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Face Detection using Skin Color Detection & Segmentation

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Abstract: Face detection is one of the important applications of human-computer interaction systems. It is a special case of object detection. There are many approaches used for face detection like Geometry based, knowledge based or appearance based & Eigen face methods, etc. Among the several methods, skin color can be considered as a good feature for detecting human faces. So the proposed face detection algorithm involves skin color detection by identifying skin & non-skin pixels or regions in an image. There are many color models or color spaces used in the process, like RGB, HSV/HSI, YIQ or YCbCr etc. YCbCr color model has been proposed in the algorithm, since it is found to be useful for robust face detection. After detecting the skin color, the image is segmented into a binary image using morphological operations. Finally the face is detected using the binary image.

Keywords: Color models, Color space, Face detection, Morphological operation, Skin color detection, YCbCr

1. INTRODUCTION

There are three major steps in Automatic Facial Expression Recognition system (AFERS). The first step is to detect the face in the scene. The second step is to extract the facial expression information (facial features) that convening the facial expression and the third step is to classify the facial display conveyed by the face. The robust AFER system [1] can be applied in many areas such as emotion science, clinical psychology and pain assessment. It includes facial feature extraction and pattern recognition phases that discriminate among different facial expressions. Face detection is a special case of object detection. Early methods focused only on the detection and localization of human faces facing towards camera. The recent works focused on the complex issues of the problem i.e., to identify the human face in multiple views with different poses, illumination variations and with different rotations. The researchers were focused on appearance-based approaches and knowledge based methods. In the proposed system, face detection method is based on skin color detection and segmentation method using YCbCr color model [3].

In the next part of the paper, section II explains the process of skin detection and its applications. Section III explains the role of skin locus model in skin detection. YCbCr color model is discussed in section IV. Lighting Compensation algorithm is discussed in section V & in section VI face detection using morphological operation has been explained. Finally, section VII gives the conclusion.

2. SKIN COLOR DETECTION

Face detection is an important part of face recognition as the first step of automatic face recognition. Skin color can be considered as a good feature for detecting human face. Color allows fast processing and is robust to geometric variations of face pattern. Skin color has proven to be a useful and robust cue for face detection, localization and tracking. Automatic skin detection has applications in image content filtering, content aware video compression and image color balancing applications. For example, in one of the early applications, detecting skin-colored regions was used to identify nude pictures on the internet for the sake of content filtering. In another early application, skin detection was used to detect anchors in TV news videos for the sake of video automatic annotation, archival, and retrieval. In many similar applications, where the background is controlled or unlikely to contain skin-colored regions, detecting skin-colored pixels can be a very efficient cue to find human faces and hands in images. An example in the context of biometric is detecting faces for face recognition in a controlled environment. Skin detection is the process of finding skin-colored pixels and regions in an image or a video. This process is used as a preprocessing step to find regions that potentially have human faces and limbs in images. Several computer vision approaches have been developed for skin detection. A skin detector typically transforms a given pixel into an appropriate color space and then uses a skin classifier to label the pixel whether it is a skin or a non-skin pixel.

A skin classifier defines a decision boundary of the skin color class in the color space based on a training database of skin-colored pixels. The appearance of skin in an image depends on the illumination conditions (illumination geometry and color) where the image was captured. Humans are very good at identifying object colors in a wide range of illuminations, this is called color constancy. Color constancy is a mystery of perception. Therefore, an important challenge in skin detection is to represent the color in a way that is invariant or insensitive to changes in illumination. Thus choice of the color space affects greatly the performance of any skin detector and its sensitivity to change in illumination conditions. Another challenge comes from the fact that many objects in the real world may have skin-tone colors. For example, wood, leather, skin-colored clothing, hair, sand, etc.

This causes any skin detector to have much false detection in the background if the environment is not controlled. Skin detection process has two phases: a training phase and a detection phase [4]. Training a skin detector involves three basic steps:

1. Collecting a database of skin patches from different images. Such a database typically contains Skin-colored patches from a variety of people under different illumination conditions.
2. Choosing a suitable color space.
3. Learning the parameters of a skin classifier.

Given a trained skin detector, identifying skin pixels in a given image or video frame involves:

1. Converting the image into the same color space that was used in the training phase.
2. Classifying each pixel using the skin classifier to either a skin or non-skin.
3. Typically post processing is needed using morphology to impose spatial homogeneity on the detected regions.

3. SKIN DETECTION USING SKIN LOCUS MODEL

Although different people have different skin color, but several studies have shown that the major difference lies largely in their intensity rather than their chrominance [5]. When several value distributions models are compared in different color spaces (RGB, HSV, YCrCb, etc.), these distribution models show some efficiency in extracting skin-like regions under certain limited conditions. When only the chromaticity information is considered, also a relative robustness against intensity changes is achieved. However, this will not solve all the problems related to illumination and camera calibrations: skin chromaticity depend on the prevailing illumination and camera calibration light source. The more these two lighting factors differ, the bigger shift in chromaticity.

Also, illumination color can be non-uniform over the face. To solve these problems, skin locus can be used which has performed well with images under widely varying conditions. Skin locus is the range of skin chromaticity under varying illumination/camera calibration conditions in NCC (normalized color coordinate) space as shown in Fig. 1. In NCC space, intensity is defined as I=R+G+B and chromaticities are r=R/I, g=G/I and b=B/I. Because r+g+b=1, only the intensity and two chromaticity coordinates are enough for specifying any color uniquely. Here r-g coordinates has been considered to obtain both robustness against intensity variance and good overlap of chromaticity of different skin colors.

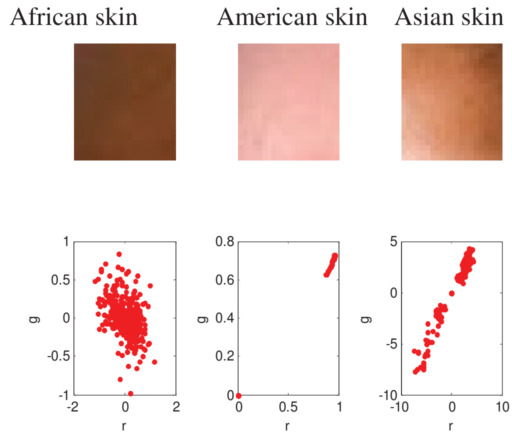

Fig. 1. Appearance of Skin loci in r-g plane for different skin patches.

4. COLOR MODELS

This is also known as color space. The purpose of a color model is to facilitate the specification of colors in some standard generally accepted way. In essence, a color model is a specification of a 3-D coordinate system and a subspace within that system where each color is represented by a single point. Each industry that uses color employs the most suitable color model. For example, the RGB color model is used in computer graphics, YUV or YCbCr are used in video systems, and so on. Transferring color information from one industry to another requires transformation from one set of values to another. In any given color space, skin color occupies a part of such a space, which might be a compact or large region in the space. Such region is usually called the skin color cluster. The choice of the color space is extremely important in skin detection.

A. Skin Detection & color spaces

The human skin color has a restricted range of hues and is not deeply saturated, since the appearance of skin is formed by a combination of blood (red) and melanin (brown, yellow) [4]. Therefore, the human skin color does not fall randomly in a given color space, but clustered at a small area in the color space. But it is not the same for all the color spaces. Variety of color spaces has been used in skin detection literature with the aim of finding a color space where the skin color is invariant to illumination conditions. The choice of the color spaces affects the shape of the skin class, which affects the detection process.

B. TV Color Spaces and Skin Detection

A different class of color spaces is the orthogonal color spaces used in TV transmission. This includes YUV, YIQ, and YCbCr. YIQ is used in NTSC TV broadcasting while YCbCr

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is used in JPEG image compression and MPEG video compression. In the YCbCr color space, Y component represents the luminance information; Cr(Y-R) component represents the red chrominance information; Cb(Y-B) component represents the blue chrominance information. One advantage of using these color spaces is that most video media are already encoded using these color spaces.

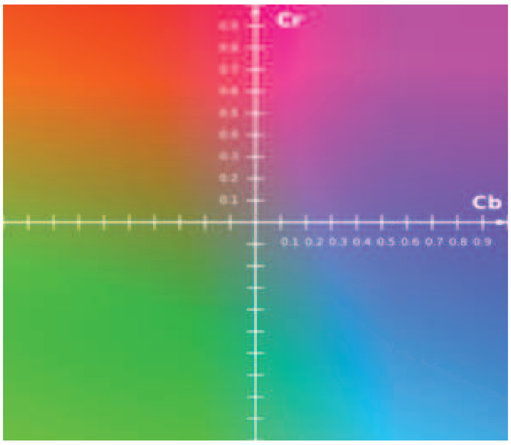

Fig. 2. The CbCr plane at constant luma Y=0.5 [7]

Transforming from RGB into any of these spaces is a straight forward linear transformation as given below:

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 16 \\ 128 \\ 128 \end{pmatrix} + \begin{pmatrix} 65.481 & 128.553 & 24.966 \\ -37.797 & -74.203 & 112.00 \\ 112.00 & -93.786 & -18.214 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

All these color spaces separate the illumination channel (Y) from two orthogonal chrominance channels (UV, IQ, CbCr). Therefore, unlike RGB, the location of the skin color in the chrominance channels will not be affected by changing the intensity of the illumination. In the chrominance channels the skin color is typically located as a compact cluster with an elliptical shape. This facilitates building skin detectors that are invariant to illumination intensity and that use simple classifiers.

Figure 3 shows the histograms of different color models for two different images. Histogram of an image represents the relative frequency of occurrence of the various gray levels in an image. From the results obtained, it is found that the gray scale distribution for Cb & Cr lies within a certain range of pixel values for any type of skin. This is due to the fact that the Cb & Cr values are independent of illumination of light. Due to this property of YCbCr color space, it is preferred for skin color detection. That is because RGB components are subject to the lighting conditions thus the face detection may fail if the lighting condition changes. Among many color spaces, this project use YCbCr components since it is one of existing Matlab functions and would save the computation time.

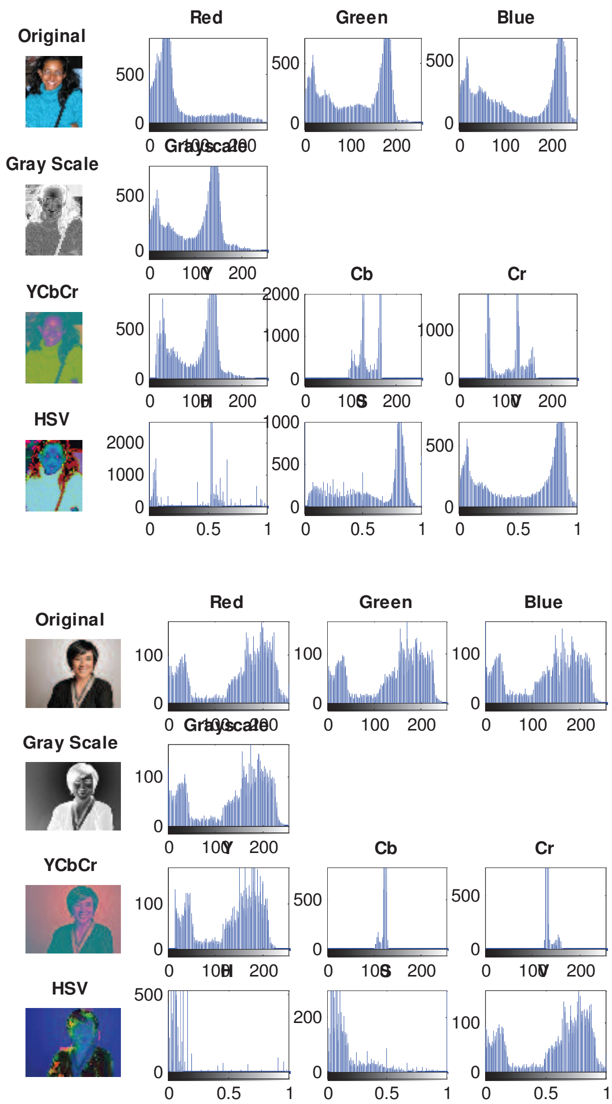

Fig. 3 Histograms of color spaces for two different images.

5. LIGHTING COMPENSATION

The skin color is often affected by light in image, which leads to deviate from the real color of skin. Here a lighting compensation algorithm has been used to do color correction in color images. This method can be described as follows [6]. The R, G and B are the amount of stimulus of red green and blue respectively in the recorded scenery. $R_{average}$, $G_{average}$ & $B_{average}$ are the average of each color channel. The results can be obtained as shown in figure 4

$$R' = R * \left[\frac{K}{R_{average}}\right]$$

$$G' = G * \left[\frac{K}{G_{average}}\right]$$

$$B' = B * \left[\frac{K}{B_{average}}\right]$$

$$K = \frac{(R_{average} + G_{average} + B_{average})}{3}$$

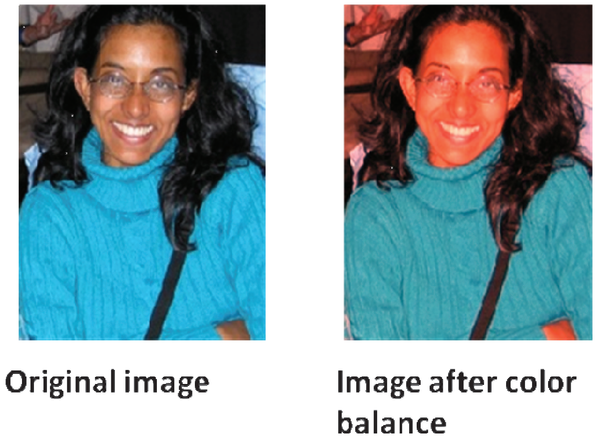

Fig. 4. Original image and the result of color balance

6. FACE DETECTION USING MORPHOLOGICAL OPERATION

The aim of Morphological operation is to transform the signals into simpler ones by removing irrelevant information. So morphological operation can reserve essential shape feature and eliminate irrelevancies. The most basic morphological operations are Dilation and Erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion removes pixels on object boundaries.

Firstly, erosion function is used to get rid of some small pieces, compared with face area, which is unwanted fragment. After that step, dilation operation will help to recover face area. This procedure can be done several times to get good result. The Figure 5, shows the effect of Morphological operation. Using morphological operations (majority operator and applying dilations followed by erosions until the image no longer changes), the number of these regions are reduced. To deal with faces of different orientations, firstly the best ellipse can be calculated fitting the face candidate. Based on the fact that the pixel value variations of other skin-like regions (such as hands) are smaller than those of face regions because of the presence of features with different brightness, all face region candidates with pixel value variations smaller than a threshold are removed. In order to improve the detection speed and achieve high robustness, the symmetry of the face is checked and all the candidates are removed when the symmetry is verified but no facial features are detected.

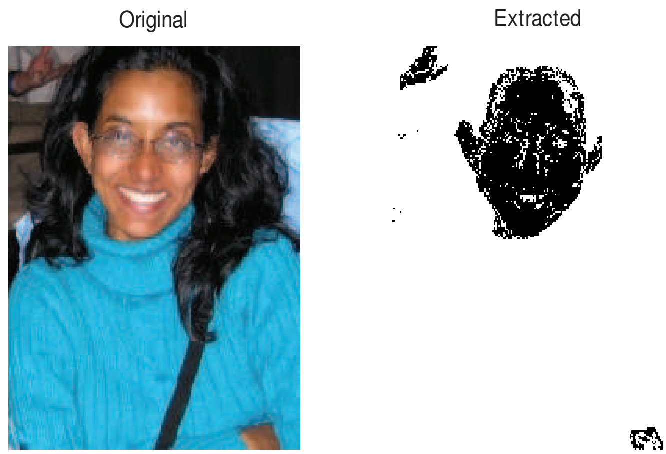

Fig. 5. Result after morphological operations

7. CONCLUSION

An automated Face Recognition System has a wide range of applications in psychological research and human-computer interaction applications. The system plays a communicative role in interpersonal relations because they can reveal the affective state, cognitive activity, personality, intention and psychological state of a person. The proposed face detection module is based on Skin Color detection and Segmentation techniques. Among different color models like RGB, YCbCr, HSI etc., YCbCr is convenient for the robust images & represents true colors of the image.

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