Preferred Skin Color Reproduction Based on Adaptive Affine Transform

Do-Hun Kim, Hyun-Chul Do, Sung-Il Chien, *Member, IEEE*
School of Electronic & Electrical Engineering, Kyungpook National University, Daegu, Korea

***Abstract*-- This paper models a preferred skin color area with an ellipse according to the average luminance of skin and proposes an effective method for skin color reproduction by introducing the affine transform between the skin color ellipse and the preferred skin color ellipse.**

I. INTRODUCTION

The observer's preference is an important measure for image quality evaluation and improvement in display equipments [1]. The skin color is one of the most significant natural colors that determine the preference. The skin color affects the image quality primarily, because it occupies relatively large area in the reproduced video signals. Therefore, many studies on the preferred skin color have been presented for efficient color reproduction [1]-[4]. This paper analyzes the Demas's works, in which the skin color area for face detection and the preferred skin color area are modeled with ellipses, and remodels the preferred skin color area by also considering the average luminance (Y) of the skin [2]. The preferred skin color reproduction method is proposed, in which the affine transform between the two ellipses of the skin color and the preferred one is performed.

II. PROPOSED ALGORITHM

An overall block diagram of the proposed method is shown in Fig. 1. *RGB* of the input video signals are transformed to $Yu'v'$ by using the color conversion matrix and then skin color pixels are extracted by Eq. (1). Figure 2 shows the two ellipses modeled by Demas et al., in which the outer blue ellipse corresponds to the skin color area and the inner red one to the preferred area. Thus, when the transformed values of $u'v'$ are located within the outer blue ellipse, Eq. (1) is satisfied.

$$\frac{\left[\Delta u'\cos\theta_s+\Delta v'\sin\theta_s\right]^2}{A_s^2}+\frac{\Delta v'\left[\cos\theta_s-\Delta u'\sin\theta_s\right]^2}{B_s^2}\leq 1, \quad (1)$$

where $\Delta u'=(u'-u'_{sc})$ and $\Delta v'=(v'-v'_{sc})$.

Here, u' and v' are converted from *RGB* values of the input video signal. u'_{sc} and v'_{sc} indicate the center coordinates of the skin color ellipse. θ_s, A_s and B_s indicate the rotation angle, the major axis, and the minor axis of the skin color ellipse, respectively.

After the skin color area is extracted in the input video signal, the average luminance value of the skin is calculated. In (u',v') color space, the color gamut decreases as the Y area as in Fig. 3. The preferred skin color ellipse is determined according to the calculated average luminance and then the

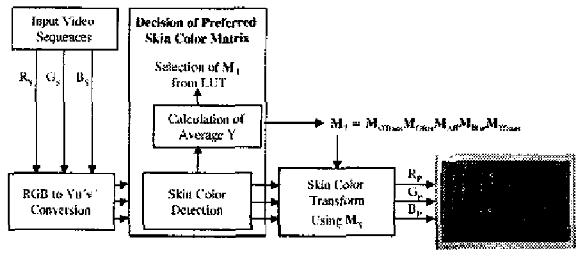

Fig. 1 Overall block diagram of preferred skin color reproduction algorithm based on adaptive affine transform.

parameters: the center point of the preferred skin color ellipse, the major axis length, and the minor axis length. Now, the input skin color is converted into the preferred skin color by using the conversion matrix $\mathbf{M}_T$ defined by

$$[u'_P \quad v'_P \quad 1]^T=\mathbf{M}_T[u'_S \quad v'_S \quad 1]^T, \quad (2)$$

where $\mathbf{M}_T$ is the 3×3 matrix for the skin color transform and decomposed into the five matrices as follows:

$$\mathbf{M}_T=\mathbf{M}_{OTrans}\mathbf{M}_{ORot}\mathbf{M}_{Aff}\mathbf{M}_{IRot}\mathbf{M}_{ITrans}, \quad (3)$$

where $\mathbf{M}_{ITrans}=\begin{bmatrix}1 & 0 & -u'_{SC}\\ 0 & 1 & -v'_{SC}\\ 0 & 0 & 1\end{bmatrix}$, $\mathbf{M}_{IRot}=\begin{bmatrix}\cos\theta_s & \sin\theta_s & 0\\ -\sin\theta_s & \cos\theta_s & 0\\ 0 & 0 & 1\end{bmatrix}$,

$$\mathbf{M}_{OTrans}=\begin{bmatrix}1 & 0 & u'_{PC}\\ 0 & 1 & v'_{PC}\\ 0 & 0 & 1\end{bmatrix}, \quad \mathbf{M}_{ORot}=\begin{bmatrix}\cos\theta_P & -\sin\theta_P & 0\\ \sin\theta_P & \cos\theta_P & 0\\ 0 & 0 & 1\end{bmatrix},$$

$$\mathbf{M}_{Aff}=\begin{bmatrix}A_S & -A_S & 0\\ 0 & 0 & B_S\\ 1 & 1 & 1\end{bmatrix}^{-1}\begin{bmatrix}A_P & -A_P & 0\\ 0 & 0 & B_P\\ 1 & 1 & 1\end{bmatrix}.$$

Here $\mathbf{M}_{ITrans}$ is the matrix translating the center of the skin color ellipse to the origin and $\mathbf{M}_{OTrans}$ is the matrix converting the origin to the center of the preferred skin color ellipse. $\mathbf{M}_{IRot}$ is the matrix to rotate the angle of skin color ellipse to 0° and $\mathbf{M}_{ORot}$ is also the matrix to rotate 0° angle to the angle of the preferred skin color ellipse. Finally, $\mathbf{M}_{Aff}$ is the affine transform matrix rescaling the skin color area to the preferred skin color area when the centers of the two ellipses are equally located on the origin by using the above matrices. The conversion factors are the major and the minor axes of the skin color ellipse and the preferred ellipse [4]. The calculated

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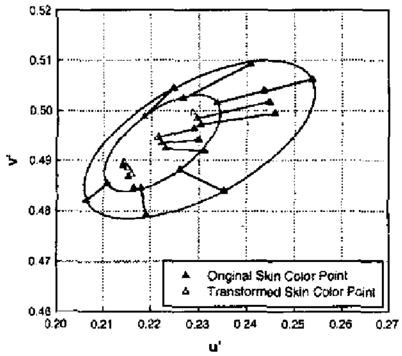


Fig. 2 Skin color and preferred skin color area on (u',v') chromaticity diagram.

conversion matrix $\mathbf{M}_r$ is stored in the form of the LUT(Look Up Table) as to make the size of the preferred skin ellipse adapted to the change of the average luminance(Y) of the detected skin area. Because of the use of LUT, the process of the preferred skin color reproduction is simply performed by applying the conversion matrix $\mathbf{M}_r$ to the original image, once the average of Y is determined from a given image.

III. EXPERIMENTAL RESULTS

Figure 2 shows that the initial chromaticity coordinates are transformed to the preferred skin color by using the affine transform. The filled triangle denotes the chromaticity coordinates of the skin color and the open triangle indicates those of the preferred skin color. Transformed skin color distribution within the preferred area is quite similar to the original skin color distribution within an ellipse. Therefore the preferred skin color can be converted, preserving the naturalness of the original video signals.

Figure 4 shows resultant images when using the proposed algorithm. The original image is unnatural, due to the excessively scarlet color pixels as in Fig. 4 (a). Such abnormal skin colors are corrected by the proposed algorithm in Fig. 4 (b).

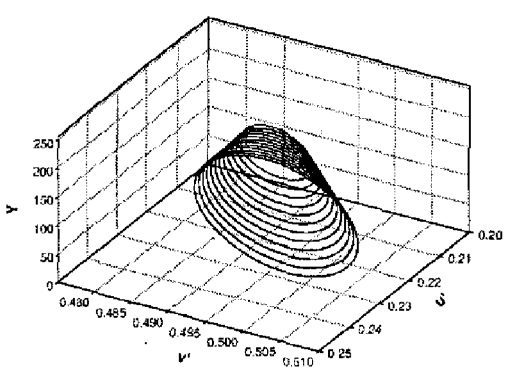
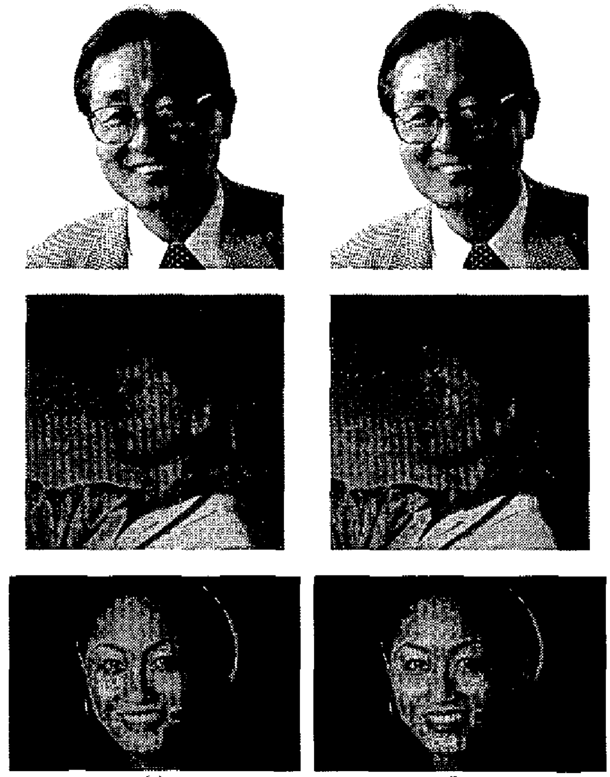


Fig. 3 Variation of preferred skin color area with respect to average luminance.



(a) (b)

Fig. 4 (a) Original image, (b) resultant image when using the proposed method.

IV. CONCLUSION

This paper proposes the preferred skin color reproduction method using an adaptive affine transform. The proposed method models a preferred skin color area with an ellipse according to the average luminance and calculates the transform matrix $\mathbf{M}_r$ converting the skin color area to the preferred one. Consequently, we could enhance the naturalness of the skin colors by applying the transform matrix to the input video signals.

ACKNOWLEDGMENT

This work was supported by grant No. (R12-2002-055-02002-0) from the Basic Research Program of the Korea Science & Engineering Foundation.

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