# Facial Pattern Detection and Its Preferred Color Reproduction

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## Abstract

We proposed a new technique of detecting facial pattern from negative color film based on the statistical pattern recognition method. After gathering the statistics data of their lightness and chromaticities, skin color region was extracted by using binary image processing. On the basis of probability distribution of five pattern variables in the labeling image, we detected the facial patterns. This detection makes color correction of facial pattern regions possible to do by applying local color correction technique. The chromaticities of skin color in many people pictures printed by offset printing were measured for comparison with the preferred color reproduction result. Afterwards, we produced facial pattern images in many different colors and evaluated these obtained images to estimate the preferred color reproduction of facial pattern in hardcopy.

## Introduction

People in a color picture, particularly facial patterns are the most important and interesting visual object. Since they are the most rewarding visual object, control over color reproduction of the facial patterns becomes the foremost treatment in printing. The first thing one has to do prior to color reproduction of this object in printing process is to detect it from an image. The detection makes the color correction of facial pattern regions achievable by applying local color correction technique.

In the current hardcopy imaging, colorimetric color reproduction is widely used. Nevertheless, it is worthwhile to take into account the preferred color reproduction in considering and anticipating the characteristics of human visual system for advanced color reproduction and transformation between different imaging systems[1].

Since the preference is ambiguous and influenced by many factors, it is difficult to determine and define it exactly. As a result, preferred color reproduction of all objects is not attainable. In case of preferred skin color, as well known, it depends on many factors such as observer, background, size, and memory color[2]. In this paper, we limited the study of preferred color reproduction only for skin color region, particularly facial pattern in portrait picture, and emphasized the memory color as the basis of color preference in hardcopy.

The objectives of this study were to detect the facial patterns from negative color film illuminated under various illumination sources in different lighting conditions by using a new approach of statistical probability analysis and to observe the preferred skin color in facial patterns of three races in hardcopy.

## Method and Experiment

### Facial Pattern Detection

Block diagram in Figure 1 shows the proposed technique and experiments. It describes the steps from digital image acquisition to facial pattern detection. This technique similar to the technique proposed in references 3, 4, and 5, except for some extensions and modifications of defining lightness and chromaticities in original image, binary image processing, number of evaluated pattern variables of pattern vector, and especially the statistical probability analysis that was new in this study.

Five pattern variables used in computation of facial pattern class probability for classifying the skin color regions are shown in the following expressions:

$$complexity = (perimeter)^2 / area \quad (1)$$

$$elongation = (x_{max} - x_{min}) / (y_{max} - y_{min}) \quad (2)$$

$$luminance\ ratio = L_{ave} / L_{min} \quad (3)$$

*average of Laplacian*

$$masked\ hair\ ratio = \frac{masked\ hair\ area}{total\ mask\ area} = \frac{A}{X_t Y_t - x_f y_f} \quad (4)$$

$L$ is luminance. Figure 2 illustrates the explanation of Eq. 4.

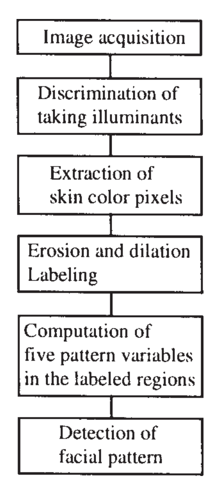



*Figure 1. Block diagram of the proposed technique and experiment*

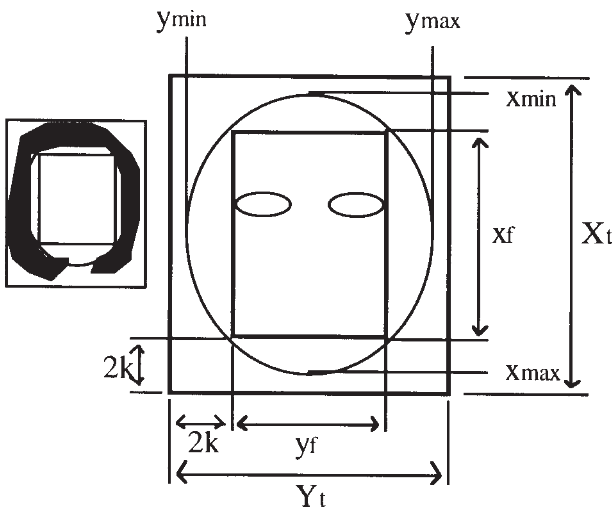



*Figure 2. Illustration of the masked hair area*

Mathematics principle applied in statistical analysis of facial pattern class probability is shown in the following equation.[6,7] Pattern variables of $m$ parameters $(X_1, X_2, \ldots, X_m)$, where the input to a pattern recognition network is a pattern variable $X_j = (x_1, x_2, \ldots, x_m)$ with $j$ = 1, 2, ... , $m$, has expectation

$$E(X) = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{5}$$

where $n$ is a number of observed samples and variance

$$D^2(X) = \frac{1}{n}\sum_{i=1}^{n} x_i^2 - \left[\frac{1}{n}\sum_{i=1}^{n} x_i\right]^2 \tag{6}$$

If element $x_j$ of $X_i$ is written as $x_{ji}$, then

$$D(X_j X_k) = \frac{1}{n}\sum_{i=1}^{n} x_{ij} x_{ik} - E(x_j) E(x_k) \tag{7}$$

The covariance matrix is defined by

$$\sum = \{\sigma_{jk}\} = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \cdots & \sigma_{1m} \\ \sigma_{21} & \sigma_{22} & \cdots & \sigma_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{m1} & \sigma_{m2} & \cdots & \sigma_{mm} \end{bmatrix} \tag{8}$$

where $\sigma_{jk} = D(X_j X_k)$ and $\sigma_{jj} = D^2(X_j)$, and has inverse covariance matrix

$$\sum^{-1} = \{\sigma_{jk}^{(-1)}\} = \begin{bmatrix} \sigma_{1'1'}^{(-1)} & \sigma_{1'2'}^{(-1)} & \cdots & \sigma_{1'm'}^{(-1)} \\ \sigma_{2'1'}^{(-1)} & \sigma_{2'2'}^{(-1)} & \cdots & \sigma_{2'm'}^{(-1)} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{m'1'}^{(-1)} & \sigma_{m'2'}^{(-1)} & \cdots & \sigma_{m'm'}^{(-1)} \end{bmatrix} \tag{9}$$

The confidence region is

$$\sum_{j=1}^{m}\sum_{k=1}^{m} \sigma_{jk}^{(-1)} \{x_j - E(x_j)\}\{x_k - E(x_k)\} \le \lambda \tag{10}$$

$$\lambda = \chi^2(\alpha, m) \tag{11}$$

Parameter $\lambda$ is a coefficient for representing the probability of samples belong to the expected class, and $m$ is degrees of freedom of $\chi^2$ distribution. If the five values of pattern variables of a skin color region fulfilled Eq. 10 for the expected class of facial pattern then it was classified as facial pattern class.

**Chromaticities of Printings and Preferred Color Reproduction**

To evaluate the chromaticities distribution of skin color of three races in hardcopy, we measured skin color chromaticities in many people pictures in magazines printed by offset printing with spectrophotometer. The number of measured samples of Mongoloid, Caucasoid, and Negroid skin colors was 216, 101, and 70, respectively. Results of measurement were plotted in CIE 1976 u'v' chromaticity diagram.

We carried out the preferred color reproduction experiment as following steps. Three portrait samples, each one represented skin color of facial pattern of a race in its image content, were sampled and quantified. Skin color regions in the digitized image were extracted using the technique of skin color region extraction above mentioned, and R, G, and B color components of the extracted skin color regions were transformed to XYZ color system. For each processed image representing skin color of a race, we made a series of 50 to 60 image copies of its duplications and altered the chromaticities of skin color regions in this series. The results were printed out to produce the sample series of skin color in facial pattern images.

The preferred color in series of hardcopies of sample images was evaluated by observer rating experiment. A panel of five naive observers was asked to rate the skin color in each sample as one of five preferred color categories: excellent, good, acceptable, poor, and bad which indexed by 5, 4, 3, 2, and 1, respectively. Afterwards, the chromaticities u' and v' of skin color in sample images rated as excellent and good were measured with spectrophotometer, and the results were plotted in u'v' chromaticity diagram to analyze their distributions.

## Experimental Result and Discussion

The experimental result of statistics data of lightness and chromaticities of skin color regions in r-g chromaticity diagram under daylight illumination source, as an example, is shown in Figure 3. Images of original, extracted skin color regions, detected facial pattern regions, and detected facial patterns under daylight illumination are shown in Figure 4a, b, c, and d, respectively.

The percentage of correct facial pattern detection depended on many factors such as confidende region set in skin color pixel extraction, techniques of binary image processing applied for region segmentation, number of evaluated pattern variables, and value of $\lambda$ used in Eq. 10. Our experiment gave ratio of correct facial pattern detection up to 80% (111 of 139 total number of regions were correctly detected as facial patterns), and

19% wrong detection (31 of 166 total number of non-facial pattern regions of skin color were incorrectly detected as facial patterns) at $\lambda$ set to include 99% of sampled facial patterns. Some improvements and modifications of skin color extraction and binary image processing techniques were needed to optimize the expected result of skin color region segmentation. Thereby, it would increase the right classification of each pattern of skin color region.

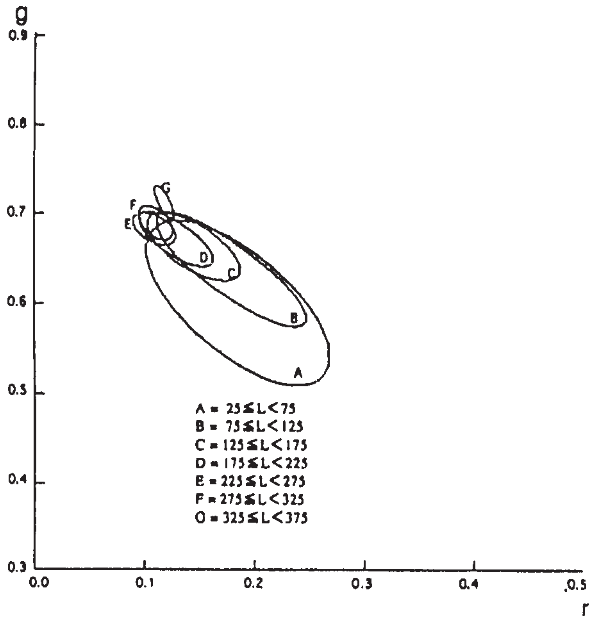
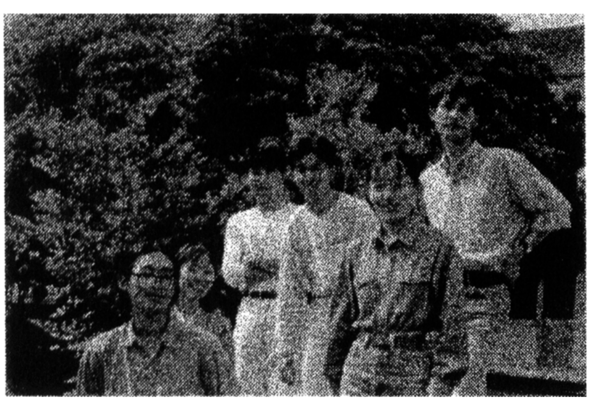


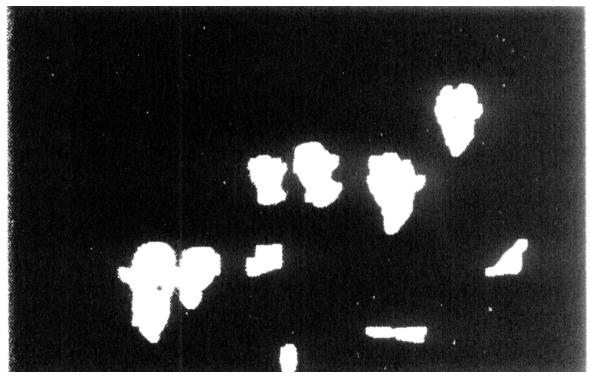

*Figure 3. The ellipsoid distribution of r-g chromaticities of skin color in a lightness interval for daylight illumination source*

Figure 5 shows the ellipsoid distributions of skin color chromaticities in printing samples plotted in u'v' chromaticities diagram at confidence region 90%. Each ellipse had longer principal axes in chroma direction than its principal axes in hue direction. The Negroid distribution was wider than the distribution of other races. Chroma of skin color increased steadily in the following order: Caucasoid, Mongoloid, and Negroid, meanwhile intensity increased in the reverse order. The hues were similar, and the dominant wavelength was about 590 nm in all distributions.

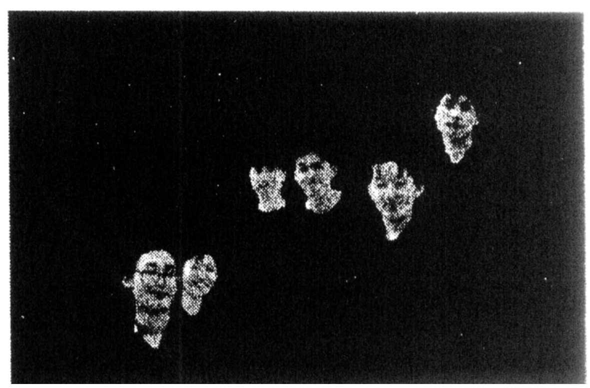


(a)

(b)



(c)



(d)

*Figure 4. (a) Original, (b) extracted skin color pixels, (c) segmented skin color regions, and (d) detected facial pattern images under daylight illumination source*

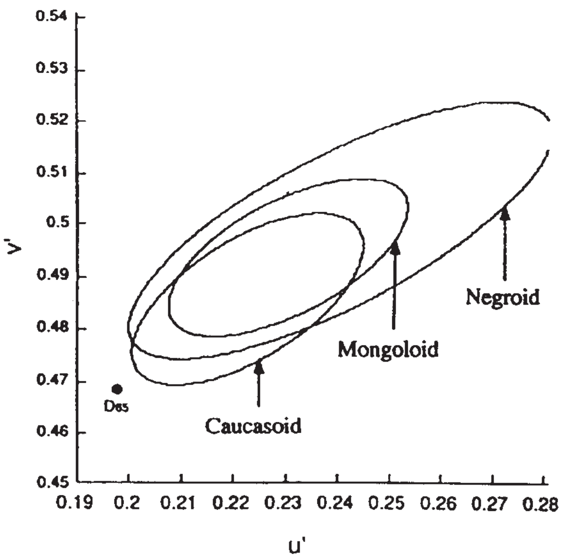



*Figure 5. Chromaticity distributions of three races skin color in people pictures printed by offset printing*

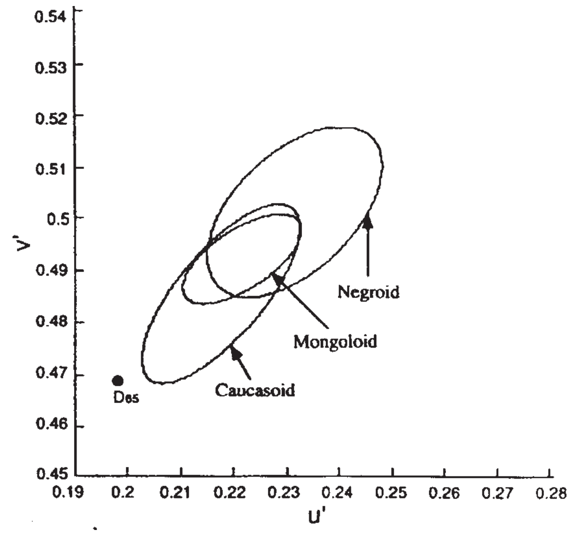



*Figure 7. Chromaticity distributions of preferred color reproduction in skin color of three races*

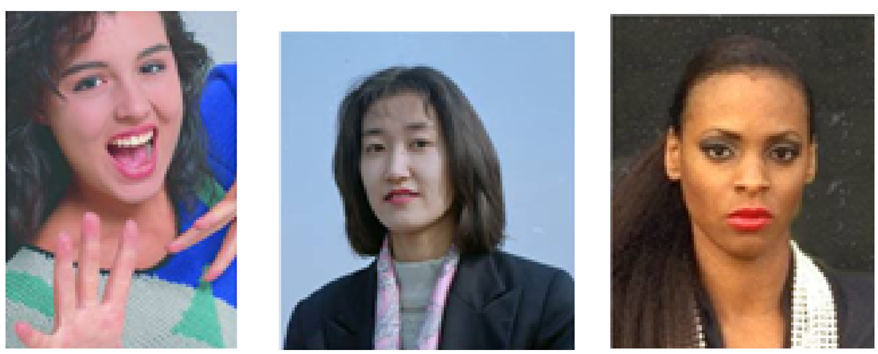


*Figure 6. Sample portraits representing (a) Caucasoid, (b) Mongoloid, and (c) Negroid facial patterns used in preferred color reproduction experiment*

Three portraits representing Caucasoid, Mongoloid, and Negroid facial patterns shown in Figure 6a, b, and c were the facial pattern samples used in the experiment. The experimental results of ellipsoid u'v' chromaticity distributions of preferred skin color at confidence region 90% are shown in Figure 7. Chromaticity distributions of Negroid and Mongoloid skin color resulted from preferred color reproduction experiment were much smaller than their distributions resulted from printings measurement. Almost all ellipse areas of each preferred skin color chromaticity distribution of a race in Figure 7 laid inside the ellipse of the same race in Figure 5. It means the chromaticity ranges of preferred color was part of the hardcopy ranges. Mongoloid ellipse was smaller than the other two races. It was affected by the subjective factor, that is all observers were Japanese. The increasing orders of chroma and intensity of skin color in three races here were same as the results of evaluation on chromaticities of printings shown in Figure 5. The hues were approximately similar one to another, and the dominant wavelength was also about 590 nm. As the results shown in Figure 4, here each ellipse had longer principal axes in chroma direction than its principal axes in hue direction, as well.

## Conclusion

The proposed technique could detect facial pattern from negative color film. To increase the percentage of correct detection of facial pattern could be carried out by adding the number of evaluated pattern variables of skin color regions in the labeling image. This technique is significant for color manipulation such as color correction and preferred color of facial pattern by applying local color manipulation techniques.

Chromaticity distributions of skin color of three races in hardcopy had characteristics similar to the chromaticity distributions of preferred color of this object. The dominant wavelength of preferred skin color reproduction in facial patterns of three races was approximately same. The distribution of preferred color in chroma direction was wider than its distribution in hue direction.

## References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