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Estimation of Surface Color with Use of Subjective Feeling: On the Influence of Contrast by Complementary Color

Kazuyoshi SAKAMOTO*, Mitsuyoshi WADA*, Byung Chan MIN**

Abstract : The unique colors of paper, that is, blue, green, red, and yellow were used in the estimation of color from the subjective feeling. The monochrome with unique color or the unique color surrounded with the background color was presented. Subject gazed the monochrome or the unique color, which was called target color. The target and background color were the complementary color each other. The various ratios of the area of gazed color and background were taken. Subject answered the level of subjective feeling consisted of pair of adjective items for unique color presented. With the use of the subjective feeling for the target color presented, the estimation of the unique color was carried out due to Fuzzy theory and neural networks. The results of color difference between unique color presented and the estimated color gave very small value for the case without background, while the results of the case with background color depended on the ratio of area of presented color and background color till the ration of 2:1, The relation showed the Kirschman's law. The color difference saturated in the increase of area of background with the ratio more than 2:1.

Key word : Estimation of color, Unique color, Contrast, Kirschman's law

1. INTRODUCTION

Recently, persons have been interesting in not the function and cost of goods but the feeling of the color and design, since the goods possessed similar property. The evaluation of subjective feeling for color was reported1), but the evaluation of color only from subjective feeling which subject imaged objective matter (e.g., color, car, flower etc.) has not been studied. In the study, surface color was treated and unique colors (i.e., blue, green, red, and yellow) of paper were studied. Surface color estimated with use of neural network and Fuzzy theory, in which theory individual difference was considered in the setting of membership function. In the evaluation of color, the color called target color with background color, in which the colors were complementary each other, was presented. That is, the effect of simultaneous contrast was studied. The various ratios of both areas of target and background colors were studied. It was found that the estimation of color was in good agreement with the color presented only for target of monochrome. The color difference between the target color presented and estimated color in case of both target and background colors depended on the ratio of area2), which relation was known as Kirschman's law. In Kansei engineering, it will much contribute to many research fields that estimation of color could be carried out by the obtaining the subjective feeling and by the analysis based on the data of the feeling of objective matter.

2. METHOD

The experimental procedure, which subject gave

*Department of System Engineering, The University of Electro-Communications, Tokyo, Japan
**Ergonomics Research Group, KRISS (Korea Research Institute of Standard and Science), Taejon, Korea

Table 1. Unique color sample of paper*

COLOR	HVC presentation	L*	a*	b*
RED	5.02R 4.14/15.25	42.68	64.41	32.83
YELLOW	4.97Y 8.05/15.06	81.84	-3.6	106.95
GREEN	4.99G 2.92/9.94	29.96	-49.97	12.01
BLUE	5.04B 4.90/9.73	50.54	-25.63	-32.74
ORANGE	4.19Y6.02/14.74	61.25	32.32	76.14
YELLOW GREEN	4.96GY6.50/12.15	65.97	-35.28	83.27
GREEN BLUE	5.08BG4.99/9.75	50.9	-48.56	-9.1
PURPLE	5.03P4.51/12.34	45.89	43.07	-38.75

*Production of Nihon shikikenn Jigyou Co.(Japan), B4 type

subjective feeling for target color without or with background color, was carried out as follows.

(1) Selection of target color and background color (complementary color of the target color).

(2) Selection of ratio of areas of target color and background color.

(3) Measurement of level of subjective feelings for the target color which subject gazed.

(4) Estimation of color from the subjective feeling with the use of neural network and Fuzzy theory.

(5) Comparison of estimated color and target color presented.

In (1) and (2), colors of paper were unique color as shown in the upper half of Table 1. The characteristics of colors in the color system in CIE, (L*, a*, b*), are shown in Table 1. The white light made by Matsushita Denki Co., type FL10N-EDL was used as illumination for unique color sample of paper. The illuminance in box in Fig. 1 was maintained to be 1100 to 1200 Lx. Subject gazed color in experimental system as shown in Fig1. Various ratios of areas of target and background colors were used as shown in Fig. 2. In (3), the evaluation of subjective feeling in SD (semantic differential) method, which was nine kinds of adjective pairs in Table 2, was carried out. The adjectives pairs were popular in the study of feeling of color. Subject gave the response one level in the scale of nine levels between each adjective pair. The response was obtained for all the adjective pairs and for four colors listed upper half of colors in Table 1. The procedure of the experiment 0f (3) was as follows: Black cloth was covered subject's head, and wait for three minute to adopt dark circumstance. The subject gazed the target color in the box, and answered the subjective feeling of color. After each response, the black cloth was

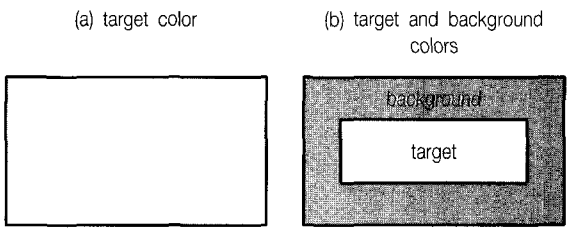

Figure 1. Experimental system

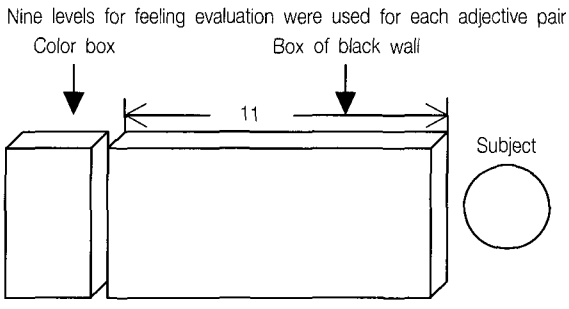

Figure 2. Color in color box

Table 2. Adjective pairs for feeling evaluation in SD method

Heavy	Light	Cool	Warm
Dirty	Pretty	Calm	Restless
Inactive	Active	Dark	Bright
Plain	Vivid	Muddy	Clean
Moderate	Violent		

removed and subject waited for one minute. The operation was repeated for four colors and for various ratios of areas of target color and background color.

In the estimation of color of (4), the neural network in which was composed of three layers was determined with the use of eight colors shown in Table 1. The eight colors were called fundamental color. The numbers of units of layers of input, intermediate, and output were 2, 6, and 1, respectively. The data of input was the quantities of (a*, b*) which presented hue. The data of output was the feeling level with the range from zero to

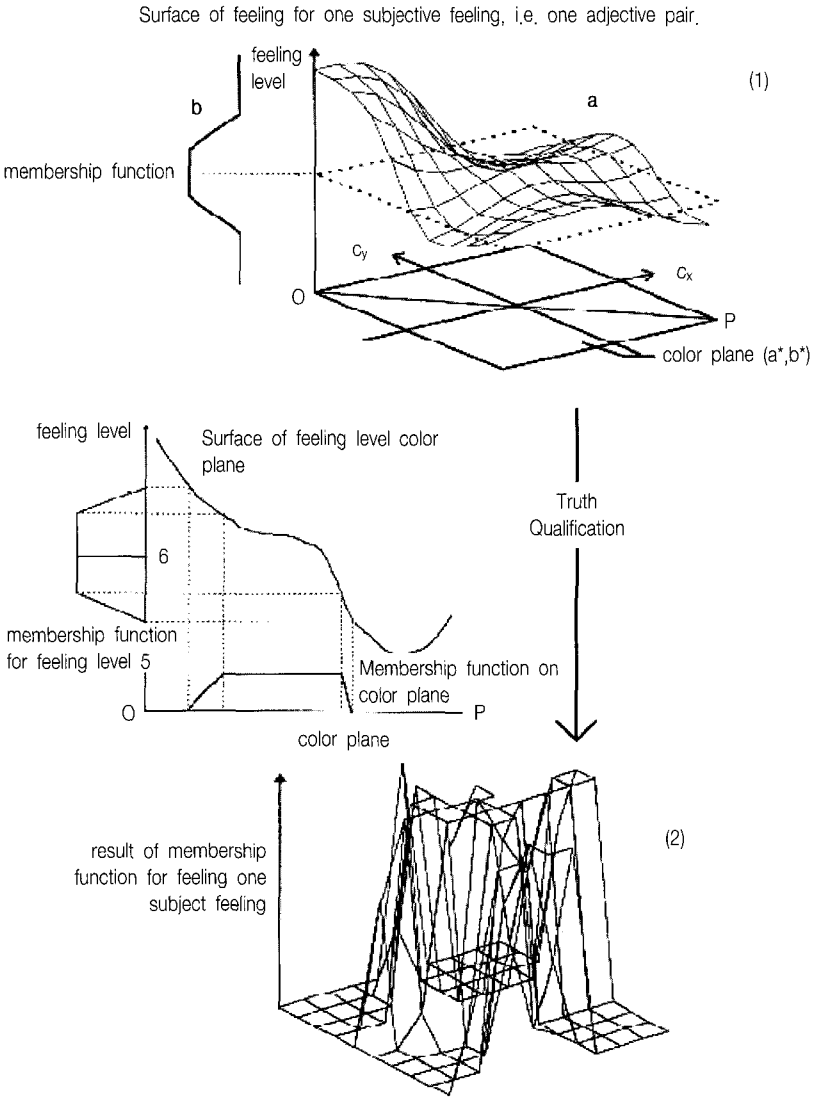

Figure 3. Process of obtaining feeling surface

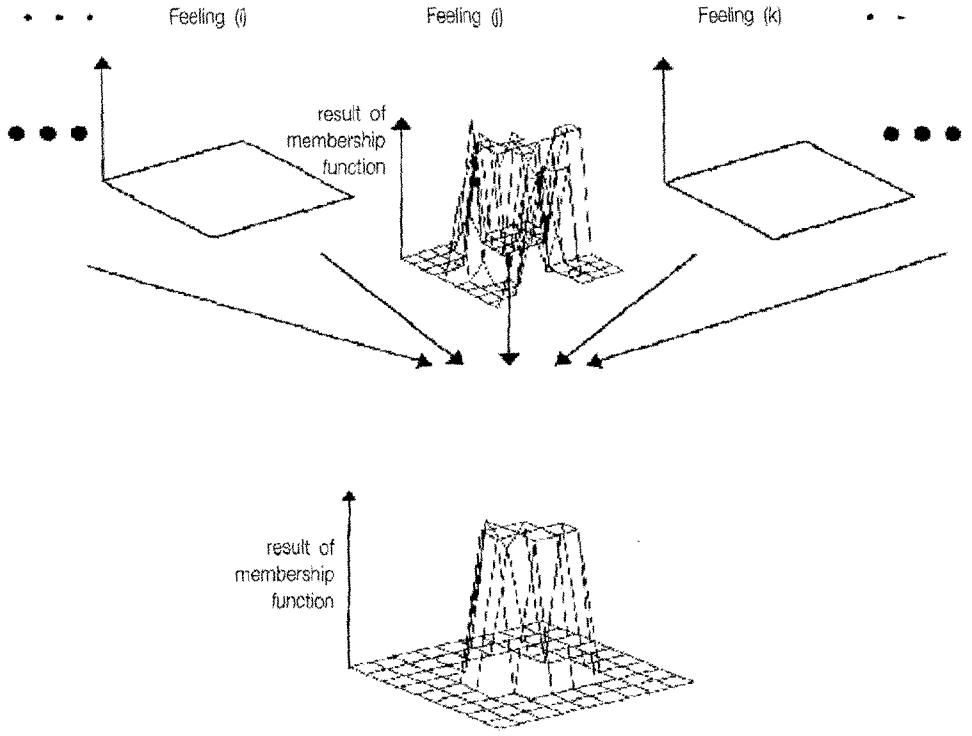

Figure 4. Process of estimation of color from feeling level

night for each adjectives pair. Using the data of input and output, the parameters of neural network was learned by back propagation method, where coefficient of unit loading Δhm, η and α in the equation of $\Delta hm = \eta\delta m + \alpha\Delta hm(r-1)$ were taken to be 0.75 and 0.80 in order to converge quickly the criterion of squared error 10^{-7}. The value of r was the number of the learning. After determination of the coefficients of unit loading, two-dimensional plane of (a*, b*) was divided into the sections of 40 ×40. The values of hue in 1600 sections were applied to determine the distribution of feeling level, which consisted of feeling surface as shown in Fig. 3. In the experiment, subject imaged a goods and gave the response of feelings level for respective adjective pairs. The feeling level was considered to be ambiguous quantity, i.e., Fuzzy quantity, so the feeling value was treated by the function of membership function. The feeling surface was selected with the use of membership function which treatment was truth qualification as shown in Fig. 3. The operation of the truth qualification was applied to all the adjective pairs, and final feeling surface on color plane was obtained as shown in Fig. 4. The mean point of color plane was evaluated in which the feeling surface obtained was used as weight value. The color coordinate (a*,b*) was estimated from the feeling for adjective pairs taken.

In (5), the color difference between the presented color (L^*_1, a^*_1, b^*_1) and the estimated color (L^*_2, a^*_2, b^*_2), $\triangle E$, was obtained by $(L^*_1-L^*_2)^2+(a^*_1-a^*_2)^2+$

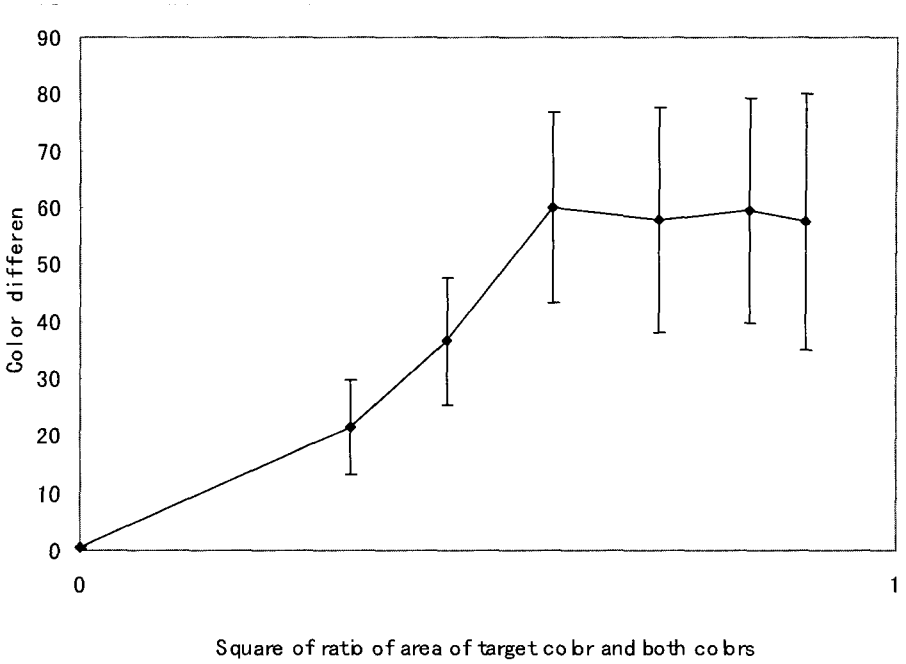

Figure 5. Relation between the square of ratio of target and background colors and the color difference

$(b^*_1-b^*_2)^2)^{1/2}$. In the experiment, the number of subjects was ten.

3. RESULTS

The results of fundamental color which monochrome of unique color was presented as target color were in good agreement with unique color presented. As for evaluation of monochrome, the color difference between presented fundamental color and the estimated color in four unique colors was less than unity compared with the maximum value of 540, that is, the estimated color denoted the color difference of 0.6%. The results denoted that the neural network was constructed to present reasonable feeling level for input of any color. On the other hand, in case of study of contrast experiment, the ratio of the area of target color and background color made much affect the color difference. The influence for four target unique colors was similar. The results of color difference for four target colors in monochrome and contrast color was shown in Fig. 5. The mean color difference at the ratio of area of 8:1 in target color and background color gave the color difference of 21.54, which was about 5% of the maximum color difference. The increase of background area in the ratio of target and background color gave the increase of color difference up to 10 % in the ratio of 2:1.The results showed that the relation between color difference and the square of the ratio on area was linear. The relation presented Kirschman's law

In the ratio more than 2:1 to 1:4, however, the color difference was saturated as shown in Fig. 5, which meant the effect of background did not recognized in case of large area of background till the ratio 2:1. The results of unique colors of red, green, and yellow showed the same tendency of the results for all target colors, while the result of blue Kirschman's law was recognized till to ratio of 1:1.

4. DISCUSSION

The color estimation system, which the neural network for input of eight fundamental colors and output of feeling level for adjective pairs in SD method was created and feeling level surface was made of 40×40 color of hue (a*, b*), and the feeling level for adjective pair was treated as ambiguous quantity and the operation of truth qualification found color for image of goods, was in good agreement with the color presented. It was significant that the estimation procedure could estimate a color desired only from feeling level of adjective pairs. In case that the influence of individual difference was called in question, the membership function could be adjusted in the operation of estimation of color. In the study, the membership function was adjusted in respective subjects, so the reasonable estimation of color was performed.

The effect of contrast for target and background colors under the relation of complementary color was investigated. It was found the influence of ratio of area of both colors was recognized. The influence of contrast was obtained up to the ratio 2:1. Especially, the square of ratio of areas of both colors was proportion to the color difference between the presented and estimated colors and the color difference was within 10 % error compared with the maximum color difference of color of paper, so the system of the estimation showed height reliability. When the feeling surface was created, if the subject feeling for any goods for adjective pairs was obtained, the estimation of the color could be estimated in high precision. The effect of contrast for complementary colors on the ratio of areas would be applied to layout or display goods in shop or public institution etc.

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