Study on A face detection method based on elliptic skin color model

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Abstract. Human face is a natural structural target with abundant details, and its detection results are easily affected by facial details, expressions and posture changes. In color images, the distribution of skin color is not affected by the changes of facial details, expression and posture, and the speed of skin color detection is very fast. This paper proposes a face detection algorithm based on elliptic skin color model. In YCbCr color space, the elliptic skin color model and logistic regression analysis were used to determine the skin color probability of each point, and the pixels of each point were mapped to [0, 1]. Based on Ostu method, a parallel genetic algorithm was used to determine the threshold of skin color segmentation to segment the face region. The results show that this method improves the speed of face detection and has good robustness to posture and expression changes.

Keywords: Skin color segmentation; Color space; Regression analysis; Genetic algorithm.

1. Introduction

With the development of science and technology, all aspects of social life towards automation, intelligent direction development. People's demand for high-speed and accurate automatic authentication is also higher and higher, which makes biometric identification technology attract extensive attention of the academic and scientific research circle. At present, the academic circle has used fingerprint, retina, iris, face and other biometric characteristics for automatic authentication. In various biometric recognition, face recognition has the sampling way friendly and convenient, and fast inspection speed, more widely, and the advantages of no special requirements for hardware, the broad application prospect of the development of it, makes more and more enterprises and research institutions to invest a lot of manpower and material resources and financial resources to its application in image processing, pattern recognition, etc.

At present, the relatively famous research methods for face recognition include: from the perspective of human perception law and psychology, explore automatic face recognition based on human face recognition law [1]; According to the role of human brain in face recognition process to explore the law of face recognition [2]; From the perspective of human vision mechanism, face recognition methods are studied by using the expression form of face in human visual system [3]. Although most face recognition algorithm has better performance on frontal face recognition, in actual applications, face recognition there are many difficulties need to be solved, such as illumination, posture, facial expressions, shelter, and because human face is an extremely complex nonrigid body, It is difficult to achieve satisfactory results on both accuracy and speed at the same time, These limits the technology's range of applications. Therefore, in order to popularize the application of this technology, its accuracy and detection speed need to be further improved.

Based on the above reasons, this paper proposes a fast face segmentation algorithm based on skin color, and improves the accuracy of detection by optimizing the segmentation threshold algorithm.

2. Skin color segmentation

The distribution of human skin color in color space is relatively concentrated, and the difference of skin color among different races is mainly caused by brightness, but has nothing to do with color attribute. There are three common color Spaces: RGB, YCbCr and HSV, Skin color has the best

clustering effect in YCbCr color space, which can effectively limit the distribution of skin color within a certain range. There is little difference in the distribution of skin color of people of different races in YCbCr space.

In YCbCr space, skin color clustering is a spinning cone with two tips, and the clustering region shows nonlinear change with the change of color. If only the clustering of skin color in CB-Cr space is considered without considering the influence of skin color, the clustering region of skin color obtained is not accurate. In this paper, a segmented nonlinear color transformation is carried out in YCbCr color space, and then elliptic skin color model is used to fit skin color region. The formula of nonlinear transformation is shown in Formula (1) and Formula (2) [4].

$$\begin{aligned}
\overline{C}_b(Y) &= \begin{cases} 108+\dfrac{(K_l-Y)*(118-108)}{K_l-Y_{\min}}, if\ Y<K_l \\ 108+\dfrac{(Y-K_h)*(118-108)}{Y_{\max}-K_h}, if\ Y>K_h \end{cases} \\
\overline{C}r(Y) &= \begin{cases} 154-\dfrac{(K_l-Y)*(154-144)}{K_l-Y_{\min}}, if\ Y<K_l \\ 154-\dfrac{(Y-K_h)*(154-132)}{Y_{\max}-K_h}, if\ Y>K_h \end{cases}
\end{aligned} \tag{1}$$

$$Wc_i(Y) = \begin{cases} WLc_i+\dfrac{(Y-Y\min)*(Wc_i-WLc_i)}{K_l-Y_{\min}}, if\ Y<K_l \\ WHc_i+\dfrac{(Y\max-Y)*(Wc_i-WHc_i)}{Y_{\max}-K_h}, if\ Y>K_h \end{cases} \tag{2}$$

$$C'_i(Y) = \begin{cases} (C_i(Y)-\overline{C}_i(Y))\dfrac{Wc_i}{Wc_i(Y)}+C_i(K_h)\ if\ K_h<Y<K_l, \\ C_iY \quad if\ Y\in[K_l, K_h] \end{cases}$$

Where: W_{cb}=46.97, WL_{cb}=23, W_{cr}=38.76, WL_{cr}=20, WH_{cr}=10, K_l=125, K_h=188, $Y_{\min}$=16, $Y_{\max}$=235.

The color space after nonlinear transformation is $\mathrm{YCb'Cr'}$ color space, the skin color samples of human faces are concentrated in an approximately elliptic region and in the smaller brightness space, $\mathrm{YCb'Cr'}$ color space is inverted cone shape, and in the larger brightness area, it is a gradually expanding elliptic column. . This paper will use ellipse formula to fit skin color distribution region. Then Logistic regression analysis was used to determine the skin color probability. Establish the elliptical skin color model as shown in Equation (4):

$$\begin{cases} x=\cos\omega*(Cb'-Cy)+\sin\omega*(Cr'-Cy) \\ y=(-\sin\omega)*(Cb'-Cx)+\cos\omega*(Cr'-Cy) \end{cases} \tag{3}$$

The ellipse model as shown in Equation (5) is established [5]:

$$d(x,y)=\frac{(x-eCx)^2}{a^2}+\frac{(y-eCy)^2}{b^2}-1 \tag{4}$$

Cx=109.38, Cy=152.02, ω=2.53(radian), eCx=1.6, eCy=2.41, a=25.39, b=14.03.

The logstic regression analysis (equation 6) is used to determine the skin color probability value of each point.

$$P_s(x,y)=1-\frac{1}{1+e^{-\beta_1(d(x,y)-\beta_2)}} \tag{5}$$

Where β_1 is 2.247 and β_2 is 1, Cx=109.38, Cy=152.02, ω=2.53, eCx=1.6, eCy=2.41, a=25.39, b=14.03

After linear regression, the skin color probability of each point was determined, and then the threshold of skin color segmentation was determined by parallel genetic algorithm. The implementation process of the genetic algorithm in this paper is shown in Figure 2, in which the adaptation function is the maximum inter-class variance, crossover rate is 0.2, and variation rate is

0.01. The overall optimal solution can be achieved when the optimal solution of the successive 5 generations within 40 generations does not change any more, and the inheritance terminates.

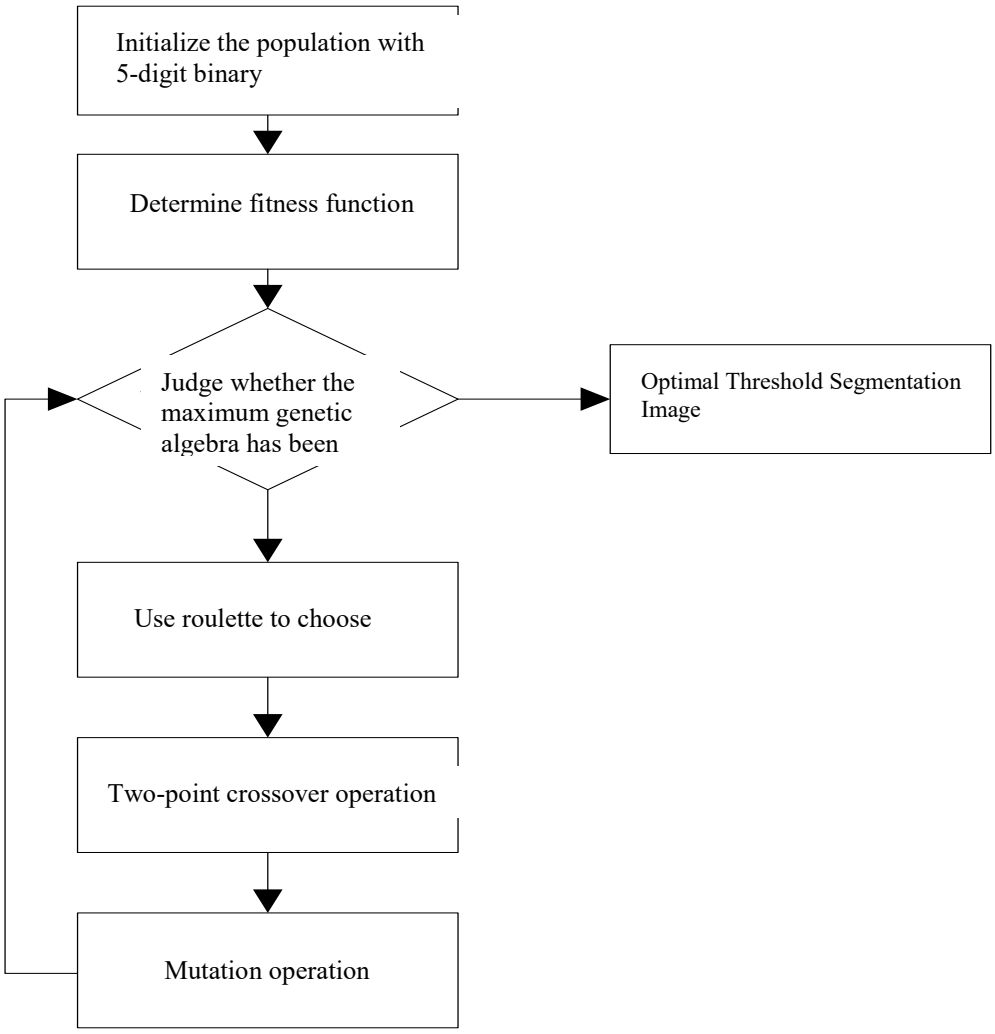


Figure 1. Flow chart of genetic algorithm

Suppose that picture L contains N pixels and the number of pixels with gray value I is n_i, then $N=\sum_{0}^{L-1} n_i$

The image is divided into face region and background region by threshold m, and A= (0,1,2... M), B = (m + 1, m + 2... L-1), and the probability of occurrence of each gray scale is $p_i = n_i / N$, It can be obtained by histogram normalization:

$$w_A = \sum_{i=0}^{t} p_i = w(t), u_A = \sum_{i=0}^{m} i.p_i / w_A = u(t)/w(t) \tag{6}$$

$$w_B = \sum_{i=m+1}^{L-1} p_i = 1-w(t), u_B = \sum_{i=m+1}^{L-1} i.p_i / w_B = u_L(t) - u_m(t) / \left[1-w(t)\right] \tag{7}$$

From equation (6) and equation (7), we can get:

$$w_A\ u_A + w_B\ u_B = u_m,\quad w_A + w_B = 1 \tag{8}$$

$$fitness(m) = w_A(u_A - u_m)^2 + w_B(u_B - u_m)^2 = w_A w_B(u_A - u_B)^2 \tag{9}$$

$$m_{opt} = Arg \max_{m\in\{0,1,2,.....255\}} fitness(m) \tag{10}$$

3. Experimental results and analysis

The test included 81 images from different backgrounds, environments and sizes of 335 faces, including yellow, white and black, taken from ordinary cameras and downloaded from the Internet.

This test compares the skin color detection method in this paper with other skin color detection methods. The comparison indexes include detection rate, false detection rate and detection time. The results are shown in Table 1:

Table 1. Test results

	Simple Gaussian model	Mixed Gaussian model	This paper algorithm
Detection rate	72.3%	84.6%	92.9%
Error detection rate	27.7%	15.4%	9.2%
Testing time	5.7ms	11.4ms	6.9ms

A total of 335 faces were correctly detected, 311 faces were correctly detected, and 4 faces were missed and 30 faces were incorrectly detected. As can be seen from the table, among the three detection algorithms, the simple Gaussian model has the fastest detection speed, but the lowest detection accuracy, and the mixed Gaussian model needs the longest detection time. The detection accuracy of the proposed algorithm is 20.53% higher than that of the simple Gaussian model and 8.22% higher than that of the mixed Gaussian model, and the detection time is only 1.16ms longer than that of the simple Gaussian model and 4.49ms less than that of the mixed Gaussian model.

From the experimental results, it can also be seen that the method in this paper has less missed detection of skin color in face detection, but sometimes exposed non-face parts will also be detected, resulting in the problem of too large skin color area of the detected face.

Although limited by the conditions, the performance of the system cannot be fully verified by large samples. But from the perspective of the test results of the above, sufficient to demonstrate the superiority of this method, reflected the detection method based on skin color of attitude change, size, expression of the advantage of robustness, and embodies the method of this paper compared with other skin color detection algorithm in the detection accuracy and the superiority of the false detection rate and detection time. Examples of experimental results:



Figure 2. The original image



Figure 3. Skin color segmentation

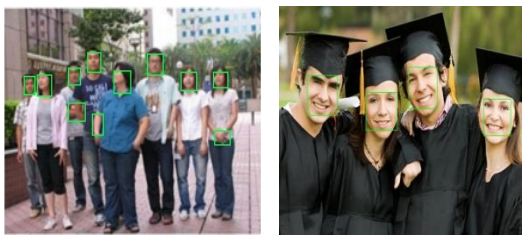


Figure 4. Test results

4. Conclusion

Face detection algorithm based on skin color segmentation is proposed in this paper, first of all in YcbCr color space through a nonlinear transformation by elliptical skin color model and logistic regression analysis to determine the skin probability of each point, in terms of image segmentation threshold, on the basis of Ostu method using parallel genetic algorithm to determine the threshold of skin color segmentation, rapid segment the face region. Experiments show that this method has good robustness to facial expression and posture transformation, but it is easy to produce false detection when the skin is exposed too much. Theror segmentation algorithm can be effectively combined with other algorithms to segment the face region first and verify it, so as to improve the detection speed and detection accuracy.

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