Face Detection Algorithm using Color and Convex-Hull Based Region Information

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Abstract

The detection of face 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. In this paper describes a new method to detect faces in color images based on the skin color and hair color. In the first step of the processing, regions of the human skin color and head color are extracted and those regions are found by their color information. Then we converted binary scale from the image. Then we are connected regions in a binary image by label. In the next step we are found regions of interesting by their region information and some conditions.

1. Introduction

Human face detection scheme has been studied since 1990's due to development of human interface and many applications have been performed. Many face detection methods have been studied such as skin colors[1][2][3], face templates and characteristic points of human eyes, nose, and lips, etc.

Also, intelligent algorithm based scheme such as statistical method, fuzzy logic, neural networks, and genetic algorithm has been adopted in face detection.

H. Wu[2] has proposed the human face recognition method using skin and head colors, and fuzzy pattern matching algorithm. However, the recognition presented in the research was not well performed and it takes much computation time in the case that the face image is rotated or deformed because the method was based on basic pattern of human face.

Usually, the skin color regions and head color regions have been closely related with intersection of their convex hull. Therefore, the relationship of the skin and head regions has a very strong possibi1)lity that they may be the face and head. In this paper, possible regions are determined using face and head colors from image, and we apply image preprocessing (noise cancelation and growing, etc) to them. After labeling to each region, convex hulls that wrap each one, are constructed. Then, the relationship of intersection of skin and head regions is investigated and they are removed from the set of the possible regions by examining the intersection property of the convex hull pairs, and the face region candidates are obtained. Finally, convex hull for the candidates are developed to get the solution for face detection.

This work was suppoted by the KOSEF(1999-2-303-004-5)

2. Color Representation

A color image is represented by three bands, corresponding to red, green, and blue tristimulus values, denoted R(x,y), G(x,y), and B(x,y), respectively, at each pixel location (x,y).

Usually, different image processing systems use different color models for different reasons. There are several color coordination models, RGB, CMY, HIS, and YCbCr etc. There are numerous color spaces based on the tristimulus values. The YIQ color space is used in broadcast television. The XYZ space does not correspond to physical primaries but is used as a color standard. It is fairly easy to convert from XYZ to other color spaces with a simple matrix multiplication. Other models include La*b*, YUV, and UVW. In this paper, we use the YCbCr model to detect skin color likeness and the RGB model to detect head color likeness. We first convert the RGB color information in image to YCbCr as [4]:

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

Y : brightness,
Cb : blueness encoded,
Cr : redness encoded

We use RGB model for extracting region of the head color likeness because the hair regions often show low brightness and chromaticity estimation of low brightness color is not stable.

3. 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.

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 1 shows an example of convex-hull.

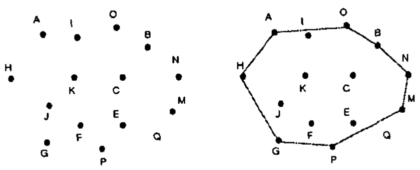


Figure 1 Convex hull

4. Fuzzy Color Segmentation System

For efficient approach, we use the fuzzy rule base system as an approximate resoning method[5]. The fuzzy system cosists of 3-input-1-output.

4.1 Input/Output Variable Definetion

There are three input variables and one output variable in our fuzzy rule base system. The input variable are Y, Cb and Cr and the output variable is desired skin color confidence.

4.2 Rule Base

In case of using the full combination of the input membership function adjectives, the total number of rules will be 3^3(27).

$$lth\ Rule: If\ Y\ is\ A_1^l\ \text{and}\ C_b\ is\ A_2^l\ \text{and}\ C_r\ is\ A_3^l\ Then\ CO\ is\ B^l \quad (2)$$

$$l = 1,2,3,\cdots,27$$

A_1^l, A_2^l, A_3^l, and B^l are fuzzy set of Y, Cb, Cr, and desired skin color confidence. The triangular is used for input mambership function and singlton is used for output membership function.

4.3 GA Tuning of Membership Functions

STEP 1 : Initialize all tuning parameters.

STEP 2 : Represent the tuning parameters as GA chromosomes.

STEP 3 : Tuning the input membership charateristc points by GA operations (reproduction, crossover, mutation) to maximize the following fitness function. The step is repeated until fitness will be over the specified value.

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

where

N_H : denotes the total number of skin color traing data

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

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

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

4.4 Fitness function

A fitness function evaluates the population of skin color. It measures how well each individual works as skin color. It represents as following eq(4)

$$f(x_1, x_2, x_3) = \frac{\sum_{l=1}^{27} y^l \left(\prod_{i=1}^{3} \mu_{A_i^l}(x_i) \right)}{\sum_{l=1}^{27} \left(\prod_{i=1}^{3} \mu_{A_i^l}(x_i) \right)} \quad (4)$$

$f(x_1, x_2, x_3)$ is desired skin color confidence. y^l is center value of B^l

5. Face detection scheme

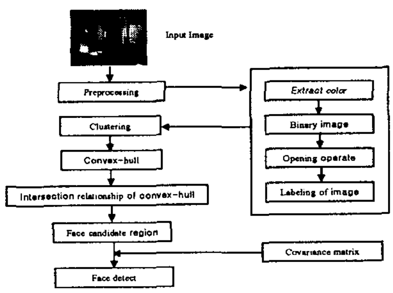
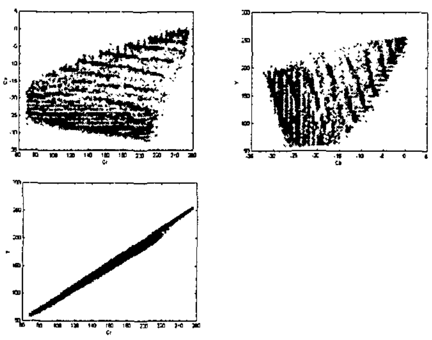


Figure 2 The flow-chart of face detection scheme

Figure 2 shows the flow-chart of proposed the face detection algorithm.

5.1 Data-base for skin and head colors

We obtain 30 representative face images which is divided by average Y value of each image and extract all visible skin color likeness from the image. We convert the RGB color information of them in the image to YCbCr. Figure 1 shows the transformed skin color likeness in YCbCr



Figre 3 Distribution of Skin color likeness using YCbCr

The skin color region is obtained using the well-known optimization techniques, GA, with the data-base. The skin color region is a combination of local features and is represented in a fuzzy logic based language. Then, the skin color region can be found by output membership function of fuzzy. Next, an input image is investigated by it and we can find the skin color likeness regions in the image.

Each GA tuninng parameter is encoded into 16bit. Thus, the total string length of the chromosome is 1300bit. This experimental conditions, it takes 50 generations for our fuzzy inference system to satisfy the termination specification for GA fitness function.

Testing with that threshold level, the skin color confidence rate is 75%.

The head regions often show low brightness and chromaticity estimation of low brightness color is not stable. Then, we use RGB coordinate model with head color range from (0,0,0) to (30,30,30) to detect head likeness color and the head color likeness can be found based on the head color range. We convert the resultant image including only skin color likeness and head color likeness into binary image for appling opening operation that has a good performance for image preprocessing of noise removal.

5.2 Face region extraction via Convex-hulls

After preprocessing, we assign labeling to each left regions in image. Define groups of head likeness color as $H_j(x,y)$ and groups of face likeness color as $F_i(x,y)$. (i=1~n, j=1~m). The n is the number of skin regions and the m is the number of head regions. Next, we make convex-hull surrounding each $H_j(x,y)$ and $F_i(x,y)$ for making distinctive region. (x,y) denote the location of pixels. We utilize the face that the human face has some intersection region with the human head. Then, the relationship of the intersection of face and head convex hulls is investigated. The face region candidates are obtained by applying Eq(5) to the set of convex-hulls and we remove the head candidate region because we want to detect only the face region.

$$\{ I_{ij}(x,y) = F_i(x,y) \cap H_j(x,y) \} \qquad (5)$$

$$\begin{cases} F_i(x,y),\ H_j(x,y) = 1 & \text{if } n[I_{ij}(x,y)] > \tau \\ 0 & otherwise \end{cases}$$

$n[\cdot]$: the number of element in the set

Finally, we find the two eigenvectors of the covariance matrix obtained by using the pixel within the region as random variables and use ellipse property of face shape. We extract final face region to select the region which has the ellipse-like ratio of two eigenvalues of the covariance matrix.

6. Experimental Results and Discussion

We implemented our method on a PC construct a semi-real-time face detection system. The system is composed of CCD camera, digital camera, image data capture board, and software which implements the proposed image algorithm.

Figure 4 shows detected skin color likeness and head color likeness using the data-base which is made by skin color and head color information of the 30 representative face image. Figure 5 shows the extracted image using figure 4. Figure 6 shows skin regions and head regions after labeling and convex-hull. They are many face regions and head regions because the background of image has similar regions of skin color and head color. Then, the relationship of the intersection of face convex-hulls and head convex hulls is investigated. It can reduce the number of the face candidate regions. Next, we find the two eigenvalues of the covariance matrix of face candidate regions and apply ellipse-like ratio of them to their regions. Figure 7 show result image.

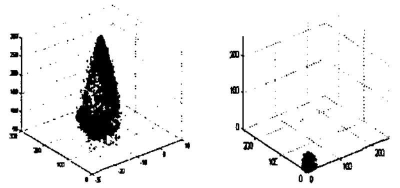


Figure 4 extracted pixels using color data-base

Figure 5 Extracted image using color data-base

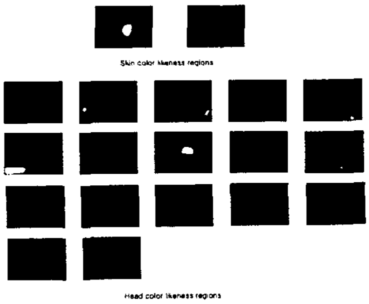


Figure 6 face regions and head regions after convex-hull

Figure 7 Result image

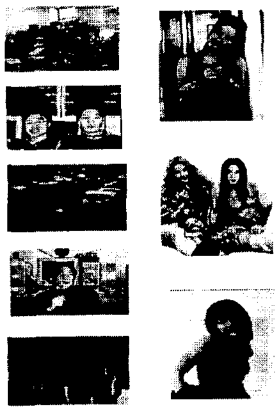


Figure 8 Experimental Images

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 facial sharp such as ellipse and ignore all the details about facial features during the face detection. Checking if there are facial features in these face candidates can help delete all false faces.

6. Conclusion

This paper has described a new approach to detect the face in images. Because we use a convex-hull based region extraction to describe the skin color and the head color, our method can detect skin regions and head regions much more accurately and stably than conventional approaches. Compared with fuzzy pattern or neural network based approach, this method is much faster and the performance is also not bad. Also, our method has a good performance in the case that the face image is rotated or deformed because of convex-hulls with face regions and head regions.

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