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Hybrid Approach for Face Detection Using Skin Color Based Segmentation and Edge Detection

Bhushan Lal Banchhor[1], Mrs. Tripti Sharma[2]

M. Tech. Scholar, Software Engineering (CSE), Rungta College of Engineering & Technology, Kohka, Bhilai[1]

Associate Professor, Department of Computer Science Engineering, Rungta College of Engineering & Technology, Kohka, Bhilai[2]

Abstract: In this paper, we propose a technique to efficiently detect human face in color images with varying illumination conditions. The strategy consists of modeling the distribution of skin colors gaussian fitted skin color model and segmenting the image into skin and non-skin parts, using threshold values that are computed automatically by an adaptive technique. Here we show that a mixture model of gaussians can provide a robust representation of the human skin color to accommodate with a lot of color variations. Using images taken from the internet, containing persons with various skin-color types in different illumination conditions, experimental results show that the proposed method can cope with a various range of illumination situations and complex backgrounds,where skin color based segmentation can segment the skin regions of human face and separated the non-skin regions and after that using edge detection operators(canny and prewitt) , which detect the face regions while reducing the noise around that region. In this way this hybrid approach provide us better system to detect the face region.

Keywords: Image segmentation, edge detection, segmentation, face detection, skin color, canny, prewitt

I. INTRODUCTION

With the ubiquity of new information technology and media, more effective and friendly methods for human computer interaction (HCI) are being developed which do not rely on traditional devices such as keyboards, mice, and displays. With the development of 2-D/3-D face recognition techniques, face segmentation and landmark detection on depth information have become very important preprocessing steps for designing fully automatic recognition systems[4].Recognizing human actions in the real-world environment finds applications in a variety of domains including intelligent video surveillance, customer attributes, and shopping behavior analysis. However, accurate recognition of actions is a highly challenging task due to cluttered backgrounds, occlusions, and viewpoint variations, etc[8]. The task of human face detection is to determine in an arbitrary image whether or not there are any human faces in the image, and if present, localize each face and its extent in the image, regardless of its three dimensional position and orientation. Such a problem is a very challenging task because faces are non-rigid forms and have a high degree of variability in size, color, shape and texture. Human identification and face recognition with applications through surveillance and data security has fascinated a lot of attention. Other applications in relation with human faces are developed, like facial feature detection, face authentication and facial expression recognition. In all of these applications and subjects, face detection is the first step.

In face detection, the goal is to determine whether there is a face in an image or not and locate existing faces. The main difficulties of detecting faces in an image are due to the variability of faces in scale, location and orientation. Various facial expressions, component occlusions and lighting conditions are other important factors affecting the appearance of faces. Statement of face detection: given an arbitrary image, the goal of face detection is to determine whether or not there are any faces in the image and if present, indicate their locations and regions. [11].

II. SEGMENTATION & COLOR INFORMATION

A. Need for Segmentation

Segmentation is a process that partitions an image into regions. In the problem of face detection, skin segmentation helps in identifying the probable regions containing the faces as all skin segmented regions are not face regions and aids in reducing the search space. Though there are different segmentation methods, segmentation based on color is considered. Precise segmentation of the input image is the most important step that contributes to the efficient detection and localization of face in skin tone color images. Segmentation of the input color image based on skin chromaticity is the first step towards detecting and localizing faces in color images. Segmentation of an image based on human skin chromaticity using different color spaces results in identifying even pseudo skin like regions as skin regions. Hence there is a need for further eliminating these pseudo skin regions. Researchers are working on adaptive skin color segmentation used for detection [5].

B. Skin Pixel Classification

As skin color pixels play an important role in detecting faces in color images, skin chromaticity values of different color spaces can be effectively used to segment the input image. It helps to identify the probable regions containing faces. Considering only the probable regions containing the faces for detection process reduces the search space [5].

The skin color of humans of different races, although perceived differently by humans, only differs in intensity rather than chrominance. This chrominance invariance of the human skin makes it possible to implement a simple and consistent skin color segmentation method. For the problem of face detection involving color images having complex scenes [9], the use of skin pixel properties for segmentation reduces the search space to a greater extent. Several researchers have exploited skin properties for initial face segmentation. On these segmented connected components several additional constraints such as number of holes present in the segmented area, whether the segmented area satisfies the golden ratio $(1+\sqrt{5})/2$ with respect to its height and width, are applied to check whether the skin segmented connected component is a valid face region.

Skin color classification aims at determining whether color pixel has the color of human skin or not. This type of classification should overcome difficulties like different skin tones (white, pink, yellow, brown and black), scene illuminations, and the fact that background pixels can have the same color as skin. Skin color based face detection techniques can be divided into three steps:

- Color space decision.
- Skin model creation and segmentation of the image
- using that model.
- Face localization of the segmented image.

C. YCbCr Color Space

YCbCr space segments the image into a luminosity component and chrominance components. The main advantage is that influence of luminosity can be removed during processing a image. Using the reference images different plots for Y, Cb and Cr values for face and non-face pixels were plotted and studied to find the range of Y, Cb and Cr values for face pixels. After experimenting with various threshold the best result were found by using the following rule for detecting the skin pixel:

$$135<Y<145$$
$$100<Cb<110$$
$$140<Cr<150$$

The results are shown in Fig 5.1, Fig 5.2 shows the final binary segmented output using all the condition on Y, Cb and Cr[10].

III. EDGE DETECTION

In biometric applications, computer vision and computer graphics, the class of objects is often the human face [7].The effectiveness of many image processing and computer vision tasks depends on the perfection of detecting meaningful edges. Edge detection has been a challenging problem in low level image processing. It becomes more challenging when color images are considered because of its multi dimensional nature. Color images provide accurate information about the object which will be very useful for further operations than gray scale images[3].Edge detection is a fundamental tool used in most image processing applications to obtain information from the frames as a precursor step to feature extraction and object segmentation. This process detects outlines of an object and boundaries between objects and the background in the image. An edge-detection filter can also be used to improve the appearance of blurred image[6].

A. Prewitt's operator

The prewitt filter is very similar to sobel filter. The 3x3 total convolution mask is used to detect gradient in the X, Y directions. Prewitt filter is a fast method for edge detection. The difference with respect to sobel filter is the spectral response. It is only suitable for well-contrasted noiseless images [3].

-1	0	+1
-1	0	+1
-1	0	+1

G_x

+1	+1	+1
0	0	0
-1	-1	-1

G_y

Figure : 3.1

B. Canny edge detector

The popular edge detection algorithm canny first presented in 1986.The problem with this type of traditional edge detection approach is that a low threshold produces false edges, but a high threshold misses important edges. First requires that the image be smoothed with a gaussian mask, which cuts down significantly on the noise within the image. Then the image is run through the Sobel algorithm, and as discussed before, this process is hardly affected by noise. Lastly, the pixel values are chosen based on the angle of the magnitude of that pixel and its neighbouring pixels. Unlike roberts cross and much like Sobel, the canny operation is not very susceptible to noise. If the canny detector worked properly it would be superior to both sobel and roberts cross, the only drawback is that it takes longer to compute [3].

The algorithmic steps as follows:
Convolution apply to image f(r,c) with a Gaussian fuction to get smooth image f^(r,c). f^(r,c)= f(r,c)*G(r,c,6) .

- Apply first difference gradient operator to compute edge strength then magnitude and direction are obtain as before.
- Apply non-maximal or critical suppression to the gradient magnitude.
- Apply threshold to the non-maximal suppression image[13].

IV. SKIN - COLOR MODEL

Although people from different ethnicities have different skin colors in appearance, experiments have shown that skin colors of individuals cluster closely in the color space, i.e. color appearances in human faces differ more in intensity than in chrominance. Therefore, the V component is discarded in order to reduce dependence to lighting conditions, while H and S are used to build a 2D model of the skin-color distribution [1].The method consists in two image processing steps. First, we separate skin regions from non-skin regions. After that, we locate the frontal human face(s) within the skin regions. In the

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first step, we get a chroma chart that shows likelihoods of skin colors. This chroma chart is used to generate a gray scale image from the original color image. This image has the property that the gray value at a pixel shows the likelihood of that pixel of representing the skin. We segment the gray scale image to separate skin regions from non skin regions. The luminance component itself is used then, together with template matching to determine if a given skin region represents a frontal human face or not. In order to segment human skin regions from non-skin regions based on color, we need a reliable skin color model that is adaptable to people of different skin colors and to different lighting conditions.The common RGB representation of color images is not suitable for characterizing skin-color. In the RGB space, the triple component (r, g, b) represents not only color but also luminance. Luminance may vary across a person's face due to the ambient lighting and is not a reliable measure in separating skin from non-skin region. Luminance can be removed from the color representation in the chromatic color space. Chromatic colors, also known as "pure" colors in the absence of luminance, are defined by a normalization process shown below:

$r = R/(R+G+B)$ $b = B/(R+G+B)$

Note: Color green is redundant after the normalization because $r+g+b = 1$.

Chromatic colors have been effectively used to segment color images in many applications. It is also well suited in this case to segment skin regions from non-skin regions. The color distribution of skin colors of different people was found to be clustered in a small area of the chromatic color space. Although skin colors of different people appear to vary over a wide range, they differ much less in color than in brightness. In other words, skin colors of different people are very close, but they differ mainly in intensities. With this finding, we could proceed to develop a skin-color model in the chromatic color space.

The color histogram revealed that the distribution of skin-color of different people are clustered in the chromatic color space and a skin color distribution can be represented by a Gaussian model N(m, C), where:

Mean: $m = E\{ x \}$ where $x = (r \ b)^T$

Covariance: $C = E\{(x - m)(x - m)^T\}$. With this Gaussian fitted skin color model, we can now obtain the likelihood of skin for any pixel of an image. Therefore, if a pixel having transform from RGB color space to chromatic color space, has a chromatic pair value of (r,b), the likelihood of skin for this pixel can then be computed as follows:

Likelihood $= P(r,b) = \exp[-0.5(x-m)^T C^{-1}(x-m)]$
Where : $x=(r,b)^T$

Hence, this skin color model can transform a color image into a gray scale image such that the gray value at each pixel shows the likelihood of the pixel belonging to the skin. With appropriate thresholding, the gray scale images can then be further transformed to a binary image showing skin regions and non-skin regions[12].

V. SEGMENTATION USING SKIN COLOR

Using the skin-color model, the original color image can be transformed into a likelihood image. This likelihood image is a grayscale image where the gray value of each pixel shows the probability of the pixel to represent skin color. Bright pixels have a high probability to represent skin color, while dark pixels have a low probability to represent skin color. With an appropriate threshold value, the likelihood image can be segmented into a binary image showing skin and non-skin regions[1]:

$$\textbf{\textit{pixel}} = \begin{cases} \text{skin pixel if likelihood>threshold} \\ \text{non-skin pixel else} \end{cases}$$

Gaussian fitted skin color modelhas been used by previous researchers for skin-color modeling. In these works, skin-color segmentation was based on a unique threshold value arbitrarily decided. However, when processing images of different people taken in different imaging conditions, the use of only one single threshold value is not adapted to deal with the wide range of variations. We use a method to compute automatically the optimal threshold value using an adaptive technique. The algorithm is based on the observation that a high threshold value will give a small segmented area, while a low threshold value will give a larger one. Decreasing the threshold from an initial high value, the size of the detected skin region will likely remain stable under a certain range of threshold values until the threshold value becomes too small such that non-skin regions merge with skin-regions, resulting in a sharp increase of the total segmented area. If the increase in size of a region is plotted as a function of the decrease in threshold value, the obtained curve gradually decreases up to a point where it sharply increases.

Furthermore, as we use a mixture model composed of k gaussian components, one optimal threshold is estimated independently for each of the k components, i.e. we compute k optimal threshold values. These are estimated *a posteriori* according to the input image and are therefore not fixed a priori. Each gaussian component with its corresponding threshold value will extract a different skin region on the face. It can be seen that each gaussian component has detected a different part of the facial area, corresponding to a different skin-color variation due to the illumination environment [1].

Figure 5.1: Face segmentation process of Tested Image-1

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Figure 5.2: Face segmentation process of Tested Image-2

A.Refinement Operation of Face Region

Due to the existence in the background of colors similar to skin tones, skin-color segmentation in images with complex background can yield small isolated groups of pixels in the segmented image. These regions have typically a size of a few pixels and may be assimilated to noise, which can be eliminated using a low pass filtering[1].Various types of scaling and thresholding operations have been done during the detection process like adaptive and optimal thresholding, so that the generated face is more relevant for the system.

VI. PROPOSED APPROACH

In this paper, a combination of color spaces to identify the skin pixels combined with canny and prewitt edge detection algorithm for good segmentation is proposed. As all the skin segmented regions are not face regions, each segmented region is passed through a face classification algorithm to check whether the segmented region is face or not.

Step-1: First we find chromatic distance for all database images which illustrates the intensity of images with pixel values and stored in matrix to plot the color distance graph with Cb,Cr as dimensions.

Step-2: In this step the image for which the Face has to be found out is chosen as input. After that the RGB color image is converted into YCbCr color space. Low pass filter have been applied to the image to get filtered image.

Step-3: The input color image is converted into gray scale image. Edge-image of this image is obtained using “Canny” and “Prewitt” edge detection algorithms separately. Then edge-images obtained by both the methods are combined and complemented to obtain region boundaries.

Step-4: On this image connected component analysis is carried out to obtain a combined-segmented image. Regions larger than certain threshold value (in our approach 0.55 to 0.05), satisfying certain aspect ratio, containing holes are selected.

Step-5: Region boundaries obtained in step-3 is multiplied with the combined-segmented image obtained in Step-4. And creating the color transformation structure. The input image is skin segmented using YCbCr colour space. After performing some operations such as coverting image into grayscale and grayscale into binary image, we get the final segmented image.

Step-6: At last for the face segmented image which we get in step 5, we calculate the Performance parameters such as rand index (ri), global consistency error (gce),variation of information (vi), peak signal to noise ratio (psnr), mean square error (mse) and manually calculated false acceptance rate (FAR) , false rejection rate (FRR). After that we plot all the evaluation parameters in graph.

The segmented regions containing holes due to the presence of eyes and mouth are assumed to be probable segmented face regions and eliminate other segmented regions. The selected candidate face regions can be further passed through face localization and classification algorithm such as one presented by the authors in paper [2], as even non-face regions can also contain holes located at positions similar to those of facial components like eyes and mouth.

VII. RESULTS

In image database there are 45 images with different illumination, pose and lighting conditions. The test was performed in 10 training images. The results of face detection process for different evaluation parameters and the elapsed time for face detection of training images are as follows:

Table 7.1: Performance evaluation and elapsed time of database images using different parameters for skin color model segmentation and edge detection :-

Images	ri	gce	vi	mse	y	Elapsed time(in seconds)
Image1	0.5793	0.2462	1.4574	1.2163e+00 4	7.2802	18.3613
Image2	0.5003	0.2749	1.6438	7.6747e+00 3	9.2802	16.3177
Image3	0.6175	0.2313	1.3221	1.0988e+00 4	7.7218	14.8981
Image4	0.5042	0.3590	1.7780	9.2501e+00 3	8.4693	15.2881
Image5	0.6859	0.1966	1.1654	1.2393e+00 4	7.1990	15.6001
Image6	0.5355	0.4007	1.7941	7.9081e+00 3	9.1501	15.3505
Image7	0.6368	0.2488	1.3642	1.1182e+00 4	7.6458	14.9605
Image8	0.5400	0.3411	1.6885	9.1266e+00 3	8.5277	15.3505
Image9	0.6952	0.2144	1.1899	1.3957e+00 4	6.6830	15.8809
Image10	0.6592	0.2765	1.3797	5.1918e+00 3	10.977 7	15.7873

The results show that the entire facial regions are clearly extracted, regardless of face orientation. In some of these examples we see that non-face objects with colors similar to skin-color, such as neck, may also be falsely extracted.

Using only color information, it is not possible to separate completely the true face regions from regions similar to skin color. However, we have shown that our method can

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be a efficient step in localizing candidate face regions in a face detection technique. The following values are measured during face segmentation and detection process for each tested image:

bmean = 124.6176, rmean =133.9366,
brcov = 55.7994 -47.6583 -47.6583 117.4705,
where bmean= maen value of blue color in image pixels,
rmean= maen value of red color in image pixels,
brcov= convolution value of red color in image pixels

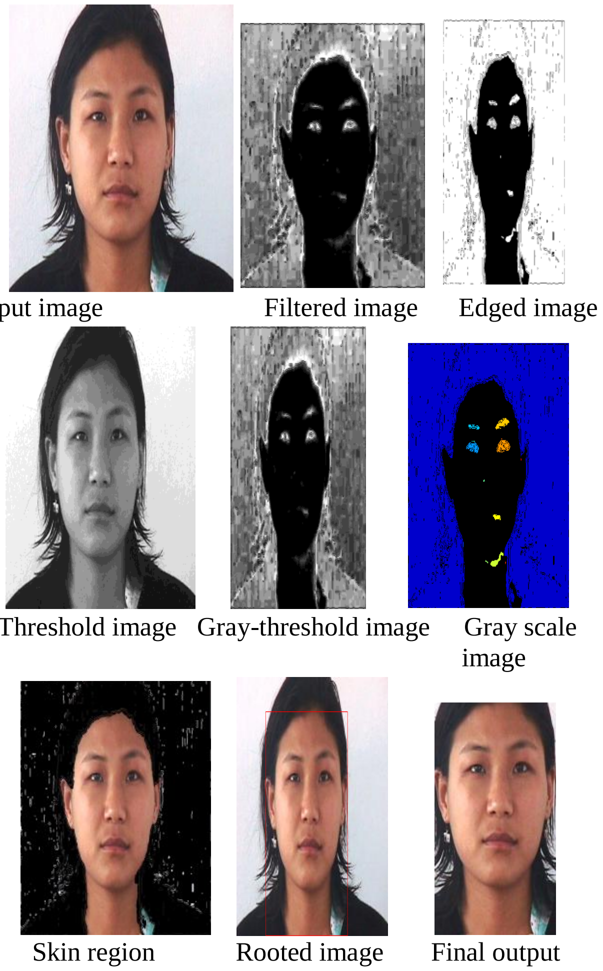

Figure7.1: Execution process of input image for face detection

Where ri=Rand index, gce=Global consistency error, vi-Variation of information, mse= Mean square error, y=Peak signal to noise ratio. The above table shows the results of different parameters of face detection and edge detection to illustrate the consistency and quality of detected face region. Also the elapsed time for face detection of different training images is around average between 15 -16 seconds, which is very less.

Hence, we can say that the applied approach can detect the Human face region very fastly because the previous techniques takes around 25-34 seconds in face detection as well as here we use only YCbCr color space, which shows that the applied approach takes less memory space.

The false acceptance rate (FAR) for the above database with 45 images is 82.22% and false rejection rate (FRR) is 17.78%.Hence, above system is much more efficient for the face detection then other techniques added earlier.
The graph for different evaluation parameters of the above training images are as follows:

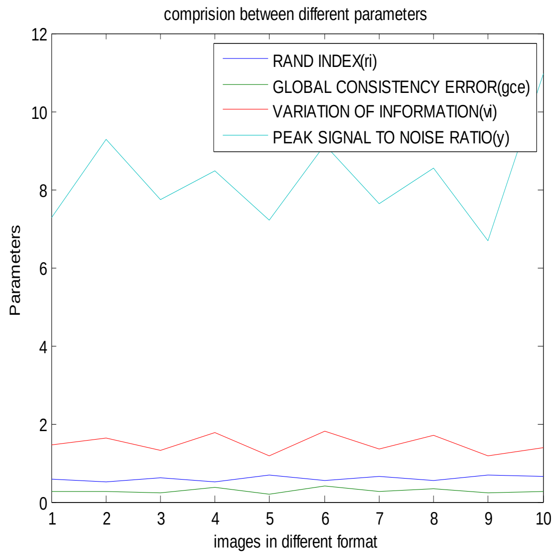

Figure 7.2: Graph for Comparison b/w ri, gce, vi, psnr

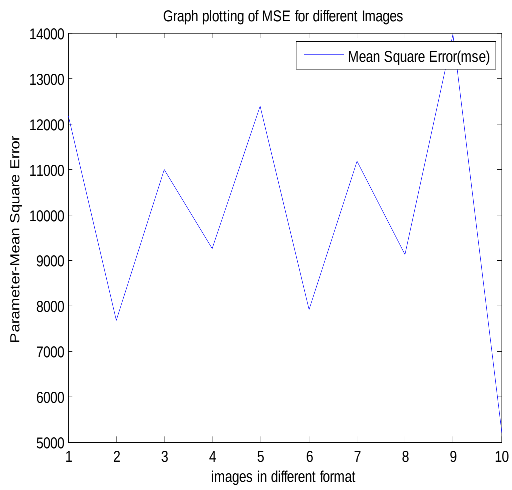

Figure 7.3: Graph for Mean Square Error

VIII. CONCLUSION

Face detection using color information usually consists of two main steps: localization of candidate face regions and validation of the face hypothesis using some additional information about face structure. We have proposed a approach to extract efficiently candidate face regions in images with varying lighting condition and in presence of complex background, with people of different ethnicities and with several persons contained within the image. While gaussian fitted skin color model and hard thresholding usually fail to extract completely skin regions in complex illumination conditions, our approach manages to detect skin regions on the entire face. Furthermore, while other GMM-based methods use skin-color segmentation with a unique threshold value defined arbitrarily, we compute automatically and adaptively the threshold value for each of the component of our model. This makes our approach more effective to process a large range of environmental variations in images. The next step in our research is the detection of facial features and the use of additional information about face structure to validate or reject the candidate regions and build a complete face detection system.

Face detection is challenging and interesting problem of itself, but significant progress has been made in the last three decades, there is still work to be done, and we believe that a robust face detection system should be effective under full variation in:

- Variant lighting conditions,
- Orientation, poses, and partial occlusion
- Facial expressions, and presence of glasses, facial hair, and a variety of hair styles.

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