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Robust Color-Based Multi-Face Detection Using Skin Color Segmentation

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ABSTRACT: *Human face detection is the first step for face recognition. Variation of illumination, the existence of occlusion and orientation effect on the performance of the face-detection algorithms. Using the skin-color segmentation technique we can overcome the above referred problem. In this paper we propose a novel color-based multiple face detection approach which is based on the color-features and skin-color segmentation. At first the image is converted into YCbCr and HSV color model. Next the resultant image is converted into skin and non-skin regions using the designed HSCbCr color model. Next the segmented image is morphed and then skin-regions are constructed. Finally the face is detected by drawing the bounding box around the faces. The proposed approach is able to localize the occluded facial features.*

Keywords - *Color-model, Morphological operation, Multiple-Face-Detection, Region-labeling, Skin Segmentation.*

I. INTRODUCTION

In recent years human face detection has gained a lot of interest as research area in many applications. This application includes video conferencing, content based image retrieval and automatic authorization. Face detection is also considered as the integral step in the analysis of Face recognition process. The accuracy of Face recognition depends on the accuracy with which face is detected. Research in face detection [1] has encompassed many more components like the detection of multiple faces, facial feature extraction facial gesture recognition and also been used as a means for surveillance. Though human beings detect faces with little difficulty it is difficult to train the computer system with the same accuracy to detect faces due to the presence of the occlusion and different facial features like wearing of glasses and growing of beard and mustaches. Various approaches are used to detect faces [2] in the given image. In general the face detection approach has been classified in to five categories. They are i) Skin color model- based [3, 4]; ii) Feature invariant [5, 6]; iii) Knowledge-based [7]; 4) Template-based [8] 5) Edge based [1]. The face-detection approach using skin color-models has been modified by combining it with different globally used approach. One of the approaches used is the combination of template matching with skin-color based segmentation [9] where in two different methods are proposed. The first method detects faces based on statistical analysis and the second method uses the template matching and geometrical relationship to detect faces. The previously proposed approaches for detecting faces suffer from high computational cost. Thus a different approach for multiple-face detection is proposed in this paper.

In this paper, an algorithm is proposed that combines a color-space transformation with morphological operation [10], region labeling [11, 12] and segmentation methods for face detection [12, 13]. A different color model “HSCbCr” is defined for detecting multiple faces. The algorithm consists of first converting the image into its YCbCr and the HSV color components. The resultant image is then segmented into skin and non-skin regions using the defined color model. The segmented image is followed by morphology operations to remove the connected components which are then followed by region labeling and reconstruction of the skin-segmented region. The bounding box is drawn around the face using the face-detector function for differentiating the face from the rest of the skin-segmented region.

The paper is organized as follows, in Section 2, various ‘color space conversion’ is discussed, in Section 3 the ‘proposed algorithm’ is presented, in Section 4 the ‘implementation details’ are laid out, in Section 5 the ‘experimental results’ are discussed followed by conclusion in Section 6.

II. COLOR SPACE

2.1 Introduction

Color is an important feature of human face. Using skin-color analysis for tracing the face has several advantages. Firstly, processing skin-color is simpler than processing any other facial feature. Secondly under certain lightning conditions, color is orientation invariant. Intensity acts as a difference for various skin-tones. Also the skin-color of human is different from most other natural objects in the world. One important characteristic in the design of the color model is the choice of Color space.

Much of the research in skin-color based face detection is based on the three color models namely [14, 15] RGB, YCbCr and HSV. The chrominance components are analyzed for obtaining a robust segmentation of skin-color region thus eliminating the variation of luminance components by selecting the CbCr plane of YCbCr color space to build the color model. The other reason for choosing the YCbCr color space is the extensive use on digital video. The HSV color space provides the hue related information that defines the purity of all the colors and the saturation provides the information related to the various shades of the colors. In this section the three color models RGB, YCbCr and HSV color models are discussed.

2.2 RGB Color Space

The RGB Color space [16] consists of three additive primaries: Red, Green, and Blue. These spectral components are used to produce the resultant color. Fig.1 shows the RGB model represented by a 3-Dimensional cube. The RGB triplet (r, g, b) represents the 3-Dimensional co-ordinate of a point of a given color within the cube or its faces or along its edges. The colors red, green and blue are at the corners of each axis. Black is at the origin and white is at the opposite end of the cube. In a 24-bit color graphics system with 8-bits per color channel, red is represented as (255, 0, 0) and on the color cube it is (1, 0, 0).

RGB color model simplifies the computer graphics application working but is not suitable for all the applications. RGB color model is not very efficient when it comes to the representation the intensity values. Also the Red, Green and Blue components are highly co-related making it difficult to execute some image processing algorithm.

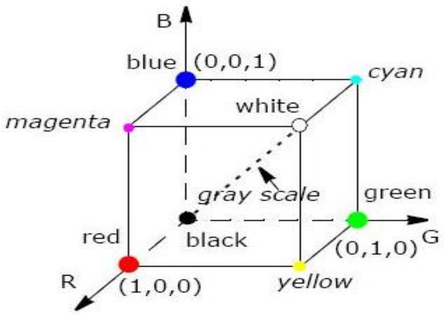

Fig.1. RGB Color Space

2.2.1 YCbCr Color Space

The YCbCr color model is not an absolute [16] color space instead it a way of encoding RGB information. YCbCr color model has been defined in response to the increasing demand of digital algorithms for handling video information and has become a widely used model in digital video. The family includes other color models such as the YIQ and YUV. YCbCr is digital color systems while YIQ and YUV are analog color spaces for the PAL and NTSC color systems. Fig.2 represents the YCbCr color model. The 'Y' component represents the luminance and 'Cb Cr' components represent the chrominance components. The chrominance components are obtained by subtracting the luma component from the red and blue component of RGB color model. The 'Y' component when represented in the frame buffer is defined to have a nominal 8-bit range of 16-235; whereas Cb and Cr are defined to have a nominal range of 16-240.

The RGB color space when converted to YCbCr, the RGB range of [0-255] is transformed into its Y, Cb and Cr component range of [0-255], [-128.0-127.0] and [-128.0-127.0]. The 'Y' component is level shifted down by 128.0 so that it falls in the range of [1-128.0-127.0].

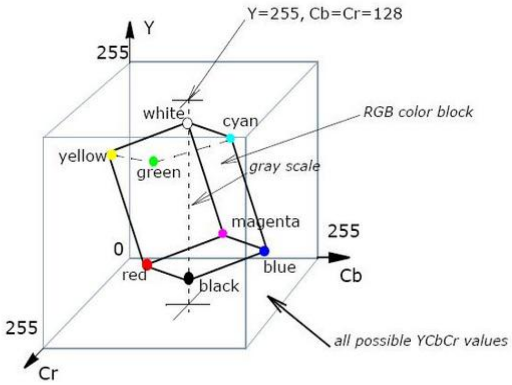

Fig.2. YCbCr color space

2.2.2 HSV Color Space

The HSV color model [16] describes colors with intuitive values based on tint, saturation and tone. When using HSV color model there exist no need to know what percentage of blue, green or red is required to produce a color by simply adjusting the hue value for the desired color. To get different shades of colors like to make a dark red color to appear pink saturation value is adjusted for the color. To make darker or lighter the intensity value is adjusted.

HSV color space is used in applications for identifying colors of different objects. HSV color space suits well for the algorithms or the operation that depends on the intensity information of an image and provides an ease for the operations to be perform on the image. Fig.3 shows the HSV color model with cylindrical co-ordinates. Hue 'H' is represented around the angle ranging from 0^0 to 360^0. Saturation 'S' ranges from 0 to 1 and corresponds to the radius. Value of Intensity 'L' varies along the z-axis with 0 being black and 1 being white.

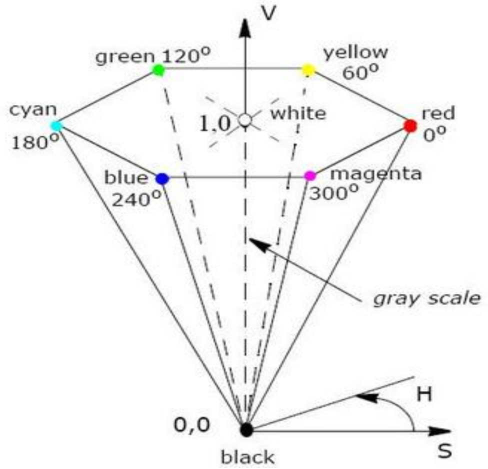

Fig.3. HSV Color Space

III. PROPOSED ALGORITHM

The block diagram for "Robust Color-model for Multi-face detection using skin-color segmentation" is shown in Fig.4. The algorithm consists of two major modules: i) localizing face candidates by using skin color segmentation, ii) verifying and detecting face regions by drawing the boundary around the faces by using face-detector function.

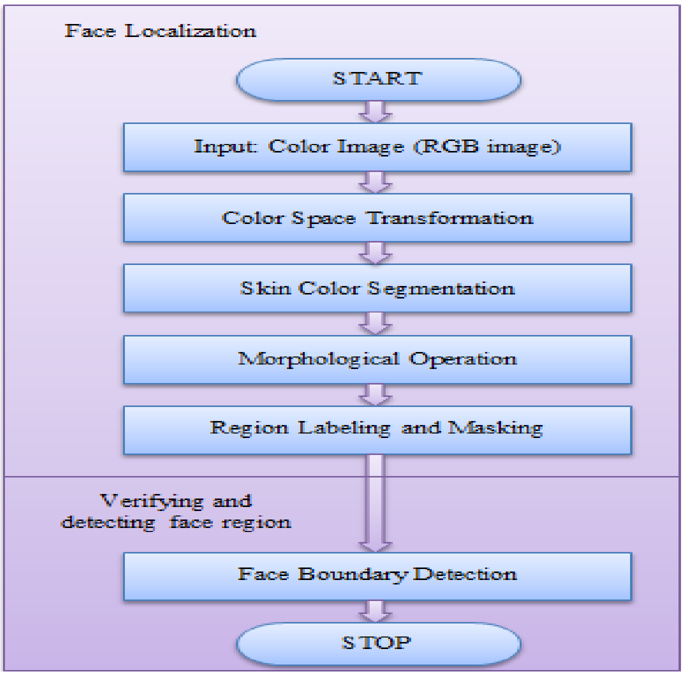

Fig.4. Flow-chart of the Proposed Algorithm

3.1 Color Space Transformation

The input to the system is the colored images. The input image is then transformed into YCbCr and HSV color spaces. The human skin color ranges from darker skin to lighter skin. On average women have lighter skin than men. The HSV color model considers the different shades and color purity of the color which is suitable for skin color detection. Also the transformation simplicity and explicit separation of luminance components make the YCbCr color space attractive for skin-color modeling.

3.2 Skin Color Segmentation

The color transformed image is threshold in to skin and non-skin regions using the “HSCbCr” color model. The thresholding values used for skin segmentation are:

$$145<=Cr<=165; 145<=Cb<=180; 0.01<=hue<=0.15$$

Several images of different persons have been explored and t was found that Cr value should be in the range of 145 to 165 and Cb value should be in the range 145 to 180 for a pixel to be classified as skin. In addition to YCbCr color model we have HSV color model to get better classification between skin-color with other. We have observed that in the hue plane skin region takes a value between 0.01 to 0.15 and these values are taken as threshold values to separate skin part in the image.

The resultant image after applying the skin-color segmentation with the defined threshold value is a binary image with two different regions: “Skin” and “Non-Skin” regions.

3.3 Morphological Operation

Morphological operation is applied on the skin segmented image. The morphological operations applied are “Opening” followed by “Dilation”. The Opening operation eliminates the small connected components, breaks the narrow isthmuses and soothes the contours. The dilation operation uses a disc shape structuring element so to shape the contour and increase the size of the skin-region which will be useful for performing the region labeling operation. The resultant is a morphed image.

3.4 Region Labeling and Masking

The morphed image is a binary image. The skin-segmented morphed image is reconstructed using the region-labeling and masking technique resulting into the visibility of only the skin-regions in the image. To perform the region labeling operation sequential region labeling approach is used.

The sequential region labeling approach re-constructs the skin areas in two basic steps. In the first step it assigns the preliminary labels to the connected regions namely “1-foreground” and “0-background”. In the second steps it scans for collisions and if found collision resolves the collision. Next, the color-based mask is applied onto the region labeled image which picks out the skin regions and recreates the regions labeled as skin. The resultant image is the reconstructed image with only the skin regions.

3.5 Face Boundary Detection

The last step in the proposed algorithm is detecting multiple faces by drawing a bounding box around the faces in the reconstructed image. To perform this step the face detector function is used which is trained with various occlusion and illumination present in the image. This face-detector function is then applied on the reconstructed image which considers the facial features for detecting and verifying the faces and draws the bounding box only around the face boundary.

IV. IMPLEMENTATION

4.1 Face Localization

The main function in face detection is to successfully locating the human-faces in the given image. When the system receives the colored image as input, the image is transformed into YCbCr and HSV color spaces. The color-space transformed image is then segmented into skin and non-skin regions. The image is segmented by using the same range of values for Cb, Cr and hue that are defined under “Section-III”. From the skin-segmentation results the next process where in the morphological operations opening followed by dilation are applied on the skin-segmented regions. The resultant morphed image then passes through the region-labeling and masking process where in the skin-segmented areas are reconstructed.

4.2 Verifying and Detecting Faces

From the Region-labeling and Masking operation step the next step is to detect the faces in the recreated image. This step decides that, which region is most probable human face region and which is not by drawing a bounding box around the faces. The recreated image is passed through a face-detector function that considers the face-candidates as a way to recognize the faces in the image and then draws a bounding box around the face detected.

V. EXPERIMENTAL RESULTS

The multi-face detection system has been implemented using MATLAB software. Test was conducted with 22 images with different number of faces and with image quality ranging from good picture quality to average picture quality and to finally poor picture quality of the images. The experimental result also displays the success rate and failure rate of detecting the faces in every image considered. Also the average success rate obtained to detect multiple faces using the proposed algorithm is 95.3325% and the average failure rate is 4.6675%.

The results of different steps involved in the proposed algorithm are shown in Fig.4 and their test results are shown in the table1.

Fig. 5(a) Fig.5 (b) Fig.5(c) Fig. 5(d)

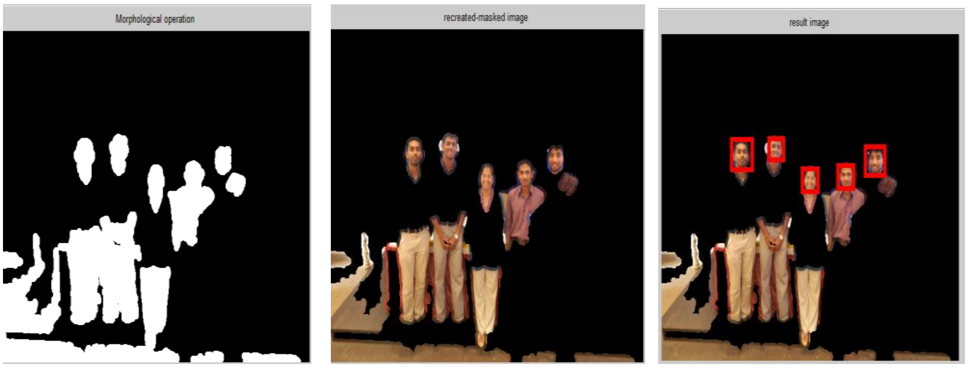

Fig. 5(e) Fig.5(f) Fig.5(g)

Fig 5: Results obtained in different stages of proposed method. 5(a). Input image. 5(b). Output of YCbCr model. 5(c). Output of HSV color model. 5(d). Skin Segmented image. 5(e). Morphed image. 5(f). Region-labeld image. 5(g). Multi-face detected image.

Table. 1 shows the test result conducted on various images.

Image Name	Number of faces	Number of Faces Detected	Number of faces Not Detected	Success %	Failure %
Pic1.jpg	01	01	00	100%	0%
Pic2.JPG	01	01	00	100%	0%
Pic3.JPG	01	01	00	100%	0%
Pic3.JPG	01	01	00	100%	0%
Pic4.JPG	01	01	00	100%	0%
Pic5.JPG	01	01	00	100%	0%
Pic6.JPG	02	02	00	100%	0%
Pic7.JPG	02	01	01	50%	50%
Pic8.JPG	02	02	00	100%	0%
Pic9.JPG	02	01	01	50%	50%
Pic10.JPG	02	02	00	100%	0%

Image Name	Number of faces	Number of Faces Detected	Number of faces Not Detected	Success %	Failure %
Pic11.JPG	02	02	00	100%	0%
Pic12.JPG	05	05	00	100%	0%
Pic13.JPG	04	04	00	100%	0%
Pic14.JPG	03	03	00	100%	0%
Pic15.JPG	14	12	02	86%	14%
Pic16.JPG	05	05	00	100%	0%
Pic17.JPG	03	03	00	100%	0%
Pic18.JPG	04	04	00	100%	0%
Pic19.JPG	00	00	00	100%	0%
Pic20.JPG	00	00	00	100%	0%
Pic21.JPG	00	00	00	100%	0%
Pic22.JPG	00	00	00	100%	0%

The average success and failure rate for 22 images are calculated as:

$$\text{Average Success}= \sum_{i=1}^{22}(success\ percent) = 95.3325$$
$$\text{Average Failure}=\sum_{i=1}^{22}(Failure\ percent) = 4.6675$$

VI. CONCLUSION

In this paper, a skin color based multiple-face detection system is designed. The system uses a color model "HSCbCr" which is obtained by combining the chrominance components of YCbCr color space with the hue and saturation values of the HSV color space. The system is based on first transforming the image in to YCbCr and HSV color model. The problem faced in detecting faces such as occlusion, orientation, pose and lightning effects (clarity) in the images have been taken into consideration and the system is able to detect multiple-faces using the proposed algorithm. The designed system gives good results for images with good quality and provides satisfactory results for images with average or poor quality. The test performed on the system shows that the average success rate is 95% above and having a failure rate of less than 5%.

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