Developing a model for predicting whiteness of human face

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ABSTRACT

Colour appearances of 60 Chinese subjects were reproduced on display using colour reproduction technology. Using magnitude estimation technique, perceived facial whiteness were assessed in psychophysical experiment by 20 Chinese subjects. Relationship between whiteness and facial colour was investigated. Existing whiteness models including CIE Whiteness index and Individual Typology Angle, were evaluated in term of whiteness prediction for facial whiteness. A new model was developed to give a better performance in facial whiteness prediction.

KEYWORDS: Facial whiteness, skin colour, facial appearance

INTRODUCTION

Facial whiteness is an important characteristic for many people but can be affected by factors of culture and environment. A typical example is that Chinese females prefer to look white whereas Caucasian females generally dislike this look. In any case, interest in the relationship between perceived whiteness and the colour of human faces has been greatly stimulated by the increased activity in the cosmetic industry [1].

Models to predict whiteness from colour specifications have been developed over many years for various applications, including the paper industry, dentistry, food industry and textiles etc. However, it was understood that there is no universal model that is capable of predicting whiteness for different applications. For example, a modification to the CIE Whiteness index (typically used for textiles) was necessary to predict whiteness of tooth colour. This is not only caused by the psychological factor in whiteness perception in different contexts, but also the way to measure colour of those objects with different materials and shapes. Moreover, for the same application, using different models, whiteness can be predicted in a very different scale. Even a negative value of whiteness can be achieved for some models. In some case, it is difficult to connect model predicted whiteness value with the appearance of perceived whiteness for a single stimulus.

The aim of this study is to evaluate existing models and further develop a new model for facial whiteness prediction. Colour appearances of a large number of human faces were reproduced on a display. A psychophysical experiment was conducted to collect perceived facial whiteness for those facial images using 20 subjects. Based on facial colour and perceived whiteness data, performance of existing models for whiteness prediction for human faces was evaluated. Finally, a new model was developed and proposed for facial whiteness prediction.

METHODLOGY

Liverpool-Leeds facial image database

A facial image database was collected in University of Liverpool in collaboration with University of Leeds [2]. Facial images of subjects were captured under controlled viewing conditions using a SLR camera with colour characterisation processing. To achieve uniform lighting, a VeriVide DigiEye® light booth was

used, the inside of which was painted with a mid-grey matte colour and illuminated by a D65 fluorescent simulator offering evenly diffused illumination. During the data collection, the participant sat on an adjustable chair in the viewing cabinet and adjusted their position until their target facial area was within the camera lens. The camera, a Nikon D7000 digital SLR camera controlled by the DigiEye system software, was used to capture images with fixed exposure, white balance and ISO settings. The image capture distance between camera lens and training colour charts (or the subject's face) was fixed to 57.5cm and the capture angle was 0 degrees. Subsequently, skin colour of each subject was measured using a Konica Minolta CM 700d spectrophotometer. Overall, facial images of 188 subjects, including 86 Orientals (41 female and 45 male), 79 Caucasians (65 female and 14 male), 13 South Asians (6 female and 7 male) and 10 Africans (5 female and 5 male) were collected.

Image Processing

In this study, 60 facial images were selected to represent Chinese faces with neutral facial impressions. From the database, each image's RGB data was transformed to CIELAB uniform colour space via a camera characterisation process. To truly reproduce colour appearance of those facial images, an Eizo CG277 colour professional display was used and the white point was set to D65 (which is the same as the illumination for facial image capturing). Colour characterisation was conducted for the display using the method of piecewise linear interpolation assuming constant chromaticity coordinate (PLCC) [3] and the CIELAB values for each image pixel were transformed to display RGB for each facial image. Subsequently, each facial image was edited to remove hair, ears and clothes and scaled to fit the center part of the screen. Finally, the image background was set to middle grey (L*=50, a*=0 and b*=0 in CIELAB colour space) as shown in Figure 1.

Figure 1: Example of processed facial image

Facial colours

For each facial image, skin colour was represented by the mean of L*, a* and b* (averaged over each pixel of facial area) in CIELAB uniform colour space. Figure 2 was plotted to indicate colour specifications of mean facial colour for these 60 facial images in CIELAB colour space.

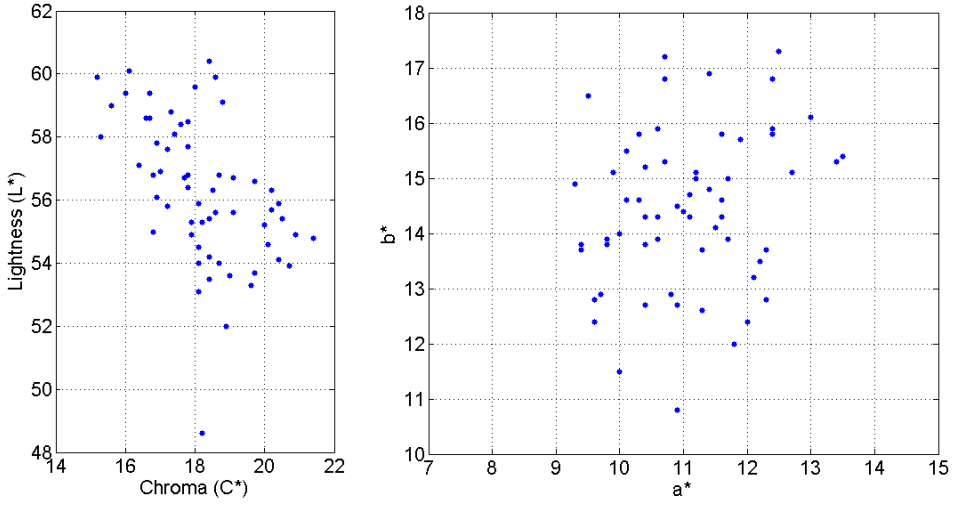


Figure 2: mean facial colours of testing images in CIELAB, Left C vs. L*, Right a* vs. b**

Whiteness index

The CIE Whiteness index [4] is widely used to predict whiteness of colour stimulus based on their CIE XYZ trisimulus values. Based on CIELAB colour space, Individual Typology Angle (ITA) [5] was developed for skin colour type classification and was also used for skin whiteness prediction. In this study, both models (Eq 1 and Eq2) were evaluated for their performance of facial whiteness prediction.

$$WI = Y + 800 \times (x_n - x) + 1700 \times (y_n - y) \quad , \qquad (1)$$

where Y is the Y-tristimuls value of the sample, x and y are chromaticity coordinate of the sample, xn, yn are the chromaticity coordinate of the reference white (where xn=0.313, yn=0.329).

$$ITA^o = [\arctan(\frac{L-50}{b})] \times \frac{180}{\pi} \qquad (2)$$

where L and b represents lightness (L*) and yellowness (b*) in CIELAB uniform colour space.

Psychophysical experiment

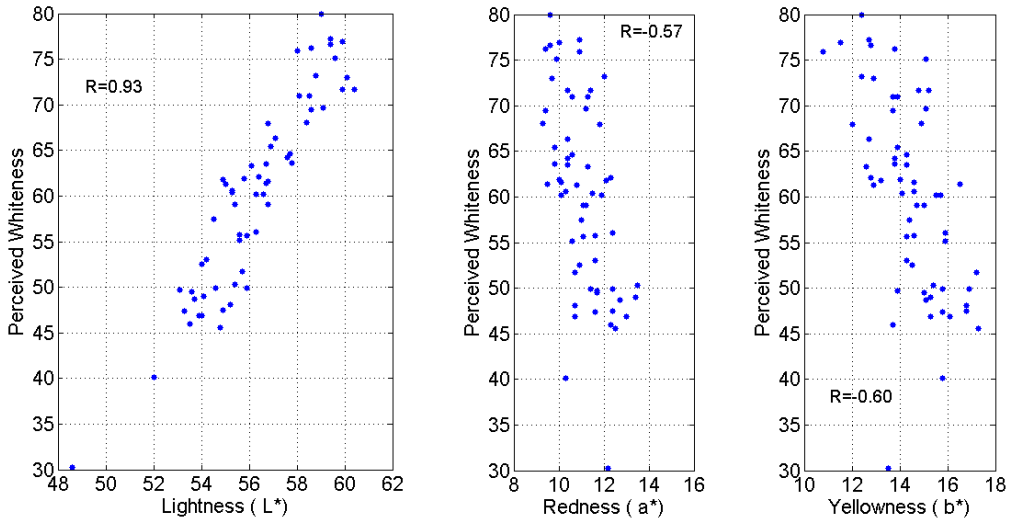
A psychophysical experiment was conducted to assess perceived whiteness by 20 Chinese subjects using the magnitude estimation technique [6]. In the experiment, a pair of facial images, (one is reference facial image, the other is test facial image) was displayed. The whiteness of the reference facial image is 50, and the subject was asked to give the whiteness of the test image in the scale of 0 to 100 based on the whiteness of reference facial image (where 0 represents completely black and 100 represents the whitest colour). Each subject assessed 60 facial images and the set of 60 assessments was repeated twice in a single session. In total, 2400 whiteness assessments (60x20x2) were made in this study.

RESULTS AND ANALYSIS

Perceived whiteness

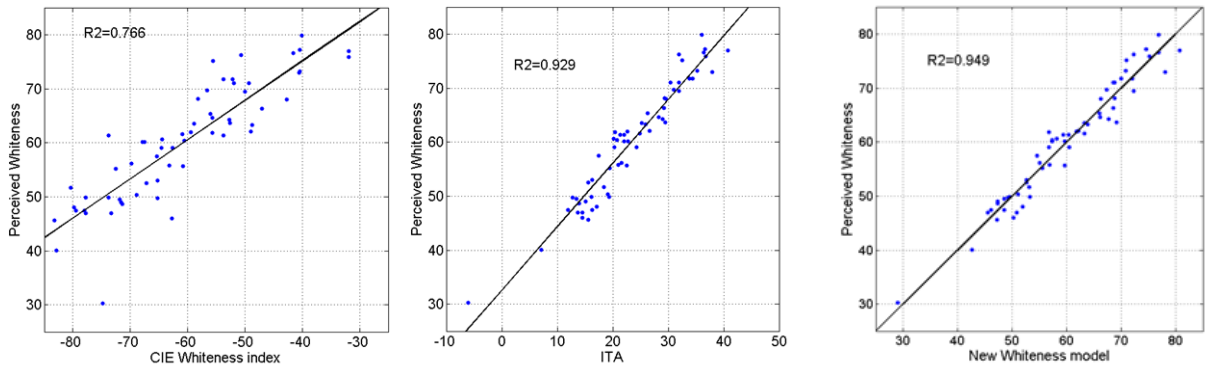
For each facial image, perceived whiteness between different subjects and different repetitions were averaged. Figure 3 was plotted to illustrate perceived whiteness for 60 facial images. It can be seen that perceived whiteness is in the range of 30 to 80.

To investigate the relationship between facial colour and perceived whiteness, Figure 3 was plotted to illustrate correlation between lightness, redness or yellowness with perceived whiteness. The correlation coefficient (r) was also calculated. Results for lightness vs. whiteness, redness vs. whiteness and yellowness vs. whiteness are 0.93, -0.57 and -0.60, respectively. These results clear shown that perceived whiteness is significantly affected by lightness, redness and yellowness of facial colour. Lightness has the largest effect, whereas redness and yellowness have a relatively smaller effect. There is a clear tendency that perceived facial whiteness increases as lightness increases, and as redness and yellowness are decreased.



(a) **(b)** **(c)**

Figure 3: Relationship between facial colour and perceived whiteness (a) lightness vs. whiteness (b) redness vs. whiteness (c) yellowness vs. whiteness



(a) (b) (c)

Figure4: Performance of whiteness prediction (a) CIE Whiteness index (b) ITA (c) Modified ITA

New model for whiteness prediction

In order to further enhance performance of whiteness prediction, a new model based on ITA was proposed (see Eq 3).

$$ITA_{New} = [\arctan(\frac{L-k}{C})] \times \frac{180}{\pi} \quad , \quad k=40.28 \qquad (3)$$

In the above new ITA model, two changes are made compared with the original ITA formula given by Equation 2. Firstly, b* was replaced by C* since both redness and yellowness affect perceived whiteness significantly. Secondly, the constant 50 is replaced by a variable k which is optimised based on the visual results in order to achieve a largest R-square value between perceived whiteness and model prediction and it was found it is the best when k equals to 40.3. In this case, R-square can achieve a best result of approximately 0.95 comapring with CIE whiteness index (0.77) and original ITA (0.93), as shown in Figure 4,

Practically, it is more convenient to transform ITA unit (degree) to a relative whiteness scale (0-100). To do that, Eq 4 was developed.

$$WI_{NEW} = 1.862 \times ITA_{New} - 16.5 \qquad (4)$$

To evaluate new model, Root-Mean-Square difference between experimental data and model prediction was calculated and result is approximately 2.4, indicating proposed whiteness index gives a very good performance for whiteness prediction.

CONCLUSION

Using a large set of facial images, facial whiteness of Chinese subjects were assessed by a psychophysical exp eriment. Based on those data, CIE Whiteness index and ITA were evaluated in term of facial whiteness predict ion. Results are clearly shown that ITA gave a significantly better performance. Based on ITA, a new model t o prediction facial whiteness was proposed and results have shown it gave a very good performance in facial whiteness prediction for Chinese.

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