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직물의 칼라패턴에 관한 객관적 평가

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Objective Evaluation of Fabric Color Patterns

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1. Introduction

There are two types of features in a fabric color pattern. The one is physical features and the other is emotional features. The physical features may be the hue, luminance, saturation and amount of energy in Fourier domain of fabric color patterns. These kinds of physical features can be extracted using the image analysis techniques. On the other hand, the emotional features include the human feelings when one see fabric color patterns. Those features can be represented in several linguistic image scales and can be obtained from psychological experiments. We use an artificial neural network[4] to transform the physical features into emotional features. The network is trained to follow the set of data obtained from Soen's psychological experiment[1, 2]. After training, the network provides a nonlinear system to transform the physical features into emotional features.

2. Soen's Psychological Experiment

Soen[1, 2] has constructed 30 random color patterns to present them to subjects and obtain numerical grades on the 13 linguistic image scales. The patterns he has used contain diverse hues, luminances, saturations, and the frequency components in Fourier domain. The image scales he has used include 'like-dislike', 'beautiful-ugly', 'natural-unnatural', 'dynamic-static', 'warm-cold', 'gay-sober', 'cheerful-dismal', 'unstable-stable', 'light-dark', 'strong-weak', 'gaudy-plain', 'hard-soft', and 'heavy-light'. From experiment, he concluded that there are several physical features that affect on human feelings. They include average hue, average luminance, and the low, medium, and high frequency components of the spatial distribution of colors.

Soen has also constructed a model that follows the psychological experiment results using the multiple regression analysis. The model takes the physical features extracted from fabric color patterns as input variables and provides output grades on 13 linguistic image scales. The model uses the CIE-LUV color space[3]. The physical features include the average color components $\overline{L^*}$, $\overline{u^*}$, $\overline{v^*}$ and the energies D_L, D_M, D_H in the low, medium, and high frequency bands of the Fourier domain. The model converts them into 13 psychological image scales.

3. Physical Features of Fabric Color Image

Fig. 1 shows procedures to obtain the physical features. Since the fabric color patterns are represented in (R, G, B) color spaces[3] with 256 quantization levels for each components, the coordinate transformation is performed through two color space conversion processes; from (R, G, B) to CIE-XYZ[3] and from CIE-XYZ to CIE-LUV[3].

After the color space conversion into (L^*, u^*, v^*) space, the color images takes 2-dimensional Fourier transformation as Eq. 1.

$$
\begin{aligned}
O_L(u,v) &= \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} L^*(x,y)\exp[-j2\pi(ux/m+vy/n)] \\
O_u(u,v) &= \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} u^*(x,y)\exp[-j2\pi(ux/m+vy/n)] \\
O_v(u,v) &= \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} v^*(x,y)\exp[-j2\pi(ux/m+vy/n)]
\end{aligned} \tag{1}
$$

The average color components ($\overline{L^*}$, $\overline{u^*}$, $\overline{v^*}$) correspond to ($O_L(0,0)$, $O_u(0,0)$, $O_v(0,0)$). The dynamic components of each frequency band in Fourier domain can be calculated as follows. At first, the energy of each frequency is obtained by Eq. 2.

$$
D(f) = [\sum_{u=0}^{m/2}\sum_{v=0}^{n/2}(|O_{L(u,v)}|^2 + |O_{u(u,v)}|^2 + |O_{v(u,v)}|^2], \qquad f = [u^2+v^2]^{1/2} \tag{2}
$$

In Eq. 2, the $D(0)$ is excluded.

To reflect the characteristics of human vision, the frequency response $D(f)$ is multiplied with the modulation transfer function(Eq. 3) of human vision system.

$$
H(f) = [C_1 + C_2(f/f_0)^{\alpha/2}]/[1+(f/f_0)^{\alpha}], \tag{3}
$$

where C_1 = 0.7, C_2 = 1.3, f_0 = 25 and α = 2.

The $H(f)D(f)$ is again filtered with Eq. 4 for the separation of frequency bands. Eq. 4 is the transfer function of the band-pass filter.

$$A_{M(f)} = 2(f/f_0)^{\alpha/2}/[1+(f/f_0)^{\alpha}] \qquad (4)$$

In Eq. 4, f_0 is 25, α is 8 and D_M corresponds to the sum of $A_M(f)H(f)D(f)$ over all frequencies. Also, D_L and D_H are the sums of remained energy after filtering for all frequencies less than f_0 and greater than f_0, respectively.

4. Conversion of the physical Features to Emotional Features Using Neural Network

As we have mentioned, the multilayer feed-forward network[4] is used for converting the physical features to the emotional features. Fig. 2 shows the block diagram for the conversion model. In the neural network architecture, there are 6 nodes in input layer, 5 nodes in hidden layer, and 13 nodes in output layer. Each node in the input layer corresponds to the value of a physical features among $\overline{L^*}$, $\overline{u^*}$, $\overline{v^*}$, D_L, D_M, D_H, and each value of output node corresponds to the value of an emotional image scale. The set of training data consists of the physical features and output emotional features for 30 random color patterns, that is the same set of the data as Soen's experiment. For the training, the output values are normalized between 0 to 1, because the range of Soen's data is between 1 and 7. The training algorithm was the error back-propagation algorithm until the error value becomes less than 0.001.

The performance of the neural network model was evaluated by calculating the correlation coefficients between the output from neural network and the average emotional features from Soen's experiments for 30 random color patterns. The results are given in Table 1. The correlation coefficients of the proposed system show higher for 8 emotional feature scales than those of Soen's system using multiple regression analysis .

In addition, the performance of the model was also evaluated using 5 real fabric color patterns as well as random color patterns. The 13 emotional features for 5 real fabric color patterns were evaluated by the panel including 6 students. The averages and standard deviations(σ) were calculated for 13 emotional feature scales evaluated by 6 students. The 13 emotional features of 5 real fabric color patterns were also evaluated using the proposed system and Soen's system. All 13 expected emotional features for 5 patterns from both systems are included within 3σ limit set up based on the subjective evaluation by panel. Except "cheerful-dismal" and "light-dark," more patterns are included within 1σ limit for emotional features expected from the proposed system than those from Soen's system. The results are given in Table 2. It concludes that the emotional features from the proposed system using neural network are closer to human feelings.

4. Summary

In this paper, we proposed an objective evaluation model based on the neural network, which can transform the physical features of a fabric color pattern to the emotional features. The model motivated by the Soen's psychological experiments, in which he found the physical features such as average hue, saturation, intensity and the dynamic components of fabric patterns affect to the emotional features represented by pairs of adjective words having the opposite meanings. The neural network model was compared to multiple regression model proposed by Soen. The performance of the neural network model is found to be more powerful than that of the multiple regression model with respect to nonlinear approximation capability and memory requirement for objective evaluation of fabric color patterns.

5. Literature Cited

1. N. Kawamoto and T. Soen, *Color Res. Appl.*, Vol. **18**, PP 260-266 (1993).
2. T. Soen, T. Shimada and M. Akita, *Color Res. Appl.*, Vol. 12, PP 187-194 (1987).
3. Wyszecki, Color Science, John Wiley & Sons, Inc. (1967).
4. Hagan, Demuth, Beale, Neural Network Design, PWS Publishing Company (1996).

Table 1. Correlation Coefficients for 13 Emotional features

Scale	Soen's system	Proposed system
like-dislike	0.812	0.825
beautiful-ugly	0.728	0.727
natural-unnatural	0.786	0.897
dynamic-static	0.946	0.942
warm-cold	0.917	0.923
gay-sober	0.925	0.903
cheerful-dismal	0.934	0.932
unstable-stable	0.836	0.866
light-dark	0.908	0.945
strong-weak	0.910	0.959
gaudy-plain	0.911	0.912
hard-soft	0.924	0.884
heavy-light	0.940	0.967

Table 2. Number of test patterns within 0.3, 0.5, 0.7, 1σ limits

Scale	Soen's system				Proposed system			
	0.3σ	0.5σ	0.7σ	1σ	0.3σ	0.5σ	0.7σ	1σ
like-dislike	1	3	3	5	2	3	4	5
beautiful-ugly	2	2	2	3	2	2	4	5
natural-unnatural	1	3	3	5	0	3	4	5
dynamic-static	0	0	0	0	1	1	2	3
warm-cold	0	1	1	1	1	2	2	2
gay-sober	0	1	2	3	0	1	4	4
cheerful-dismal	1	1	1	2	1	1	1	1
unstable-stable	1	2	4	4	4	4	4	4
light-dark	0	1	2	2	1	2	2	2
strong-weak	0	0	1	2	2	4	4	4
gaudy-plain	0	0	0	1	1	2	2	3
hard-soft	1	1	3	4	1	2	4	5
heavy-light	1	1	1	2	0	0	1	3

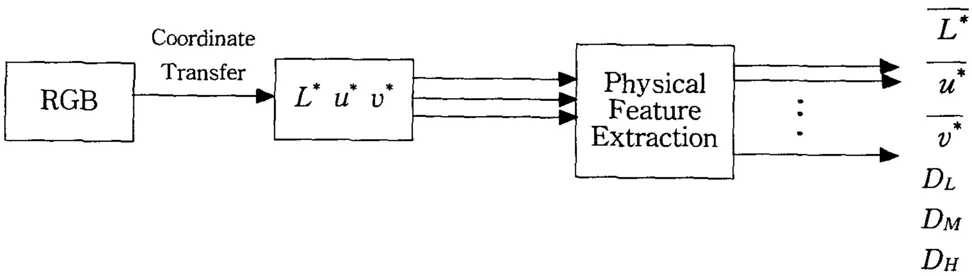

Figure 1. Extraction of Physical Features

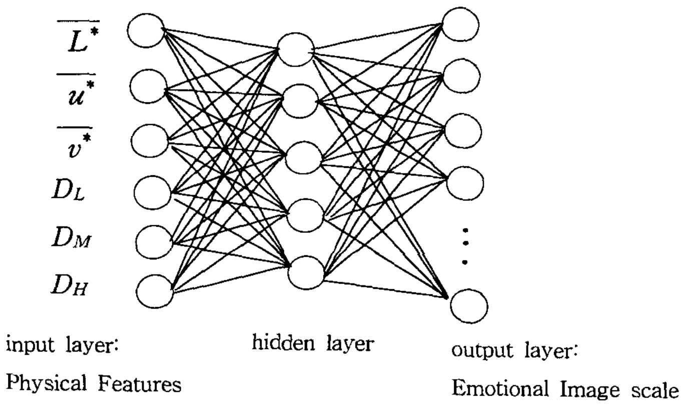

Figure 2. Architecture of Neural Network