Constructing the Predict Model for Perceptual Image Quality using Non-Linear Models

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ABSTRACT

This study established the predict model for perceptual image quality, and compared the non-linear and linear analysis method to assess perceptual image quality. This study focused on constructing a predict model of perceptual image quality. Ninety participants joined the visual assessment experiment. Four images were carefully selected from the ISO standard image by the focus group in the colour and image lab of NYUST. Each image was modulated by four physical attributes including lightness, chroma, hue angle, and contrast. All images were processed according to colour conversion and physical adjustment based on CIECAM02 function.

The results showed that lightness and chroma directly influenced the subjective feelings of the test subjects toward brightness and Colorfulness, respectively. The three criteria of image quality, preference, and naturalness are not easily directly influenced by the single variables of the four physical image attributes but rather by the interactive effect of the combination of these attributes.

1. INTRODUCTION

Recent colour science studies have used mathematical algorithms to predict perceptual image quality and subjective preference (Choi *et al*., 2009; Sheikh & Bovik, 2006; Ginesu *et al*., 2006), not only to focus on image appearance issues, but also to study the relationships between physical attributes of images and psychophysical attributes scales. Due to the model should be easy to apply to image industries and practical issues, most studies use the simple linear regression (LR) analysis method to construct the model. However, many assessment items used to evaluate an image are complex items such as preference, naturalness, or total image quality. Thus, this study questioned the linear analysis method is sufficiently accurate to construct the predict model based on simple assessment items, or whether other mathematical algorithms could also be used to construct the predict model based on complex assessment items, such as the Non-Linear regression analysis. Based on preliminary study which confirming the parameters of physical attributes for assessing image quality and checking the image stimuli (Tsai *et al*, 2009), this study focuses on constructing the predict model of perceptual image quality. The results could to clarify relationship between physical and psychophysical attributes, and to provide the image and display industries a better understanding of how physical attributes relate to human perceptual image quality.

2. EXPERIMENT

2.1 Experimental Design and Environment

Each observer was seated facing a calibrated 30 inch Sharp LCD-TV with fixed luminance and color temperature control on 120cd/m^2 and about 6500k. The laboratory light was fixed luminance and color temperature was controlled by 233lux and abut 6500k. Th e resolution of screen was multiply 1360 by 768 pixels. Each trial randomly showed an image, and the background color was set by a mid-grey colour having *L** about 60. The serial order in which the images were projected was randomized by the computer so that the image order changed every trial. Totally, that about 40 minutes for finish the experiment. The experimental environment has set as the same as to the environment of pervious study (Tsai *et al*., 2009).

2.2 Image Stimuli

In order to reduce the number of assessment trials in main experiment, there are four images used in the main experiment (Figure 1). Each image was modulated by four physical attributes including lightness, chroma, hue angle, and contrast. All images were also processed according to colour conversion and physical adjustment based on CIECAM02 function by the Boland + program. To show the image and set the experiment interface for visual assessment tasks, the modulated images were represented to the screen by Visual Basic 6.0 software. The 'linear regression (LR)' analysis, 'non-linear regression (NLR)' analysis were be used in this study.

Figure 1: Image stimuli set for main experiment.

2.3 Participants of Experiment

Ninety observers participated in the visual assessment experiment. 64 observers were undergraduate and postgraduate students from the school of design at National Yunlin University of Science and Technology. 26 observers were image and display researchers of the TTLA. All observers possessed normal colour vision according to the Ishihara colour vision test.

3. RESULTS AND DISCUSSION

This study implemented the stepwise regression method to establish a regression prediction model with the statistical analysis system SPSS 17. The data adopted to establish the regression model in this stage was obtained by randomly selecting two-thirds of the 90% participants (81 people) from the original 90 participants. The remaining one-third of the 10% participants (9 people) were reserved for model verification. The total number of observation from experiments were 26,244 (four images x 81 scale adjustment variations x 81 participants). Finally, 81 averaged samples were set for linear and non-

linear regression analysis. In terms of Multi-Collinearity testing based on the Person correlation coefficient analysis (see Table 1).

Ninety observers participated in The results show that there were high correlation coefficient between naturalness, preference, and image quality. In the other words, that may have non-linear relationship between those three variables. The results of LR show in the Table 5, five models has constructed by using LR method which shows on Eq. (1) to Eq. (5). In order to compare the performance of linear analysis, the non-linear regression analysis has also analyzed in Table 3.

Table 1: The results of Person correlation coefficient analysis.

Psychophysical attributes	Brightness	Colorfulness	Naturalness	Preference	Image Quality
Brightness		.154	.368**	.352**	.360**
Colorfulness			.699**	.732**	.722**
Naturalness				.979**	.992**
Preference					.997**
Image Quality					

Table 2: Explanatory power and Cross-Validation of different prediction models with linear regression by stepwise method.

Linear Model	Brightness	Colorfulness	Preference	Naturalness	Image Quality
Including Independent Variables	*Li* *Ch* *Co* *Ha*	*Ch* *Ha*	*Ch*	*Ch*	*Ch*
Adjust R^2	.933	.810	.200	.150	.184
F	281.019	171.616	21.013	15.679	19.017
Sig.	.000	.000	.000	.000	.000

Li: Lightness, *Ch*: Chroma, *Ha*: Hue angle, *Co*: Contrast

Table 3: Explanatory power and Cross-Validation of different prediction models with non-linear regression by stepwise method.

Non-Linear Model	Brightness	Colorfulness	Preference	Naturalness	Image Quality
Including Independent Variables	*Li* *ChHaCo* Li^2 $Li^2Ch^2Ha^2Co$ *LiChHaCo* $Li^2ChHaCo$	*Ch* Ch^2 $LiCh^2HaCo$ $LiCh^2Ha^2Co^2$ $Li^2ChHaCo$ *LiChHaCo* *ChCo*	*Ch* Ch^2 *LiCh* Li^2 *Li* $Li^2ChHa^2Co^2$ *LiChHaCo*	*LiCh* Li^2 *Li* Ch^2 *Ch*	*Ch* Ch^2 *LiCh* Li^2 *Li* $Li^2ChHa^2Co^2$ *LiChHaCo*
Adjust R^2	.968	.948	.767	.651	.764
F	402.972	207.606	38.679	30.823	37.951
Sig.	.000	.000	.000	.000	.000

$$\text{Brightness} = 5.736 \times \text{Lightness} + 1.067 \times \text{Chroma} + 2.210 \times \text{Contrast} + 0.919 \times \text{HueAngle} - 1.005 \quad (1)$$

$$\text{Colorfulness} = 4.060 \times \text{Chroma} + 1.175 \times \text{HueAngle} + 0.706 \quad (2)$$

$$\text{Preference} = 1.689 \times \text{Chroma} + 2.201 \quad (3)$$

$$\text{Naturalness} = 1.541 \times \text{Chroma} + 2.291 \quad (4)$$

$$\text{Image Quality} = 1.543 \times \text{Chroma} + 2.114 \quad (5)$$

4. CONCLUSIONS

The results of those two analysis methods showed that lightness and chroma directly influenced the subjective feelings of the test subjects toward brightness and Colorfulness, respectively. The results of correlation analysis showed that the assessment results for image quality, preference, and naturalness demonstrated significant, positive correlation between the three. This study recommends that preference and naturalness be first assessed and then linear function used to constitute image quality, to effectively increase the execution efficiency of human factor experimental evaluation. The three criteria of image quality, preference, and naturalness are not easily directly influenced by the single variables of the four physical image attributes but rather by the interactive effect of the combination of these attributes. Therefore, the data type for these criteria shows non-linear structure.

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