Face Detection Based on Improved Color Space of YCbCr

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Abstract: Face detection is increasingly common in face recognition. Face detection is the most important step, so it is necessary to improve the accuracy of face detection. In this paper, the traditional YCbCr color space has been improved in the face detection, and the improved color space can fully reflect the face color, so that the system can detect the face more accurately. Lots of tests on face image show that the established system created in this paper, the face detection algorithm based on improved YCbCr color space can carry on the face detection more accurate, improve the detection rate of the whole system.

1. Introduction
Today, the development of science and technology is advancing rapidly, and information security has become an increasingly important topic, and identification technology is becoming more and more important in today's information age. Compared with other types of biological characteristics, face recognition [1] has a larger advantage, first, the data source is more extensive, and then the result of the face recognition is also very intuitive, so face recognition can be widely applied in all kinds of fields.

Face recognition mainly consists of three steps: the first step is face detection, the second step is facial feature extraction, the last step is feature matching. The first step is one of the key parts of face detection. The central idea if face detection is not only to determine whether or not a human face exists in the center of the research of image or video capture, but also determine the face in the location, size [2][3] and posture, etc. It can be described as follows: given a static or dynamic image to determine whether the face is included, if the answer is yes, separate all faces from the background and determine the location of each face in the image. Face detection, as a key technology in face recognition, has been increasingly active in various research situations recently [4][5][6].

In this paper, the main method used in face detection is skin color segmentation. The color space of YCbCr is used as the research carrier. The traditional YCbCr color space has been optimized to make the color of skin area closer to human face skin, at the same time, the system can be more accurate during its operation. A lot of tests show that the established system created in this paper, based on the improved face detection algorithm can detect face image more accurately, at the same time, the accuracy rate of the improved system established in this paper is also higher than before.

2. Face detection based on skin color.

2.1 YCbCr color space.
YCbCr color space is commonly used in TV display, video compression coding and other fields. The color space is converted from the RGB color space\(^7\), and the transformation formula is as follows:

\[
\begin{bmatrix}
Y \\
Cb \\
Cr
\end{bmatrix} = \begin{bmatrix}
0.2990 & 0.5870 & 0.1140 & 0 & 1
\end{bmatrix} \begin{bmatrix}
R \\
G \\
B
\end{bmatrix} \begin{bmatrix}
-0.1687 & -0.3313 & 0.5000 & 0.5 & 0
\end{bmatrix} \begin{bmatrix}
Cr \\
Cb \\
1
\end{bmatrix} + 1.4966 \times Cb + 96.67
\]

2.2 YCbCr color space color extraction.
In the color space of YCbCr, the brightness value \(Y\) has little influence on the sample, and the sample data aggregation is concentrated in the plane of \(Cb\) and \(Cr\). This paper makes a statistical analysis of more than 1.2 million color pixel points of 100 color face images and gets the following skin color curve:

![Figure 2-1 three-dimensional distribution of skin color on y-cb-Cr.](image)

![Figure 2-2 two-dimensional distribution of skin color on Cb-Cr.](image)

Statistical analysis of \(Cb-Cr\) subspace can be obtained: the majority of skin color is concentrated in the area, which is enclosed by the above four function curves.

\[
\begin{align*}
Cr & \leq 1.4966 \times Cb + 96.67 \\
Cr & \geq -0.3947 \times Cb + 183.33 \\
Cr & \leq -5.0989 \times Cb + 884.316 \\
Cr & \geq -0.59 \times Cb + 270.54
\end{align*}
\]

Therefore, the following skin color modeling rules can be defined:

Rule C: \((1) \cup (2) \cup (3) \cup (4)\)

In the above formula, the symbol \(\cup\) represents logic or.

3. Improvement of skin color modeling space.
Through the analysis of the above content, the establishment of skin color model in YCbCr color space, is concise and easy to operate, however, this method still has its shortcomings, for example, the accuracy rate is not particularly high. At the same time, the miss rate is slightly higher. Therefore, in order to get higher detection rate and lower miss rate, further optimization must be done. The method of color space color modeling of YCbCr was improved in the following part to improve the accuracy of skin color extraction.
The first step is to analyze the facial skin color of people\cite{8}. The reason for the use of skin color for face detection, is that details such as facial expressions have little effect on it. More importantly, the color difference between skin color and other background is larger and easier to separate. Studies have shown that even when people are different, the skin tone of a human face is not too large in tone\cite{8}. Humans can show black, yellow and white skin, mainly because of different brightness. If the brightness of all human facial images is ignored, the facial skin color will show clustering characteristics. Therefore, if we remove the brightness component of face image, we will get the ideal result.

The second step is the basis of the improved color space of YCbCr. In this paper, the color space of YCbCr is improved. The color space of YCbCr can distinguish the brightness and color information of the image. This process can be done by making a linear transformation of the RGB color space.

Through a large number of experimental verification, in RGB color space, R, G, B three-component values can be easy to get, at the same time, the above three component has a certain relationship: \( R > B > G \), that is, the greater the value, the more intense the effects on facial skin color distribution is. Therefore, this paper has improved a new color space of YCbCr so as to optimize some problems in the previous space to a certain extent. The purpose is to improve the detection rate and reduce the miss rate.

### 3.1 Improved YCbCr color space.

According to the introduction introduced above, the formula of color space conversion from RGB space to YCbCr is as follows:

\[
\begin{pmatrix}
Y \\
Cb \\
Cr
\end{pmatrix} = \begin{pmatrix}
16 & 65.481 & 128.553 & 24.966 \\
128 & -37.797 & -74.203 & 112 \\
128 & 112 & -93.786 & -18.214
\end{pmatrix} \begin{pmatrix}
R \\
G \\
B
\end{pmatrix}
\]

The above simplification can be obtained:

\[
Y = xR + yB + zG
\]

\[
Cb = \frac{1}{2(1-y)}(B-Y)
\]

\[
Cr = \frac{1}{2(1-x)}(R-Y)
\]

In the above equation, \( x, y \) and \( z \) have the following relation: \( x+y+z=1 \), so the value of the fourth component is as follows:

\[
C_g = \frac{1}{2(1-z)}(G-Y)
\]

For reference to itu-r's BT.601 protocol, the text set \( x=0.299, y=0.114, z=0.578 \). Therefore, the improved color space is shown as follows:

\[
\begin{pmatrix}
Y \\
C_g \\
Cr
\end{pmatrix} = \begin{pmatrix}
16 & 65.481 & 128.553 & 24.966 \\
128 & -81.085 & 112000 & -30.915 \\
128 & 112000 & -93.786 & -18.214
\end{pmatrix} \begin{pmatrix}
R \\
G \\
B
\end{pmatrix}
\]

### 3.2 New color space skin modeling.

In this paper, 200 face images from different ages and sexes are tested. At the same time, the color of the skin in the picture covers all parts of the body. Extract all pixels in the skin area, convert their R, G, and B values into YCgCr, and then project the above in Cg-Cr space, as shown below:
We can obtain that from analysing the above image, the red part represents the skin color clustering region. According to the rules, the cross section of the pixels of Cg and Cr can be seen as skin color area, as shown below:

From the figure above, the red part can be seen as two pairs of parallel lines. The equation of the two pairs of lines is shown below:

\[
\begin{align*}
    Cr &= -Cg + 260 \\
    Cr &= -Cg + 280 \\
    Cg &= 85 \\
    Cg &= 135
\end{align*}
\]

that is \( Cr \in [-Cg + 260, -Cg + 280] \)  
\( Cg \in [85, 135] \)

When the pixel value falls within the above range, it is considered to be the color pixel, otherwise it is non-skin pixel.

After the establishment of skin color model\(^9\), the skin color area of the image is then extracted, and skin color segmentation will be done after that.

4. Skin color segmentation

As shown above, Skin color models have been established in the improved color space of YCbCr. separating the skin color from background. The method of establishing the skin color model in the improved YCbCr color space is called threshold segmentation.
The central idea of threshold segmentation of is: the first step, make statistics of the images which need to be tested, the purpose of this is to choose a threshold. Next step is to make a comparison between the information we have got and the threshold, in order to make a classification of all the images which to be tested. After that, all the objects will be assigned in order to get images that we need. What have been introduced above is called the method of threshold segmentation. In all of these processes, Selecting an appropriate threshold is the most important.

Through a series of experiments, it can be verified that, in the color space of YCbCr improved in this paper, even the face images with occlusion on the face are relatively accurate.

5. Follow-up work of skin color segmentation.
The subsequent work of skin color segmentation in this paper is to expand and corrode the image, so as to get better results.

The expansion process is as follows:
\[
X \oplus B = \{ p \in \mathbb{E}^2 : p = x + b, x \in X \quad \text{and} \quad b \in B \}
\]

The process of corrosion is shown as follows:
\[
X \Theta B = \{ p = \epsilon^2 : x + b \in X \quad \text{for} \quad \text{every} \quad b \in B \}
\]

As introduced above, Extract the skin color area from the image in YCbCr color space first, and then make corrosion and expansion operation for once or more time, after that, the skin color area can be extracted in general, at the same time, there are no obstructions in the images we have got. After that, fill the skin color. All the work should be done can we get a complete skin color area that we need.

6. Summary
This paper selected the YCbCr color space, analyzed some shortcomings in traditional YCbCr color space, and put forward a way to reduce the shortcomings above, that is, the parameters in the transformation matrix from RGB space to YCbCr color space were changed, and the proportion of R and G components were increased. When the parameters changed, the transition matrix would also change, thus make the face detection system detect the human face more quickly and accurately, so that the detection rate can be much more improved.

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