivity analysis method is efficient.

Index Terms — Color Information, Location Information, Fuzzy Inference Rules, Sensitivity

I. INTRODUCTION

Picture is an important method to communicate with other persons by representing one's inner life style. In general, personality, state of sensitivity or psychological state of a person can be understood by favorite colors expressed in the picture painted by oneself [1]. In case of adults, the number of persons having acquaintanceship are increasing and aspects of conflict with other persons become to be complicated, because social interactions with people are more frequent than before. By this reasons, pictures by adults represent emotion of diverse and complicated defiance and defense. But pictures by children represent their attitude, wish, emotion, thinking, interest and so on more clearly, because they have non-defensive and spontaneous attitudes for the public. Recently, researches on analyzing states of mind and mental disorder such as feeling, thinking, imagination, conflict, worry and curing of psychological problems by using colors and locations of the objects in a picture, are accomplished actively [2]. Therefore, we proposed a method for analyzing human's state of sensitivity using colors and locations of the objects drawn in a picture and the Min-Max fuzzy inference method proposed by Mamdani.

Manuscript received May 17, 2009; revised June 11, 2009. Kwang-Baek Kim(first author) is with the Division of Computer and Information Eng., Silla University, Busan, 617-736, Korea, (e-mail: gbkim@silla.ac.kr). Young Woon Woo (corresponding author) is with the Dept. of Multimedia Eng., Dong-Eui University, Busan, Korea, (e-mail: ywwoo@deu.ac.kr).

II. RELATED RESEARCHES

A. State of Sensitivity by Single Color Based on Alschuler and Hattwick's Theory

According to the researches by Alschuler and Hattwick, they said color is the most expressive factor to represent one's emotional life in a picture, and colors represented in the picture are almost accord to their emotion [3]. When a person's life changes from impulsive and emotional life to non-impulsive and rational life, the person becomes to be less interested in colors. Persons more interested in shapes like line and curve than color, have strong tendency for self-defense, and also show interests on objects in outer world and rational activities. We can see that color is very closely connected to emotion from these facts. States of sensitivity by single color are classified to 11 kinds [4][5].

1) Black: State of strong mind

This color represents defiance, abandonment, and inclination to depending on destiny. The person who likes black color may lack liberty, and feels fear, uneasiness, pressure and loneliness. The person wearing black clothes has a desire to show oneself as a cultural and interesting person. But this color means hiding and oppressing of internal wish and mundane desire, too.

2) Yellow: State of open mind

This color represents change, adventure on intellectual fields, pursuit of new things and self-achievement, interest in philosophy, religion and world view. The person who likes yellow color may have good relationship and popularity. But yellow color is preferred by schizophrenics.

3) Green: State of demand for spiritual fulfillment

This color represents gentleness, sincerity, patience, humbleness and temper of open mind on life and people. But the person who uses green color excessively such as wearing clothes of green too often or painting the surroundings by green only, may have precariousness unconsciously. So a person may cling to green color in order to escape from uneasy and hostile environments.

4) Purple

This color represents sensibility, mysticism. The person who likes purple color may be unhappy at home and may be left out in the cold, so the person is concerned about mystic groups or religion.

5) Red: State of desire

This color represents optimism and pleasure. The person who likes red color has inclination to extroverted activity such as physical action, adventure and sports, and also has impatience, aggressive propensity, less objectivity and simplicity.

6) Orange: State of strong intercourse

This color represents good relationship between friends and good accommodation. The person who likes orange color may have courtesy, careful consideration, cheerful personality and popularity in social life. But the person who likes orange color does not like to be a target of other person's interest in social group.

7) Pink

This color represents kindness and consideration but also antipathy to annoying the real world. The person who likes pink color may show sensitive reaction on changes in temperature of air or body.

8) Blue: State of tenderness and rationality

This color represents duty, conscience, deliberation, self-observation, discernment and composure. The person who likes blue color may join communal living well and be faithful to friends. The person also may have wealthy emotion and self-control, but sometimes have inclination to get worry much.

9) Brown

This color represents desire to stay in babyhood. The person who likes brown color may dislike dirtiness. The person who uses brown color continuously, is related to deficiency of maternal affection.

10) Gray

This color represents disharmony of personal relations, strong cautiousness and inferiority. The person who likes gray color may have chronic pent-up feelings in home and evades excitement and stimulus. The person is also very diligent and manages business well regardless of other's praise or acknowledgement. But the person who likes gray has inclination to dislike change and hide and cover personality.

11) White: State of wish

This color represents restlessness of mind, intention to hide oneself in such mind. The person who wears white clothes may show immature humanity or have inclination to perfectionism and impossible imagination.

B. Space disposition proposed by Grunwald

Grundwald with some researchers understood and analyzed the peculiar meanings of object's locations in a picture. Mandara also presented symbolic meanings for each location divided by left, right and top, bottom [1]. Fig. 1 shows space disposition proposed by Grunwald and the psychological meanings are defined by each location. The locations in the figure have different meanings and the states of sensitivity by location are classified to 9 kinds [7].

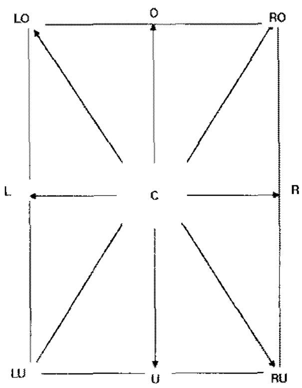

Fig. 1. Space disposition proposed by Grunwald

1) LO

This location represents degenerated imagination or schizophrenic autistic imagination, and also represents an uneasy feeling, atrophy and instability.

2) O

This location represents desire, high level of ambition, and shows possibility of feeling trouble and stress by a difficult goal could not be achieved. This location also represents inclination to find satisfaction in one's own imagination, not in the real world. This inclination relates to excessive optimism discord with a situation or excessive indifference to personal relations, social circumstances.

3) RO

This location represents desire to suppress unpleasant memory of the past, excessive optimism for future, fantasy about future-orientation, positiveness and hope.

4) L

This location represents inclination to act impulsively, inclination to pursuit prompt satisfaction of desire and impulse, desire for change and extroversion.

5) C

This location represents ego-centered inclination and stable and unified psychological state. If someone tries to draw something in exact center of a picture, the one may feel instability or may have characteristics of rigid recognition and emotion. The one may be also too stubborn and inadaptable in personal relations.

6) R

This location represents inclination to keep up stability and to control one's own actions and also shows inclination to retard satisfaction of desire and to prefer intellectual satisfaction. This location represents inclination to control emotion cognitively and to resist negatively introversion or the authorities and also shows delusions of grandeur, distortion of the real world, a sense of inferiority, a sense of languor, melancholy and timidity.

7) LU

This location represents inclination to hypochondria of the past, pessimism and inadaptability.

8) U

This location represents instability and unsuitableness in the inside or state of melancholy. This location also represents inclination to pursuit obvious and actual things based on reality rather than imaginative or ideal things.

9) RU

This location represents no hope for future, desire for optimism and unreality.

III. THE PROPOSED METHOD FOR SENSITIVITY ANALYSIS USING FUZZY INFERENCE RULES

A. Membership Functions for Colors

The equations for calculating membership grades for R, G, B colors are as follows. Membership functions are shown in Fig. 2 and membership grades by R, G, B colors are shown in Table 1.

1) Membership grades for low frequency of R, G, B colors (L)

$$\begin{cases} If(L \le 32) & Then \quad \mu(L) = 1 \\ ElseIf(L \ge 80) & Then \quad \mu(L) = 0 \\ Else & \mu(L) = \dfrac{80 - L}{80 - 32} \end{cases}$$

2) Membership grades for somewhat low frequency of R, G, B colors (SL)

$$\begin{cases} If(SL \le 48) or (SL \ge 144) & Then \quad \mu(SL) = 0 \\ ElseIf(SL < 96) & Then \quad \mu(SL) = \dfrac{SL - 48}{96 - 48} \\ ElseIf(SL \ge 96) & Then \quad \mu(SL) = \dfrac{14 - SL}{144 - 96} \end{cases}$$

3) Membership grades for somewhat high frequency of R, G, B colors (SH)

$$\begin{cases} If(SH \le 112) or (SH \ge 208) & Then \quad \mu(SH) = 0 \\ ElseIf(SH < 160) & Then \quad \mu(SH) = \dfrac{SH - 112}{160 - 112} \\ ElseIf(SH \ge 160) & Then \quad \mu(SH) = \dfrac{208 - SH}{208 - 160} \end{cases}$$

4) Membership grades for high frequency of R, G, B colors (H)

$$\begin{cases} If(H \le 176) & Then \quad \mu(H) = 0 \\ ElseIf(H \ge 224) & Then \quad \mu(H) = 1 \\ Else & \mu(H) = \dfrac{H - 176}{224 - 176} \end{cases}$$

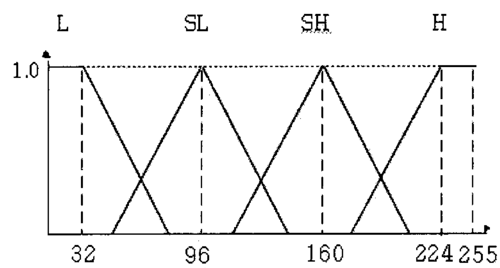

Fig. 2 Membership functions for R, G, B colors

Table 1 Membership grades for R, G, B colors

Frequency of R,G,B Colors	Interval
Low (L)	[0, 79]
Somewhat Low (SL)	[49, 143]
Somewhat High (SH)	[113, 207]
High (H)	[177, 255]

B. Inference Rules for Color Information

The final color information is derived by fuzzy inference rules with fuzzy membership values on R, G, B components. R, G, B in the following inference rules are membership grade values by colors and Y means the resultant membership grade value for each color. The fuzzy inference rules for 11 colors are shown below.

< *Inference rules for 'Red'* >
If R is H and G is L and B is L
then Y is H
If R is SH and G is L and B is L
then Y is H

< *Inference rules for 'Blue'* >
If R is L and G is L and B is (SL, SH, H)
then Y is H
If R is L and G is SL and B is (SH, H)
then Y is SH
If R is L and G is SH and B is (SH, H)
then Y is SH
If R is L and G is H and B is H
then Y is SH
If R is L and G is SL and B is (SH, H)
then Y is SH
If R is SL and G is SH and B is (SH, H)
then Y is SL
If R is SL and G is H and B is H
then Y is L
if R is SH and G is SH and B is H
then Y is SH
If R is SH and G is H and B is H
then Y is L

Inference rules for 'Yellow'
If R is H and G is H and B is L
then Y is H
If R is H and G is H and B is SL
then Y is SL

< *Inference rules for 'Green'* >
If R is L and G is (SL, SH, H) and B is L
then Y is H
If R is L and G is SL and B is SL
then Y is L
If R is L and G is SH and B is SL
then Y is SL
If R is L and G is H and B is (SL, SH)
then Y is SH
If R is SL and G is SH and B is (L, SL)
then Y is SL
If R is SL and G is H and B is (L, SL, SH)
then Y is SH
If R is SH and G is SH and B is L
then Y is SL
If R is SH and G is H and B is (L, SL, SH)
then Y is SH

< *Inference rules for 'Black'* >
If R is L and G is L and B is L
then Y is H

< *Inference rules for 'Orange'* >
If R is H and G is SL and B is (L, SL)
then Y is SH
If R is H and G is SH and B is L
then Y is H
If R is H and G is SH and B is SL
then Y is SH

< *Inference rules for 'Brown'* >
If R is SL and G is L and B is L
then Y is SH
If R is SL and G is SL and B is L
then Y is SL
If R is SH and G is SL and B is L
then Y is H

< *Inference rules for 'Purple'* >
If R is SL and G is L and B is (SL, SH)
then Y is SH
If R is SL and G is L and B is H
then Y is H
If R is SH and G is L and B is SL
then Y is L
If R is SH and G is L and B is (SH, H)
then Y is H
If R is SH and G is SL and B is (SH, H)
then Y is SL
If R is H and G is L and B is H
then Y is H
If R is H and G is (SL, SH) and B is H
then Y is SL

< *Inference rules for 'White'* >
If R is H and G is H and B is H
then Y is SL

< *Inference rule for 'Gray'* >
If R is SL and G is SL and B is SL
then Y is H

If R is SH and G is (SL, SH) and B is SL
then Y is SL
If R is SH and G is SH and B is SH
then Y is SH
If R is H and G is H and B is SH
then Y is L

< Inference rules for 'Pink' >
If R is H and G is L and B is SL
then Y is SH
If R is H and G is L and B is SH
then Y is H
If R is H and G is SL and B is SH
then Y is SL
If R is H and G is SH and B is SH
then Y is L

C. Mamdani's Min-Max Calculation Method by Color Information

Minimum of membership grades of R, G, B calculated by membership functions is derived using when the color chosen by a user is ambiguous color. Maximum value from minimum membership grades by same colors and fuzzy inference rules, is calculated. Min-Max calculation method by Mamdani is shown in equation (1).

$$\mu_{Ci}(z)=\mu_{Ai}(R)\wedge\mu_{Bi}(G)\wedge\mu_{Ci}(B)$$
$$\mu_{C}(z)=\mu_{C1}(z)\vee\cdots\mu_{Cn}(z) \quad (1)$$

The membership grades calculated by Min-Max calculation method are not decisive values. So we apply COG(Center Of Gravity) defuzzification method[2] to decide the final resultant color using each Max value by color. The equation used for COG defuzzification method is shown in equation (2). We analyze one's state of sensitivity using colors mostly used in a picture.

$$y^{*}=\frac{\sum\mu(y_i)\cdot y_i}{\sum\mu(y_i)} \quad (2)$$

D. Center of Gravity Method for an Overall Picture

In order to calculate center of gravity for an overall picture, center of gravity for each object in the picture is calculated. After calculating center of gravity for the overall picture using area and center of gravity of each object, the final location of the picture is derived by Mamdani's Min-Max calculation method applied to location information of each object.

$$\vec{G}_i=\left(\frac{x_i+x_{i+1}}{3},\frac{y_i+y_{i+1}}{3}\right) \quad (3)$$

$$\vec{G}=\frac{\sum A_i\vec{G}_i}{\sum A_i} \quad (4)$$

$\vec{G}_i$ of equation (3) means center of gravity for each object. $\sum A_i$ of equation (4) means area of each object and $\vec{G}$ means center of gravity for an overall picture.

E. Membership Functions for Location Information

Equations for calculating membership values for X, Y coordinates representing center of gravity for overall picture, are as follows. Fig. 3 shows membership functions and Table 2 shows membership grades for location information represented by X, Y coordinates.

1) Low Interval (L)

$$\begin{cases} If(L\le 84) & Then\ \ \mu(L)=1 \\ ElseIf(L\ge 209) & Then\ \ \mu(L)=0 \\ Else & \mu(L)=\frac{209-L}{209-84} \end{cases}$$

2) Middle Interval (M)

$$\begin{cases} If(M\le 126)or(M\ge 375) & Then\ \ \mu(M)=0 \\ ElseIf(M<250) & Then\ \ \mu(M)=\frac{250-M}{250-127} \\ ElseIf(M\ge 250) & Then\ \ \mu(M)=\frac{375-M}{375-250} \end{cases}$$

3) High Interval (H)

$$\begin{cases} If(H\le 291) & Then\ \ \mu(H)=0 \\ ElseIf(H\ge 416) & Then\ \ \mu(H)=1 \\ Else & \mu(H)=\frac{H-291}{416-291} \end{cases}$$

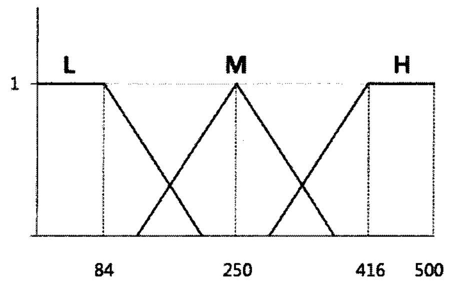

Fig. 3 Membership functions for X and Y coordinates

F. Inference Rules for Location Information

Location information is derived using membership grades of X, Y coordinates applied to inference rules. The inference rules for deriving D for 9 locations in Fig. 1 are as follows.

< *Inference rules for locations* >
If X is L and Y is L then D is LO
If X is L and Y is M then D is L
If X is L and Y is H then D is LU
If X is M and Y is L then D is O
If X is M and Y is M then D is C
If X is M and Y is H then D is U
If X is H and Y is L then D is RO
If X is H and Y is M then D is R
If X is H and Y is H then D is RU

Table 2 Membership grades for location information

X coordinate	Interval	Y coordinate	Interval
L(Left)	[0,208]	L(Top)	[0,208]
M(Middle)	[126.374]	M(Middle)	[126,374]
H(Right)	[292,500]	H(Bottom)	[292,500]

G. Mamdani's Min-Max Calculation Method for Location Information

Mamdani's Min-Max calculation method for deriving location information is shown in equation (5). The values calculated by Min-Max calculation method are not the final location value, so the final resultant location is decided by the COG(Center Of Gravity) defuzzification method using the Max values for each object's location calculated by equation (5). The final location value is used for analyzing state of sensitivity by location information in the picture.

$$\mu_{Ci}(z) = \mu_{Ai}(x) \wedge \mu_{Bi}(y)$$
$$\mu_C(z) = \mu_{C1}(z) \vee \cdots \mu_{Cn}(z) \quad (5)$$

IV. EXPERIMENT AND RESULT ANALYSIS

In order to implement the proposed sensitivity analysis method using color, location information and fuzzy inference rules, we used a personal computer of Pentium IV CPU and Eclipse software with JDK 5.0. Fig. 4 shows the initial screen of the proposed system.

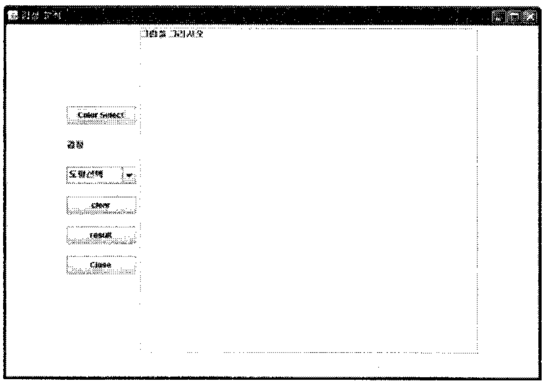

Fig. 4 The initial screen of the proposed system

Fig. 5 shows the screen for a user to select colors by the predefined color palette. After a user selects colors from the predefined palette and draws a picture with the colors, membership grades for each color are calculated by membership functions for colors. And then the resultant R, G, B values are derived by Mamdani's Min-Max calculation method and COG defuzzification method. The sensitivity analysis by color is performed using mostly used colors in the picture painted by the user. As a next step, membership grades for center of gravity of the overall picture are calculated by membership functions and the final X, Y coordinates are derived by Mamdani's Min-Max calculation method and COG defuzzification method. The sensitivity analysis by location information is performed using fuzzy inference rules for location. Fig. 6 shows a picture to be analyzed and Fig. 7 shows results of sensitivity analysis by color and location.

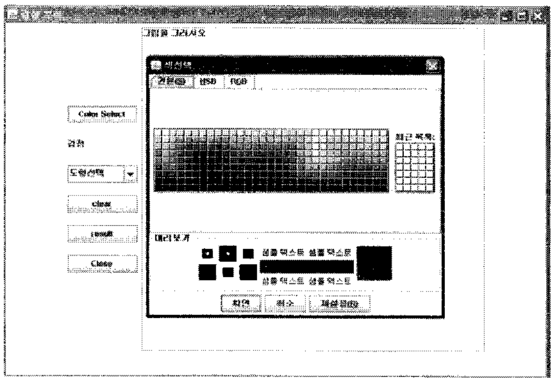

Fig. 5 Color selection by the predefined palette

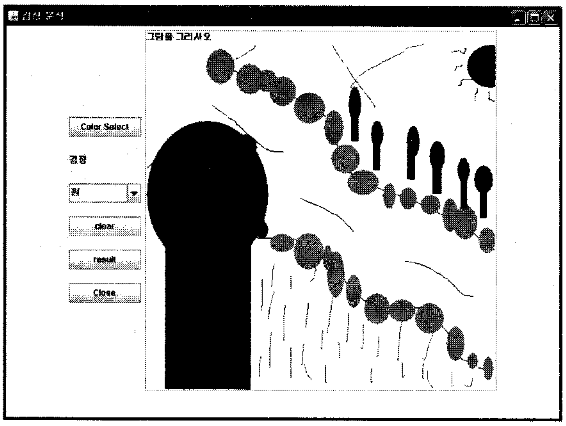

Fig. 6 A sample picture for analysis

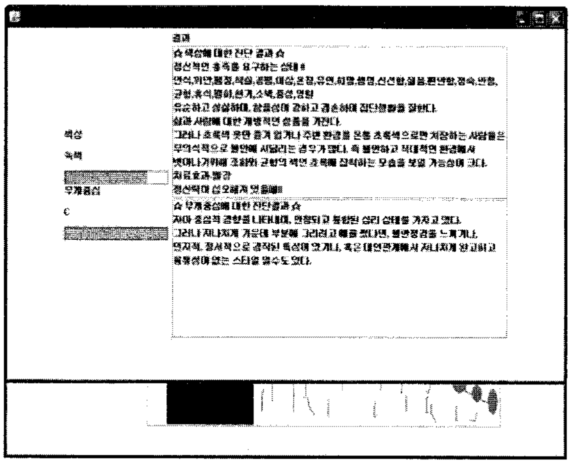

Fig. 7 Results of sensitivity analysis

IV. CONCLUSIONS

In this paper, we proposed a method to analyze state of sensitivity of human using color information in the picture painted by pre-defined colors, location information of objects in the picture, Mamdani's Min-Max calculation method and the COG defuzzification method. We verified that the proposed sensitivity analysis method is efficient by applying the method to description of sensitivity state according to color proposed by Alschuler and Hattwick and psychological state according to location proposed by Grunwald. We need to study more precise and overall analysis methods using location of object and HTP(Home, Tree, Person), one of integrated psychological test methods as future researches.

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Kwang-Baek Kim
Received his M. S. and the Ph.D. degrees in Department of Computer Science from Pusan National University, Busan, Korea, in 1993 and 1999, respectively. From 1997 to present, he is a professor, Division of Computer and Information Engineering, and Silla University in Korea. His research interests include Fuzzy Neural Network and Application, Bioinformatics, Image Processing.

Young Woon Woo
Received the B.S. degree, M.S. degree and Ph.D. degree in electronic engineering from Yonsei University, Seoul, Korea in 1989, 1991 and 1997, respectively. Since 1997, he has been a professor in Department of Multimedia Engineering, Dong-Eui University, Busan, Korea. His research interests are in the area of Artificial Intelligence, Image Processing, Pattern Recognition and Medical Information.