A Face Detection Method Based on Skin Color Features and AdaBoost Algorithm

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Abstract. The face detection based on skin color features is greatly affected by illumination and the face detection based on AdaBoost algorithm is greatly affected by multi-pose of face, and this means that the large face deflection will make the detection less accurate. So we investigated a face detection method that combines the skin color model and the improved AdaBoost algorithm in this paper. This method first judges whether the collected face image needs illumination compensation. The image is converted from RGB color space to YCbCr color space with higher pixel clustering characteristics and distribution rules by whether it is needed or not. Meanwhile, the candidate regions containing face images are carried out through morphological process and shape select after establishing the Gaussian model. Finally, the face detection results are obtained through detecting the candidate regions with face images by improved AdaBoost algorithm. A large number of experimental results show that this new method can effectively reduce the false detection rate and improve the efficiency of face detection.

1. Introduction

The current face detection[1] algorithm research can be divided into the following categories: methods based on prior knowledge[2], methods based on skin color model[3], methods based on AdaBoost algorithm[4], methods based on neural network[5].

The face detection method based on skin color model mainly uses the clustering of skin color to separate the face region from the background region. RGB color space is converted into YCbCr color space for calculation[6], because YCbcR has a better clustering effect on skin colors. Face image is preprocessed to eliminate the interference of various noises[7]. Then, according to the position invariance of eyes, the skin region of face is found, and the face position is finally detected. The face detection algorithm based on skin color model has faster detection speed, but when there are more skin like regions in the background, the interference is larger. Moreover, the method of skin color model has low robustness and low detection accuracy.

AdaBoost algorithm was first proposed in 2001 and applied to face detection[8]. In order to improve the detection accuracy of face detection algorithm, a self-confidence rate formula to improve the learning performance of the algorithm in [9]. Combining particle swarm optimization algorithm, artificial fish swarm algorithm and AdaBoost algorithm can reduce the training time of AdaBoost algorithm and improve the detection accuracy of the algorithm[10]. To date, considerable research have been conducted to prevent loss of the feature number, proposed an AdaBoost algorithm for "T" region [11]. The traditional Harr like feature number is large, and this algorithm can effectively reduce the feature number. In [12], a face detection algorithm combining CAMSHIFT algorithm and
AdaBoost algorithm is proposed, which can detect and track faces in real time. It also has some obvious disadvantages, such as excessive system resource consumption and low accuracy under high-definition image.

In order to solve the problem that the face detection is greatly affected by illumination and the accuracy is low, we propose an adaptive face detection method in this paper.

2. Method design
The proposed method includes two parts: (1) face image preprocessing and skin color segmentation; (2) AdaBoost algorithm. In this paper, through the research and analysis of the above two face detection algorithms, a new face detection method based on skin color features and AdaBoost algorithm is proposed. Firstly, we can preprocess the face image to be detected, remove the noise in the background, and get the region with face to be detected. Then, the skin color region is classified by cascade classifier, and the face region is further screened out, so as to improve the detection accuracy, and finally get the face region results. The overall process is shown in Figure 1.

2.1. Skin color characteristics
The method of face detection based on skin color features mainly uses the clustering of skin color to separate the face region from the background region[13].

2.1.1. Color space selection.
YCbCr color space is mostly used in the field of digital TV and image compression, where $Y$ represents luminance component, $Cb$ represents blue chrominance component, and $Cr$ represents red chrominance component. This color space can separate luminance from chroma, and RGB color space can be converted into YCbCr color space. The conversion formula (1) is as follows:

$$
\begin{bmatrix}
Y \\
Cb \\
Cr
\end{bmatrix} = 
\begin{bmatrix}
0.299 & 0.587 & 0.114 \\
-0.169 & -0.331 & 0.500 \\
0.500 & -0.419 & -0.081
\end{bmatrix}
\begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
$$

(1)

It can be seen from the above formula that YCbCr color space is transformed from RGB color space to a certain linear relationship. Therefore, YCbCr color space is selected as the spatial modeling of skin color region.

2.1.2. Skin color model selection.
Skin color model is a mathematical model of spatial distribution of skin color pixels in color space[14]. Through this mathematical model, we can obtain the probability distribution of pixels in the color space. The clustering effect of skin color in different color spaces is different. In this paper, skin color model is established in YCbCr color space with better clustering. Gaussian model is a model that describes the distribution of pixels in color space with normal distribution curve. It mainly calculates the probability of pixels in a large number of samples to get the mean value and covariance of each sample. According to formula (2), (3), (4), the probability value of pixels in each skin color can be
obtained. Finally, the threshold size is set to determine whether the pixel is the probability of skin color. The color pixel probability formula of Gaussian model is as follows:

\[
P(x) = \frac{1}{2\pi|\Sigma|} \exp\left\{-\frac{1}{2}(x - \beta)^T \Sigma (x - \beta)\right\}
\]

(2)

\[
\beta = \frac{1}{n} \sum_{j=1}^{n} X_j
\]

(3)

\[
M = \frac{1}{n-1} \sum_{j=1}^{n} (X_j - \beta)(X_j - \beta)^T
\]

(4)

In formula (2), (3), (4), \( \beta \) is the mean value of color samples, and \( M \) is the covariance matrix.

Combined with the characteristics of the real environment, Gaussian model is selected.

2.2. Face image preprocessing and skin color segmentation

After selecting the appropriate color space and skin color region model, the next step is to preprocess the face image and segment the skin color.

2.2.1. Image binarization.

When the obtained face image is processed by skin color model, the skin color likelihood map is obtained. It should be separated. The common method is to determine a threshold to divide the boundary, so as to get the binary image corresponding to the initial face image.

The real-time requirements of the experiment are high, and the face image is easy to be affected by external factors such as illumination and rotation. The threshold will change with the actual situation, and the fixed threshold method can not adapt to this situation. OSTU adaptive dynamic threshold method can solve this problem. These figures shows the binarization image obtained by using dynamic threshold method to separate face images when customers enter the store. Black area is non skin color area, white area is skin like area.

2.2.2. Morphological treatment.

The binary image obtained by dynamic threshold method needs morphological processing for denoising. At present, the common morphological methods are expansion, corrosion and so on. The expansion operation calculation formula (5) is as follows:

\[
M \oplus N = \left\{ x \left| \left(\hat{N}\right)x \cap M \neq \emptyset \right. \right\}
\]

(5)

In the above formula, \( N \) is expanded by \( M \), \( M \) is the area to be detected, \( \hat{N} \) represents the image of \( N \), and \( \left(\hat{N}\right)x \) represents the value of displacement.

Firstly, the binary image is processed or operated according to the structure element \( n \). If the pixel value obtained is the same as the structure element, it is represented by 1. Otherwise, use 0. The corrosion operation calculation is as follows:

\[
MN = \{ x | N \subseteq M \}
\]

(6)

In the above formula, \( N \) is used to corrode \( M \), and \( N \) is set as a structural element. Scan the image to be detected for sum operation, and find the first point with pixel value of 1. Then the initial point of structure element \( n \) and the starting point of the set image are moved to the change point. Then scan to
determine whether there are non skin color pixels in the image of the area to be detected. If so, all pixels are replaced with 0. The expansion operation can make the image to be detected larger.

2.2.3. **Skin color segmentation.** The above steps remove part of the noise, but also mistakenly detect a part of the face area.

   Determination of aspect ratio: The results show that the closest aspect ratio of the face part is \((1 + \sqrt{5}) / 2\). The length and width of all coordinates in the connected region are calculated respectively. If the aspect ratio meets the aspect ratio of the face, it is regarded as the face area.

   Area judgment: In this paper, we mainly refer to two points: the size of connected region \(num\) and the ratio of detected face area \(S\) to external skin area \(T\).

   \[
   num > 20 \times 20 \quad \frac{S}{T} > 0.8 \tag{7}
   \]

2.3. **Face detection based on improved AdaBoost algorithm**

In this paper, the AdaBoost face detection algorithm is improved by using human skin color features to improve its detection performance.

2.3.1. **Design of classifier.** AdaBoost algorithm uses integral graph to get face feature value. The next step is to construct classifier for training. Classifiers include weak classifier and strong classifier[15].

   Weak classifier: In face detection, AdaBoost algorithm is used to select the best Harr like matrix feature from multiple matrix features to construct a weak classifier. A Harr like feature can be used as a weak classifier. By comparing the feature value of the weak classifier with the feature value of the input face image, we can judge whether the image is a face region. But the classification effect is poor, that is, the optimal weak classifier needs to be selected iteratively from a large number of weak classifiers. The classification formula of weak classifier is as follows:

   \[
   h_j(x) = \begin{cases} 
   1 & p_j f_j(x) < p_j \theta_j \\
   0 & \text{others}
   \end{cases} \tag{8}
   \]

   Where \(x\) is the window to be detected, \(j\) is the sample feature, \(p_j\) is the way of inequality, the value is \(\pm 1\), \(\theta_j\) is the threshold value of weak classifier, and \(f_j(x)\) represents the Harr eigenvalue represented by the \(j\)-th matrix in the window to be detected. When the feature value of the image to be tested is less than the value, the weak classification class determines that there are still faces in the region, otherwise it is non face.

   Strong Classifier: The steps to construct a strong classifier are as follows, firstly, select an initial data set, the number of samples is \(n\), the sample image is \((X_1, Y_1), (X_2, Y_2), ..., (X_n, Y_n)\), where \(X_i\) is the it sample to be detected, \(Y_i\) is the classification result, \(Y_i = 1\) is the face sample, \(Y_i = 0\) is the non face sample. Secondly, initialization of weight: set \(m\) and \(l\) to represent the number of faces and non faces in the sample, \(n = m + l\). Thirdly, cascade classifier, normalization of weight:

   \[
   w_{t,i} \leftarrow \frac{w_{t,j}}{\sum_{j=1}^{n} w_{t,j}} \tag{9}
   \]

   A weak classifier is set for each \(j\) feature \(h_j\) and the corresponding weighted error rate formula is as follows:

   \[
   \omega_j = \sum_{i=1}^{n} w_{t,i} |h_j(x_i) - y_i| \tag{10}
   \]

   According to the result of weak classifier \(w_j\), the classifier with the least error is selected and the error \(\epsilon_t\) is calculated. When the sample is correctly classified \(W_{t+1,i} = w_{t,j} \frac{\epsilon_t}{1-\epsilon_t}\), if the sample is wrongly classified \(W_{t+1,i} = w_{t,j}\).

   Finally, all the optimal weak classifiers are cascaded to get a strong classifier:
\[ h(x) = \begin{cases} 
1 & \sum_{t=1}^{T} \partial_t h_t(x) \geq \frac{1}{2} \sum_{t=1}^{T} \partial_t \\
0 & \text{otherwise} \end{cases} \quad (11) \]

### 2.3.2. Cascade classifier structure.

In the AdaBoost algorithm, the Harr eigenvalues of the image to be detected are calculated by integral graph, and a weak classifier is constructed for each Harr eigenvalue. After several times of training, the strong classifier is finally obtained. Each layer of multi-level joint strength classifier is composed of strong classifiers. With the increase of the number of layers, the number of weak classifiers in each layer increases. The structure of strong classifiers also becomes complex. Each level of classifier will set a threshold to exclude the face samples. After multi-layer filtering of classifier, face samples will be detected. The detection rate and detection time of a single strong classifier is poor, so a cascade classifier can effectively improve the detection rate.

### 3. Experimental results and analysis

#### 3.1. Dataset

We select the video collected in the entrance of a sales shop exhibition hall in this paper. The video includes 500 multi pose and illumination face images.

#### 3.2. Experimental results

The original two algorithms are compared with the algorithm in this paper, and the detection results are as follows.

![Comparison of experimental results](image)

**Figure 3.** Comparison of experimental results, feature algorithm (a); adaBoost algorithm (b); ours (c)

**Figure 3 (a)** is a face detection algorithm based on skin color features, and there is a skin like region graph in the graph, and **Figure 3 (b)** is a customer face detection algorithm based on AdaBoost. **Figure 3 (c)** is our algorithm in this paper, which can adaptively detect customer's face relatively accurately.

| Table 1. Analysis of experimental results |
|------------------------------------------|
| **Feature** | **AdaBoost** | **Ours** |
| Total face image | 500 | 500 | 500 |
| Number of faces detected | 421 | 435 | 475 |
| Number of missing faces | 79 | 65 | 25 |
| Number of false faces | 350 | 375 | 25 |
| False detection rate(%) | 70 | 75 | 5 |
| Detection rate(%) | 84.2 | 87 | 95 |
| Average time(ms⁻¹) | 42 | 125 | 70 |

It can be seen from the data in the table that the algorithm based on the skin color feature has a low accuracy rate, the AdaBoost detection takes a long time, and the false detection rate is high. In this paper, the combination of the two algorithms can basically meet the actual requirements.

### 4. Summary

In this paper, aiming at the practical problems of the impact of complex environment on face detection, common face detection algorithms are studied. After analyzing the advantages and disadvantages of each algorithm, the skin color features and AdaBoost algorithm are combined to apply to the face detection method in automobile sales stores, which greatly improves the accuracy of face detection,
reduces the false detection rate, and has strong practicability. The next research direction is how to reduce the detection time.

Acknowledgments
The National Key R&D Plan “Intelligent Robots” Key Project of P.R. China (Grant No.2018YFB1308602), the National Natural Science Foundation of P.R. China (Grant No. 61173184), the Chongqing Natural Science Foundation of P.R. China (Grant No. cstc2018jcyjAX0694).

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