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Intelligent and Robust Face Detection

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Abstract

A face detection in color images is important for many multimedia applications. It is the first step for face recognition and can be used for classifying specific shots. This paper describes a new method to detect faces in color images based on the skin color and hair color. This paper presents a fuzzy-based method for classifying skin color region in a complex background under varying illumination. .The Fuzzy rule bases of the fuzzy system are generated using training method like a genetic algorithm(GA). We find the skin color region and hair color region using the fuzzy system and apply the convex-hull to each region and find the face from their intersection relationship. To validity the effectiveness of the proposed method, we make experiment with various cases.

Key Words : Fuzzy, Skin Color, Genetic Algorithm(GA), Adaptive fuzzy Color Classifier(AFCC)

1. Introduction

This paper addresses a method to automatically detect out a person's face from a given image that consists of a hair and face view of the person and a complex background scene. Our method suggests two types of problem, how to decide skin color region in the color space and effectively decide facial location.

Many studies have been made on modeling the distribution of color pixel value[3][6][7][13]. The skin color map can be designed by adopting histograming technique on a given set of training data and subsequently used as a reference for any human face. Such a method was successfully adopted in [14],[15],[16]. It was practical and appealing, as it attempts to cater to skin color region in an automatic manner, albeit in a less precise way. This, however, raises a very important issue regarding the coverage of all luminance condition with one system.

Our method involves an effective detection algorithm that exploits the spatial distribution characteristics of human skin color via an adaptive fuzzy color classifier (AFCC). The universal skin-color map is derived on

the chrominance component of human skin color in Cb, Cr and their corresponding luminance. The desired fuzzy system is applied to decide the skin color regions and those that are not. We use RGB model for extracting the hair color regions because the hair regions often show low brightness and chromaticity estimation of low brightness color is not stable[6]. After some preprocessing, we apply convex-hull to each region. Consequent face detection is made from the relationship between a face's convex-hull and a head's convex-hull. The algorithm using the convex-hull shows better performance than the algorithm using pattern method [9][18][19].

The performance of the proposed algorithm is shown by experiment. Experimental results show that the proposed algorithm successfully and efficiently detects the faces without constrained input conditions in color images.

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2. Skin Color Classification

2.1 Color model

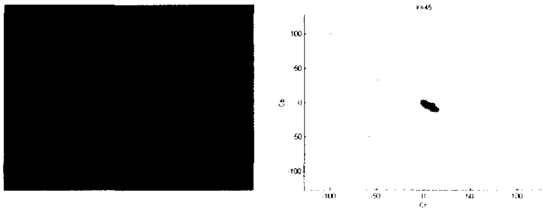
The use of color information has been introduced to the object-location problem in recent years. These are some, but certainly not all, of the color space models available in image processing. Therefore, it is important to choose the appropriate color space for modeling human skin color. In this paper, the skin color map derived from the RGB color space will be inferior the those obtained from the YCbCr color space. RGB values can be transformed to YCbCr color space using eq(1). Given that the input RGB values are within the range of [0,256] for Y, the range of the output values of the transformation will be [-128,128] for Cb and Cr.

$$\begin{cases} Y = 0.299R' + 0.587G' + 0.114B' \\ C_b = -0.169R' - 0.331G' + 0.500B' \\ C_r = 0.500R' - 0.419G' - 0.081B' \end{cases} \quad (1)$$

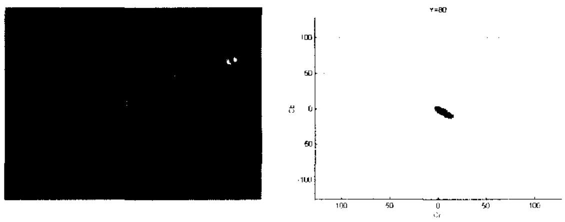
Y: brightness, Cb: bluenessencoded, Cr: rednessencoded

2.2 Color segmentation

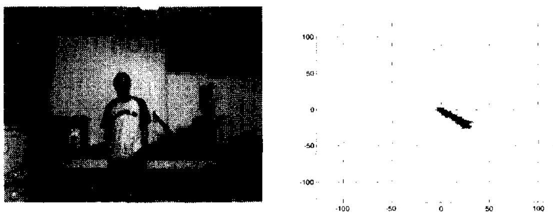
The first work is classifying pixels of the input image into skin color and non-skin color. In order to do so, we have devised a skin-color reference map in YCbCr color space and found that a skin color region can be identified by the presence of a certain set of chrominance values narrowly and consistently distributed in the YCbCr color space. We have further tested the skin-color map with 30 sample images. The sample image were grouped into three classes: bright image (the average Y is near 120), middle image (the average Y is near 80), and dark image(the average Y is near 45). Their skin color distributions of Cb and Cr components of each group are presented in Fig. 1



(a) Dark image (Y=45)



(b) Normal image (Y=80)



(c) Bright image (Y=120)

Fig. 1. Skin color distributiuon of Cb and Cr

From Figures, we can know that the major difference between the skin color maps depend on the brightness of the skin color, which is governed by Y and the skin color regions can be identified by the presence of a certain set of chrominance values narrowly.

3. Fuzzy Color Classifier (FCC)

For the efficient skin color map modeling according to Cb and Cr, we use a FCC as an approximate reasoning [11]. The FCC system consists of fuzzy rule base that associate 2-input-1-output. The inputs of the fuzzy rule base are Cb and Cr and the output presents the similarity of skin color.

3.1 Fuzzy rule base

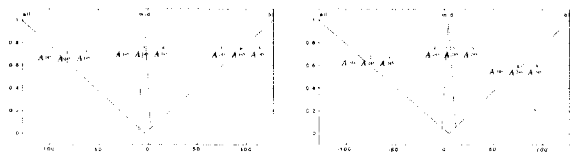
In the case of using the full combination of three input membership function adjectives for each input, the total number of rules is 9. The fuzzy rule base is as following.

$- l\ th\ \ Rule$

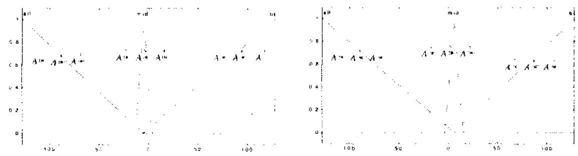
$$IF\ C_b\ is\ A_{1i}^{l}\ \text{and}\ A_{2i}^{l}\ Then\ f_i\ is\ B_i^{l} \quad (2)$$

$$(i=1,2,3;\ l=1,2,3...9)$$

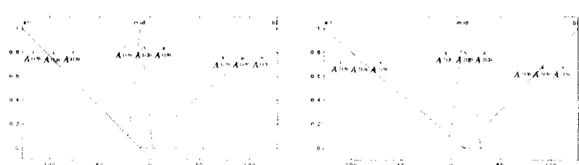
A_{1i}^{l}, A_{2i}^{l} and B_i^{l} are fuzzy sets of Cb, Cr and the similarity of skin color. The triangular input membership function is used. Figure.2 presents input membership functions of FCC and B_i^{l} is as shown in table 1 The parameters constructing fuzzy system are optimized by the global search algorithm, genetic algorithm(GA)[12], the center, width of each membership function and the single to value of B_i^{l}, δ



(a) Input membership function (Y=45)



(b) Input membership function (Y=80)



(c) Input membership function (Y=120)

Fig. 2. Input membership function of the FCC

Table 1. Center values of B_i^{l}

	$A_{1i}^{1,4,7}$	$A_{1i}^{2,5,8}$	$A_{1i}^{3,6,9}$
$A_{2i}^{1,2,3}$	0.00012	δ	0.000156
$A_{2i}^{4,5,6}$	δ	1	δ
$A_{2i}^{7,8,9}$	0.0001445	δ	0.00001

3.2 Training of the FCC

We want to find a set of fuzzy rules that best describe the training samples. The training data for GA optimization are Cb and Cr components of skin color in sample images

The GA configuration is as follows.

STEP 1: Initialize all tuning parameters. (Center values and width values of the input membership functions,

STEP 2 : Represent the tuning parameters as GA chromosomes.

STEP 3 : Tuning the input membership characteristic points by GA operations (reproduction, crossover:0.1, mutation:0.1) to maximize the following fitness function.

The step is repeated until fitness will be over the specified value.

$$Fitness\ \ function = \frac{1}{\sum_{i=0}^{N_H}(1-F_i^H)^2 + \sum_{i=0}^{N_N}(F_i^N)^2} \tag{3}$$

where

N_H : denotes the total number of skin color training data

N_N : denotes the total number of non-skin color training data

F_i^H : denotes the fuzzy reasoning result of the i-th skin color training data :

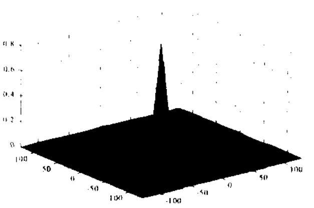
F_i^N : denotes the fuzzy reasoning result of the i-th non-skin color training data

3.3 FCC with defuzzifier

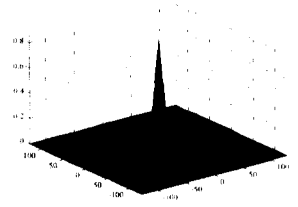
The FCC use center average defuzzifier, which evaluates the similarity of skin color and the resulting FCC can be designed like

$$f_i(x_1, x_2) = \frac{\sum_{l=0}^{9} y^l \left(\prod_{z=1}^{2} \mu_{A_{zi}^l}(x_z) \right)}{\sum_{l=0}^{9} \left(\prod_{z=1}^{2} \mu_{A_{zi}^l}(x_z) \right)} \tag{4}$$

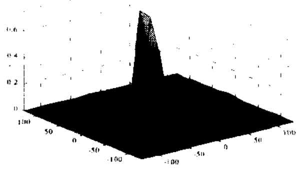
x_1, x_2 and Cb, Cr and the similarity of skin color respectively. the skin color region about luminance value of sample images can be found from inferred function of FCC. The similarity of the skin color region inferred from AFCC applied varying luminance condition shows as Figure 3.



(a) Y=45



(b) Y=80



(c) Y=120

Fig. 3. The similarity of the skin color region inferred from FCC about sample images

However, the FCC method is only used in limited luminance condition of sample images. Therefore, we designed the Adaptive fuzzy color classifier.

4. Adaptive Fuzzy Color Classifier(AFCC)

In this section, Adaptive fuzzy color classifier(AFCC) is designed for adapting the fuzzy rules to the varying illuminations. The input of AFCC in Y value and the output is the similarity of the skin color region according to the illumination of the image. The eq(5) and Figure.4 show fuzzy rule base and input membership function of AFCC.

$$\begin{aligned} &-l\ th\ \ Rule \\ &IF\ \ Y\ \ is\ \ A^l\ \ Then\ f\ is\ f_i(x_1, x_2) \\ &\qquad (i=1,2,3;\ l=1,2,3) \end{aligned} \tag{5}$$

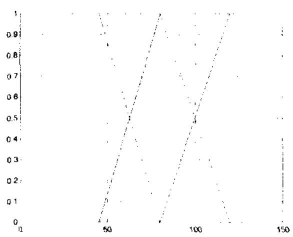
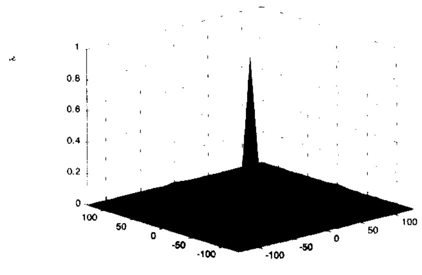


Fig. 4. Input membership function of AFCC

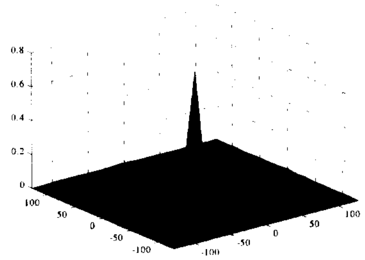
Where f_i(i=1,2,3) are the trained FCC in the case of Y=45, 80, 120. Therefore, the resulting AFCC can be constructed as

$$f(Y, x_1, x_2) = \frac{\sum_{l=0}^{3} f_i(x_1, x_2)\, \mu_{A^l}(Y)}{\sum_{l=0}^{3} (\mu_{A^l}(Y))} \tag{6}$$

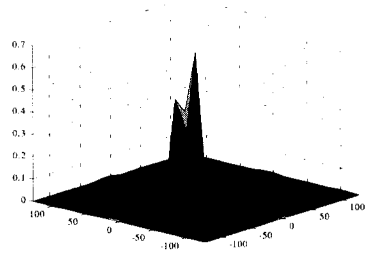
x_1, x_2 and $f(Y, x_1, x_2)$ indicate Cb, Cr and the similarity of skin color and $f_i(x_1, x_2)$indicates inferred function of FCC. The similarity of the skin color region inferred from AFCC applied varying luminance condition shows as Figure. 5



(a) Y=60



(b) Y=90



(c) Y=100

Fig. 5. The similarity of the skin color region inferred from AFCC

Table 2. Parameters values of membership function

	Center		Width		δ
	Cb	Cr	Cb	Cr	
Y=45	-3.5	4.5	-10	-3	0.014
Y=80	-5	6	-13	-3	0.017
Y=120	-10	13.5	-23	-23	0.018

Table 2 shows the parameters values constructing the membership function of FCC.

Figure.6 shows the overall skin color classification structure using the fuzzy system in this paper.

To make a final decision, the output variable of the fuzzy system, Color should be divided into two classes, Skin color and Non-skin color by the threshold. The percent recognition rate for the final decision can be calculated as following.

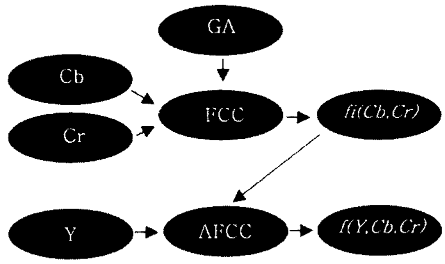


Fig. 6. The structure of fuzzy system

$R_H = \frac{C_H}{N_H} \times 100$ denotes the recognition rate for skin color training data

$R_N = \frac{C_N}{N_N} \times 100$ denotes the recognition rate for non-skin color training data

where

C_H denotes the number of correct decision for skin color training data

C_N denotes the number of correct decision for non-skin color training data

5. Region extraction via convex hull

5.1 Convex hull

When we have a large number of points to process, we're interested in the boundaries of the point set. People looking at a diagram of a set of points plotted in the plane, have little trouble distinguishing those in the "inside" of the point set from those lying on the edge[17].

The mathematical name for the natural boundary of a points in the plane is defined to be the smallest convex polygon containing them all. Equivalently, the convex hull is the shortest path surrounding the points. Figure.7 shows an example of convex-hull.

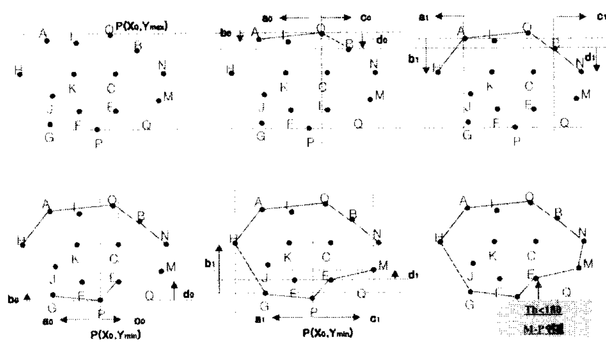


Fig. 7. Convex hull

5.2 Skin color region and Hair color region

We obtain 30 representative face images which is divided according to an average luminance value and extract all visible skin color region from the image. It is represented in a fuzzy logic based language and the parameters constructing fuzzy system is optimized by

GA. The skin region is extracted by AFCC and we make the convex-hull surrounding each region.

The hair regions often show low brightness and chromaticity estimation of low brightness color is not stable. Then, we use RGB color space for obtaining head color region. We find the image points including RGB space from (0,0,0) to (30,30,30) to detect head color regions.

5.3 Face region extraction via Convex-hulls

After preprocessing of the image, which is shown by experimental result, we assign labeling to each regions in the preprocessed image and make convex-hull surrounding each regions.

Define the convex-hull of head color region as H_j and that of face color region as F_i. (i=1~n, j=1~m) and intersection region as I_{ij}. Usually, the skin color regions and hair color regions have been closely related with intersection of the skin color regions and hair color regions has a very strong possibility that they may be the face and hair.

$$\{((x,y),\ I_{ij}(x,y)) : I_{ij} = F_i(x,y) \cap H_j(x,y)\} \quad (7)$$
$$\begin{cases} F_i(x,y),\ H_j(x,y) = 1 & \text{if } I_{ij}(x,y) > \tau \\ 0 & otherwise \end{cases}$$

n[·] : the number of element in the set

We can find the face region in the image from Iij, which is characterized by (7).

6. Experimental Result

We implemented our method on a Pentium III to construct a face detection system. The system is composed of CCD camera, digital camera, image data capture board, and software, which implements the proposed image algorithm. The figure.8 presents preprocessing scheme. The first work for the preprocessing is an extracting the skin color region and hair color region and the second work is converting the image into the binary image and the final work is applying the opening operator to the binary image for removing the noise. Then, we find two skin color regions and seventy hair color regions. The figure.9 shows the convex hull of each regions and the intersection relationship between H_j and F_i.

Fig. 8. Preprocessing scheme

Then, we find a face region from I(x,y) as mention above section.

However, all the images are the varying face appearance and luminance condition. Therefore, we try four types of experiments classified according to face condition in the image

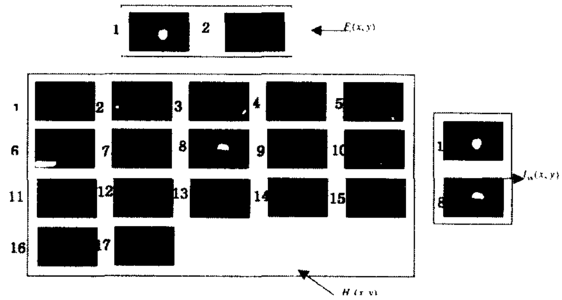


Fig. 9. Face region

6.1 Experimental resultant image involving the single face

It shows experimental result of detected the face when the image involves a face.

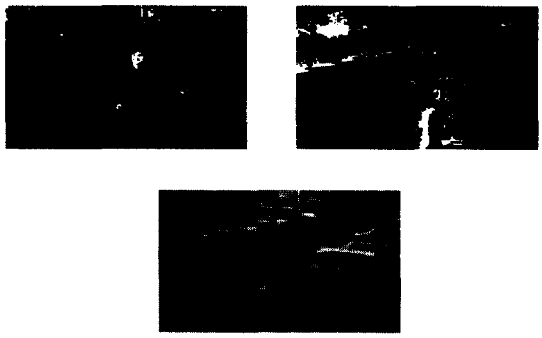


Fig. 10. Experimental resultant image involving the single face

6.2 Experimental resultant image involving two or more faces

It shows experimental result of detected the face when the image involves a face. The algorithm shows better performance than other algorithm because of the robust property of the AFCC and it uses the convex-hull.

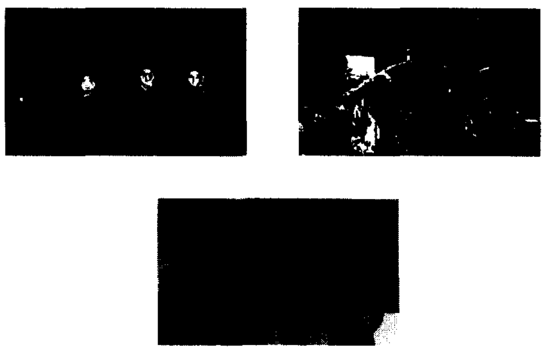


Fig. 11. Experimentally resultant image involving one or more people

6.3 Experimental resultant image involving rotated image

Figure.12 shows experimentally resultant image involving the turned face.

And, in comparison to previous research reports, our method shows better capabilities. The previous research using the fuzzy pattern method [9] or the neural pattern method [18],[19] for finding the face have some problems. Whereas, our method finds rotated image in the fast time and our method dont need the parameter constructed pattern method because it uses convex-hull. The figure.13 shows experimentally resultant image involving the rotated image.

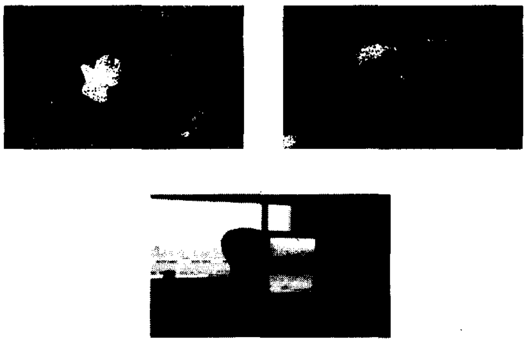


Fig. 12. Experimentally resultant image involving the turned face

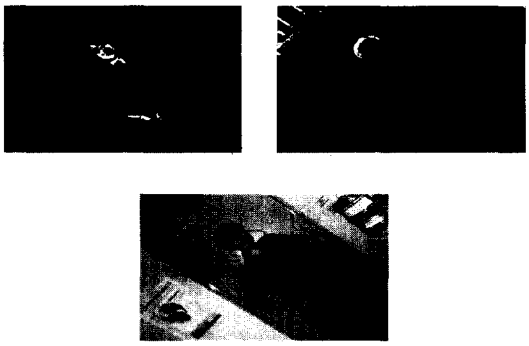


Fig. 13. Experimentally resultant image involving the rotated face

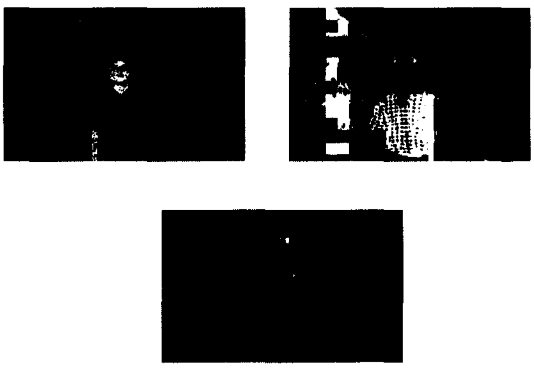


Fig. 14. Experimentally resultant image of dark luminance condition

6.4 Experimental resultant image of dark luminance condition

Our method involves a effectively detectable algorithm under varying illumination because of inferred capacity of AFCC about varying luminance value. Fig.14 shows face detection in dark luminance condition.

7. Conclusion

This paper has described a new approach to detect the face in images. This paper has three kinds of merits compared with fuzzy pattern or neural network based approach. Our method can detect skin regions and hair regions much more accurately and stably than conventional approaches because we use a convex-hull based region extraction to extract the skin color and the hair color. And this method is much faster and the performance is also not bad. Also, our method has a good performance when the face in an image is rotated or deformed and robust property against the illumination condition.

As shown in the experimental results, the proposed method sometimes fails to detect the real face. Reasons under concern include the following :

1) Hairstyle : Faces with special hair styles, such as skinhead, or wearing a hat, may fail to be detected.
2) If people wear a clothe of skin color, the clothe may show skin color.
3) If two or more faces are too close, the skin parts of them may be merged together.

Our method may also give some false positives under some condition. The most important reason is that we only use the convex-hulls and ignore all the details about facial features during the face detection. Checking if there are facial features in these face candidates can help deleting all false faces.

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