Research of Face Detection Based on Skin Color Feature

Pei Li¹, Hongjuan Wang², Yeli Li¹, Fucheng You¹ and Mengyang Liu¹

¹ School of Information Engineering Beijing Institute of Graphic Communication, Beijing, China
² School of New Media Beijing Institute of Graphic Communication, Beijing, China
Email: xinxigongcheng@bigc.edu.cn; xinmeiti@bigc.edu.cn

Abstract. Face image contains many pattern features and this paper studies a face detection algorithm based on skin color features. Through the analysis of the face detection method based on skin color features, the calculation process and principle are understood, and the algorithm and detection techniques such as color space, preprocessing face image detection technology. Building a corresponding skin color model based on face characteristics are analyzed in depth. Because the skin color only occupies a specific range in the primary color of color space, the probability likelihood graph of skin color is obtained by calculating skin color similarity. Then the binary image of the possible face region is obtained by smooth filtering, threshold segmentation, and other operations. Then the area center and height ratio are used to calculate the center of mass and deflection angle, and the correlation coefficient is matched with the face module. Finally, the face area is detected and marked. Test results show that the algorithm can achieve face detection well.

1. Introduction
In recent years, with the development of information science and technology, face recognition system now plays an important role in most fields, especially in the security and management of enterprises and residences, the security and attendance of organs and units, e-passport and ID card, public security, judicial and criminal investigation, bank business processing, payment of current smart phones and other functions. Among them, face detection, as a key technology in face recognition, has become an important and very popular subject in the field of pattern recognition and computer vision [1].

The research on dynamic face detection technology in our country has just started, and face detection technology is a tricky but very challenging problem. The research of face detection technology is still far from the actual widespread use, so there are still many problems that need to be solved by researchers. Among them, the problem of face detection people originally originated from one of the links in face recognition. This paper uses OpenCV and Visual Studio software to establish a Gaussian model of skin color distribution based on skin color features, and realizes face detection based on skin color features through operations such as image smoothing, threshold segmentation, broken plate matching, and grayscale processing. Experiments show that the effect of the feature research in this paper is good, and it can be used in the face detection link in the face recognition system.

2. Feature Extraction
Gray features include facial contour features, facial features (such as symmetry, etc.), facial gray distribution features, template features, etc. For gray features, the contour feature is an essential
feature of the human head. In the process of face detection, craw [2] and others first match the approximate contour of the face with the template in the high rule image, then use Sobel [3] algorithm to extract the direction and position in the low rule image, and finally form a complete face contour.

The features of eyes, nose, and mouth in the core area of the face are darker and more evident than those of other features, so it has a unique gray distribution feature. The eye, nose, mouth, and other features of the facial core area are deeper and more evident than other features, so it is a unique gray distribution feature. According to its characteristics, it can be used to distinguish various parts of the face correctly. In these features, the elements of human eyes are more visible. In this premise, the images to be detected are screened, and the images that may have human faces are selected, and then the face is determined by the location algorithm. The gray level of facial region is also used as a template feature, and the central area of eyes, nose, and mouth is usually used as a standard template feature, and this method can eliminate most of the hair and both sides of the cheek in the positioning process.

In the low-resolution image, the facial features of the face will be confused with the background. Based on the research on the detection method of mosaic, Yang et al. [4] established a hierarchical three-level detection system to determine the face candidate area, as shown in figure 1, find the same features of the face in the candidate area in the low-resolution image, and then select the front from the candidate area with a rule and binarize the face area to further verify the mosaic method.

![Figure 1. Face candidate area.](image)

3. Establishment of Skin Color Mode

Because skin color is an important part of the face, skin color is one of the most commonly used features in face detection. Different from the background color of most images, skin color is relatively stable, which is mainly described by the established skin color model. The model uses a table-like form to express the color of space pixels belonging to the skin color, or express the degree of similarity between the pixel color and the skin color. In the process of face detection, the choice of chromaticity space is very important to the choice and use of the skin color model, as shown in the following formula:

\[
\begin{align*}
R &= \frac{R}{R+G+B} \\
g &= \frac{R}{R+G+B}
\end{align*}
\] (1)

Skin color model is generally divided into clustering model and Gaussian model: the “multi-model tracking of faces for video communications” established by Crowley and Berard [5] is to normalize the RGB color of skin color area, and use the \((r, g)\) value of color histogram \(H(r, g)\) to obtain the threshold value of skin color variable.

RGB to “rg” space.

RGB to YUV (YCrCb) space, converting to “FI” space.

\[
\begin{align*}
Y &= 0.299*R + 0.587*G + 0.114*B \\
U &= -0.169*R - 0.331*G + 0.5*B
\end{align*}
\] (2)
\[ V = 0.5 \times R - 0.419 \times G - 0.081 \times B \]

\[ F = \tan^{-1} \left( \frac{|V|}{|U|} \right) \] (3)

\[ I = (0.596, -0.274, -0.322) \begin{pmatrix} R \\ G \\ B \end{pmatrix} \] (4)

Yang and Huang [6] in “Detecting human faces in color images” use statistical principles to believe that the color value of the skin color area of the human face is in a Gaussian distribution, so the mean and variance of the Gaussian distribution are used to obtain the skin color. The threshold of the variable. Jebara and Pentland [7], “Parameterized structure from motion for 3D adaptive feedback tracking of faces” believe that people of different races and countries have different colors. This forms multiple clusters on the color histogram, which is represented by a Gaussian mixture model, as shown in the following formula and figures 2 and 3:

\[ F \sim N(\mu, \sigma) \] (5)

\[ \mu = \frac{1}{N} \sum_{i=1}^{N} F_i, \sigma^2 = \frac{1}{N} \sum_{i=1}^{N} (F_i - \mu)^2 \] (6)

\[ N(\mu, \Sigma) \text{ where } \mu = \begin{pmatrix} r \bar{=} \\ g \bar{=} \end{pmatrix}, F \sim N(\mu, \sigma) \] (7)

\[ \bar{r} = \frac{1}{N} \sum_{i=1}^{N} r_i, \bar{g} = \frac{1}{N} \sum_{i=1}^{N} g_i \] (8)

\[ \Sigma = \begin{pmatrix} \sigma_{rr} & \sigma_{rg} \\ \sigma_{gr} & \sigma_{gg} \end{pmatrix} \] (9)

Figure 2. One dimensional normal distribution skin color model.

Figure 3. Bivariate normal distribution skin color model.

Extract skin color area:
Detect the detected facial skin area (1) close to the ellipse; (2) some known facial skin areas (such as facial features, hair, etc.

The formula for judging the skin color area in the image is as follows:
\[ d(x, y) = \exp(-0.5\times(I(x, y)\times V - 1 \times (I(x, y) - m)) \] (10)

4. System Implementation Design

In the normalized RGB color space, the Gaussian model of skin color distribution is established by skin color sampling statistics and cluster analysis [8], and the probability likelihood map of skin color is obtained by calculating skin color similarity. Second, by smoothing filtering, threshold segmentation and other potential for facial regions of the binary image of the operation. Then, the deflection angle of the center of mass is calculated by the area center and height ratio, and the correlation coefficient is matched with the face model to detect and mark the face. By calculating the deflection angle and area ratio of candidate face image blocks, the template registration is optimized and the accuracy of template matching is improved [9]. Thus, a face inspection system based on template verification and skin color segmentation is constructed. The system design flow chart is shown in figure 4.

![System design flow chart.](image)

5. Analysis of Skin Color Segmentation

Firstly, the skin color model is established in the chroma space, and then the skin color is tested. After the skin pixels are detected, the region that may be the face is segmented. Finally, the face is verified by geometric features and gray features.

The rgb symbols commonly used in experiments do not apply to the skin color model, because in the chromaticity space, R, G, B three primary colors not only represent color, but also represent brightness. In this paper, we use the chromaticity space of \(Y, C_b, C_r\) to carry out the experiment, which is mainly because it is the least influenced by the external brightness. The input image conversion formula in the chroma space is as follows:

\[
Y = 0.298R + 0.588G + 0.115B \]
(11)

\[
C_b = -0.168R - 0.332G + 0.501B \]
(12)

\[
C_r = 0.501R - 0.418G - 0.082B \]
(13)

Experiments show that different people’s skin color is relatively similar (excluding brightness differences), so different skin color can also be used to represent \(g(m, V^2)\) with the same two-dimensional Gaussian model.

\[
m = (\overline{C_r}, \overline{C_b})V = \begin{pmatrix} \sigma_{C_r,C_r} & \sigma_{C_r,C_b} \\ \sigma_{C_b,C_r} & \sigma_{C_b,C_b} \end{pmatrix} \begin{pmatrix} \overline{C_r} \\ \overline{C_b} \end{pmatrix} = \frac{1}{N} \sum_{i=1}^{N} C_{ri} \overline{C_r} = \frac{1}{N} \sum_{i=1}^{N} C_{bi} \]
(14)

\[
\overline{C_r} = \frac{1}{N} \sum_{i=1}^{N} C_{ri} \overline{C_r} = \frac{1}{N} \sum_{i=1}^{N} C_{bi} \]
(15)
In some complex case studies, we mainly need to consider two aspects: one is the influence of light and facial organs. The face can be divided into several unrelated skin areas. The other is that the face area may be connected with other similar areas. So we often use clustering-merging-verifying method to experiment. Before carrying out this experiment, prepare for the conversion of chromaticity space, as shown in figure 5.

![Figure 5. Converting and preparing the chroma space.](image)

6. Result analysis
The experimental images are preprocessed first, as shown in figure 6, and then the processed images are processed for skin color segmentation. The following are the results of some experimental processing detection steps, as shown in figure 7.

![Figure 6. Image preprocessing results.](image)

(a) Grayscale processing  (b) Histogram equalization and normalization

![Figure 7. Skin color segmentation.](image)

(a) Many people  (b) Single person
After the preprocessing and skin color segmentation in the above figure, face detection is carried out according to the features of skin color segmentation. The results are shown in figure 8.

![Figure 8. Comparison results of algorithm analysis.](image)

The comparative analysis of the results of face detection based on traditional detection technology and the optimized detection results is shown in figure 9.

![Figure 9. Detection results of facial feature processing.](image)

7. Conclusions
The images in the experiment include different environments, faces in different states, and different backgrounds. It can be seen from the experimental results that the algorithm proposed in this paper has strong robustness and individual anti-tilt ability. Moreover, experiments show that the color
segmentation accuracy of the preprocessed image in the chromaticity space has been significantly improved, and it has also verified that the thresholds of $C_r$ and $C_b$ are relatively accurate. However, in this experiment, when multi-person images are detected, the detection frame will be partially lost. This is where the experiment needs to be improved.

Acknowledgments
This work was supported by Top Youth Program of Beijing Excellent Talent Training Program (Grant No. 10000200527) and Beijing Education Commission Project (Grant No. KZ201710015010).

References
[1] Xu X Y 2015 Overview of face recognition technology Electronic Testing (5x) 885-894.
[2] Craw I, Ellis H and Lishman J 1987 Automatic extraction of face features Pattern Recognition Letters 5 183-187.
[3] Yuan C L, Xiong Z L, et al. 2009 Image edge detection based on Sobel operator Image and Signal Processing 39 (1) 85-87.
[4] Yang G Z and Huang T S 1994 Human face detection in a complex background Pattern Recognition 27 (1) 53-63.
[5] Crowley J L and Berard F 1997 Multi-modal tracking of faces for video communications Proceeding of 1997 IEEE Computer Society Conference on Computer Vision and Pattern Recognition.
[6] Yang M-H and Ahuja N 1998 Detecting human faces in color images Proceedings of 1998 International Conference on Image Processing (ICIP 98).
[7] Jebara T S and Pentland A 1998 Parameterized structure from motion from 3D adaptive feedback tracking of faces Proc. Sixth IEEE Int’l Conf. Computer Vision pp 128-135.
[8] Bi X and Hui T 2015 Face detection based on skin color segmentation and AdaBoost algorithm Foreign Electronic Measurement Technology 34 (12) 82-86.
[9] Wang Dun and Yuan Jie 2017 Face recognition research in complex environment Automation application 11 75-78.