AN EFFICIENT COLOR COMPENSATION SCHEME FOR SKIN COLOR SEGMENTATION

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ABSTRACT

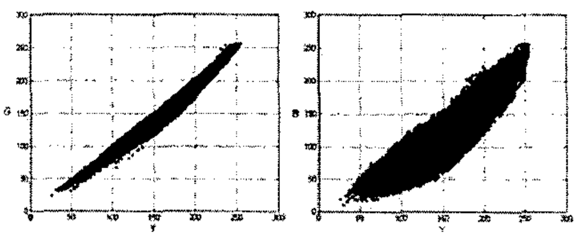
Skin color is a useful means for human face detection. In this paper, we propose an efficient color compensation method for skin color segmentation under varying lighting conditions. One of the major problems of using skin color is that a face region may not be detected under poor or uneven lighting conditions. Our approach considers the distribution of the color components of skin pixels and the color response of capturing machines under different illuminations. Experimental results show that this algorithm can improve the performance of face segmentation under poor or strong lighting conditions.

1. INTRODUCTION

Real-time face detection has received considerable attention due to its wide range of applications, such as intelligent human-computer interaction, human face recognition [1,2], personal verification, model-based video coding [3], low-bandwidth communication for videophone [4], etc. However, the computational complexity of face detection in grey level [5] may be too expensive for real-time applications. In order to reduce the detection time, the color information has been used to segment the human face region from complex background [6,7]. For example, in [6], the skin-like regions are extracted by using both of the normalized RGB color model and the HSV color model. In [7], the chrominance information in YCrCb color space is used for the segmentation of skin-like regions. However, these methods can achieve a good performance only if the face images are captured under good lighting conditions. Some skin pixels will not be identified under poor lighting conditions. In order to overcome the above problems, Hayit *et al.* [8] proposed a mixture-of-Gaussians distribution to model the color distribution of shadowed face images. Hsu *et al.* [9] proposed a non-linear color transformation to compensate for the lighting effect. In our approach, a simple and efficient color compensation method that considers the lighting effect on the color of human face for segmenting the skin-like regions in an image is proposed. The effect of different lighting conditions on a color component and the details of our approach for face color segmentation will be described in the following section.

2. SKIN COLOR SEGMENTATION

2.1 Characteristics of Skin Color under Different Lighting Conditions



(a) (b)

Fig. 1. Skin color distribution: (a) green color component against Y, and (b) blue color component against Y

We manually extracted the face skin regions in 150 facial images, which gives over 220,000 skins pixels for investigating the distributions of skin color under different lighting conditions. Some of the face images were captured using a digital video camera, and some of them were downloaded from the Internet. It is found that the skin color distributions of the green and blue color components are linear to the luminance intensity Y, as illustrated in Fig. 1. However, the intensity level of the red color component is saturated when the luminance component Y of a skin pixel is greater than a value of 175. Fig. 2 shows the distribution of the red color component under different luminance intensities. As the skin tones reflect more red light than green or blue light, the detected intensity level of red color by a capturing machine will be saturated. The effect for color segmentation in the CrCb plane under normal lighting conditions (i.e. $60<Y\leq 175$) and strong lighting conditions (i.e. $Y>175$) are shown in Fig. 3. The distributions of these two areas are different to each other significantly. The minimum and maximum Cb values of skin color under normal lighting conditions are

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130 and 185, respectively, while the minimum and maximum values of Cb component under strong lighting conditions are 110 and 170, respectively. Therefore, the performance of existing skin color segmentation will be degraded if the face images are recorded under strong lighting conditions.

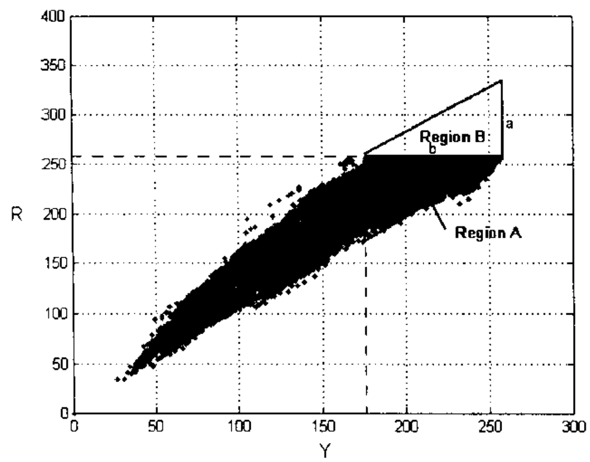


Fig. 2. The distribution of the red color component of skin pixels under different luminance intensities.

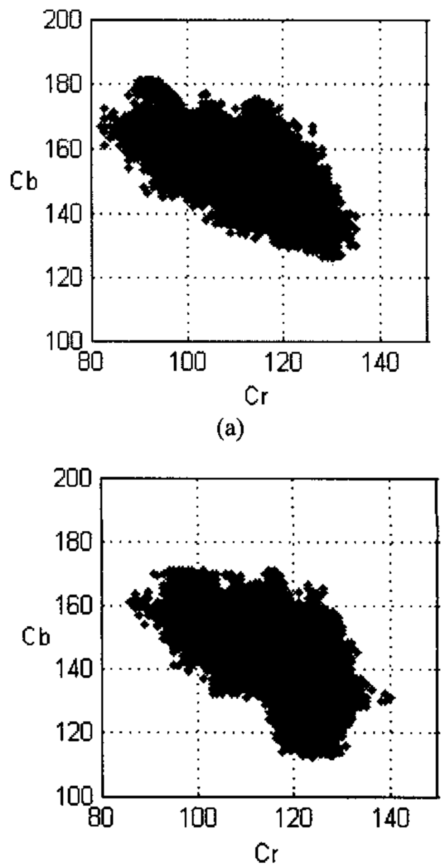
2.2 Color Compensation for Skin Color Segmentation

The difference between the normal and strong lighting conditions in the CrCb plane is due to the saturation of the red color component in a capturing device. Therefore, in our approach, data in Region A, i.e. the triangular region, will be mapped into Region B, i.e. the parallelogram (see Fig. 2), to compensate the above effect for color segmentation. The equation for the mapping process is defined as follows:

$$\tilde{R} = \frac{a}{h}(h-(255-R)) + R(255-R-h) \qquad (1)$$

where $h = \frac{a}{b}(255-Y)$.

R is the red color intensity level of a pixel under consideration, a is the height of Region B, b is the distance between the saturated point (Y=175) and the maximum intensity of Y component, and h is the approximated height of Region A at a particular value of Y. According to the red color distribution as obtained in our experiment, the value of a and b are 75 and 80, respectively. The mapped results in the R-Y plane and the CrCb plane are illustrated in Fig. 4(a) and 4(b), respectively. After the compensation process, the maximum intensity levels of the R channel will be extended to 335. Some holes may appear inside the mapped region. From Fig. 4(b), we can observe that the above effect will make the distribution of the skin color under strong lighting conditions become similar to that of under normal lighting conditions. The minimum and maximum Cb values of skin color after this compensation process are changed to 125 and 175, respectively. In other words, after this compensation process, the same skin color map can be used for the segmentation of skin-color pixels reliably under different lighting conditions.



(b)

Fig. 3. Skin color distribution under (a) normal lighting conditions (60<Y≤175), and (b) strong lighting conditions (Y>175).

In order to improve the reliability level for face detection, the noise and small holes in the segmented results due to facial features such as the eye and mouth regions are considered. In our approach, morphological operations (dilation and erosion) are applied to the segmentation output for removing the noise and holes. The purpose of dilation is to fill in small holes in the facial areas, while erosion is to remove small objects in the background. The equation is defined as follows:

$$Seg(x,y) = P(x,y) \bullet B, \tag{2}$$

where

$$P(x,y) = \begin{cases} 1, & \text{if } (Cr(x,y) \text{ and } Cb(x,y)) \in \text{Skin}_{\text{Map}} \\ 0, & \text{else.} \end{cases}$$

$Cr(x,y)$ and Cb(x,y) are the two color intensity levels of a pixel at location x and y, Skin_{Map} is the skin color map as shown in Fig. 3(a), • represents the closing operation, and B is the structuring element.

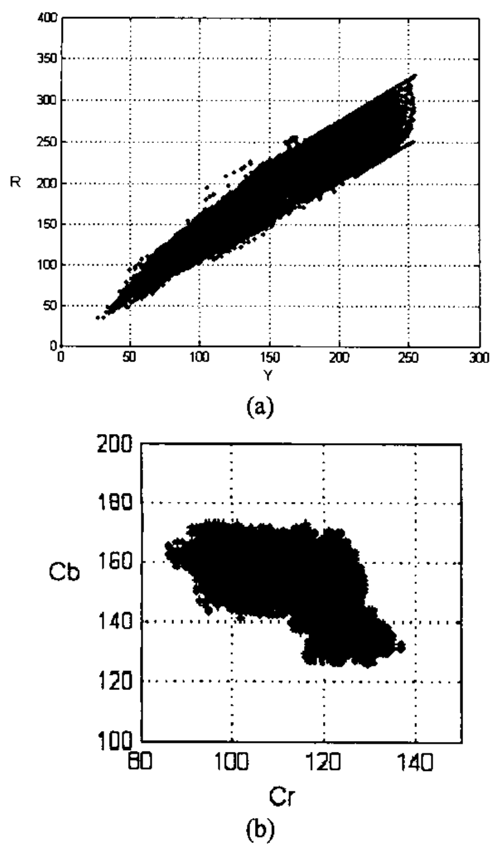


Fig. 4. Results after the compensation process. (a) Compensated result in the red color component, and (b) the compensated results in the CrCb plane under strong lighting conditions.

3. EXPERIMENTAL RESULTS

The performance of our method for face color segmentation is compared with the methods proposed in [6] and [7], which are based on the normalized RGB color space and the YCrCb color space. The black color in the Fig. 5 represents the non-skin regions, while others are the segmented possible face regions. The result of skin-like region detection using the HSV color space works well over those regions under strong lighting but fails to detect those skin regions under shadow. Furthermore, the use of the YCrCb color space does not work properly for those face regions under strong lighting conditions.

We evaluate the performance of our proposed method based on 230 face images. All the face regions including the eye, nose and mouth can be segmented. Some experimental results are illustrated in Fig. 6. The left column is the original image, while the right column represents the segmented possible face region. In our experimental results, some of the neck regions will not be extracted because the noise removing process will remove the shadow formed between the chin and the neck regions. When our proposed compensation scheme is applied, it can detect most of the skin regions by a single skin color map irrespective of the lighting conditions. Furthermore, the possible regions to be examined by the face detector can be reduced after the possible skin regions are extracted. As a result, the runtime required for face detection can be reduced.

4. CONCLUSION

Based on the distribution of skin color and the response of different color components to the light intensity, an algorithm to compensate for color saturation effect by a capturing device for skin region segmentation is proposed. This is particularly important for detection of human faces using a video camera as the input because we cannot control the lighting conditions in this case. Our approach can extract the face regions under poor and strong lighting conditions reliably. In conclusion, the performance of our method outperforms the traditional methods for skin color segmentation under varying lighting conditions.

5. REFERENCES

1. K.M. Lam and H. Yan, "An analytic-to-holistic approach for face recognition based on a single frontal view", IEEE Trans. on Pattern Anal. and Mach. Intell. 20 (1998) pp. 673-686.
2. K.H. Lin, Baofeng Guo, K.M. Lam and W.C. Siu, "Human face recognition using a spatially weighted modified Hausdorff distance", Proceedings of 2001 International Symposium on Intelligent Multimedia, Video and Speech Processing, 2001, pp. 477-480.

3. D.E. Pearson, "Developments in model-based video coding", Proceedings of the IEEE 83 (6) (1995) pp. 892-906.

4. K.W. Wong, K.M. Lam, W.C. Siu, and K.M. Tse, "Face segmentation and facial feature tracking for videophone applications", Proceedings of 2001 International Symposium on Intelligent Multimedia, Video and Speech Processing, 2001, pp. 518-521.

5. K.W. Wong, K.M. Lam and W.C. Siu, "An efficient algorithm for human face detection and facial feature extraction under different conditions", Pattern Recognition 34 (10) (2001) pp. 1993-2004.

6. Yanjiang Wang and Baozong Yuan, "A novel approach for human face detection from color images under complex background", Pattern Recognition 34 (2001) pp. 1983-1992.

7. D. Chai, and K.N. Ngan, "Face segmentation using skin-color map in videophone applications", IEEE Trans. on Circuits and System for Video Technology 9 (4) (1999) pp. 551-564.

8. Hayit Greenspan, Jacob Goldberger and Itay Eshet, "Mixture model for face-color modeling and segmentation", Pattern Recognition Letters 22 (14) (2001) pp. 1525-1536.

9. R.L. Hsu, M. Abdel-Mottaleb, A.K. Jain, "Face detection in color images", IEEE Transactions on Pattern Analysis and Machine Intelligence 24 (5) (2002) pp. 696-706.

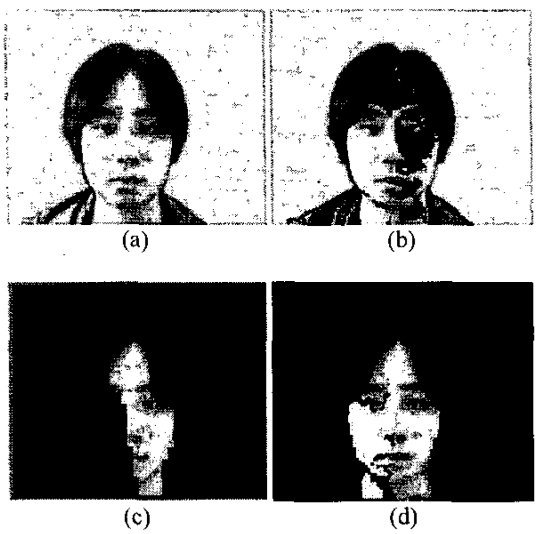


Fig.5. Color segmentation results: (a) Original image, (b) results based on HSV color space [6], (c) results based on YCrCb color space [7], and (d) results of our proposed method.

Fig .6. Experimental results based on our proposed skin color segmentation algorithm.