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Segmentation Algorithm for Multiple Face Detection in Color Images with Skin Tone Regions using Color Spaces and Edge Detection Techniques

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***Abstract*—In this paper, an improved segmentation algorithm for face detection in color images with multiple faces and skin tone regions is proposed. Algorithm ingeniously combines different color space models, specifically, HSI and YCbCr along with Canny and Prewitt edge detection techniques. Improvement over previous approaches by other researchers is demonstrated using example images where segmentation stage is critical for face detection.**

***Index Terms*—skin-tone, canny edge, detection, color models, face.**

I. Introduction

Face detection and localization is the task of checking whether the given input image contains any human face, and if so, returning the location of the human face in the image. The wide variety of applications and the difficulty of face detection have made it an interesting problem for the researchers in recent years. Face detection is difficult mainly due to a large component of non-rigidity and textural differences among faces. The great challenge for the face detection problem is the large number of factors that govern the problem space [9]. The long list of these factors include the pose, orientation, facial expressions, facial sizes found in the image, luminance conditions, occlusion, structural components, gender, ethnicity of the subject, the scene and complexity of image's background. The scene in which the face is placed ranges from a simple uniform background to highly complex backgrounds. In the latter case it is obviously more difficult to detect a face. Faces appear totally different under different lighting conditions. Not only do different persons have different sized faces, faces closer to the camera appear larger than faces that are far away from the camera. A thorough survey of face detection research work is available in [9]. In terms of applications, face detection is quite important for the face recognition problem, as a pre-processing step. Face detection is the first step in online face recognition. Apart from this face detection also has potential applications in

- Human-Computer Interface,
- Surveillance Systems
- Content Based Image Retrieval.

Typical face detection is as shown in "Fig. 1a" and "Fig. 1b".

II. Segmentation

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 colour is considered. Precise segmentation of the input image is the most important step that contributes to the efficient detection and localization of multiple faces in skin tone colour images.

Figure 1a. Input image

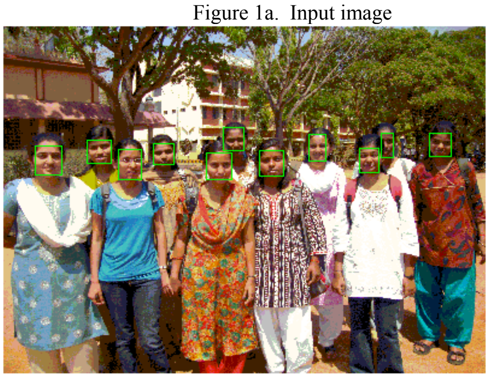

Figure 1b. Image with detected faces

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Segmentation of the input image based on skin chromaticity is the first step in detecting and localizing faces in color images. Segmentation of an image based on human skin chromaticity using different colour 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 colour segmentation used for detection [2].

B. Skin Pixel Classification.

As skin colour pixels play an important role in detecting faces in colour images, skin chromaticity values of different colour 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.

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 colour images having complex scenes [1], 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. Colour Spaces

For skin based face detection many color spaces have been proposed throughout the literature. Some popular examples of color spaces are: RGB, Normalized RGB, YCbCr (YUV), HSI (Hue, Saturation and Intensity) as well as many others. A thorough survey of different colour space is carried out by Veznevets et.al.[8]. HSV and YCbCr colour spaces help to a greater extent in handling intensity variations. As there is distribution of skin colour across different ethnic groups, a robust method to extract chromaticity values associated with the skin tone using statistical approaches is interesting.

A change in light source distribution can cause a significant change in the appearance of the face image. Which color space is the best for skin color segmentation is still subject to discussion. The transformation simplicity and explicit separation of luminance and chrominance components make YCbCr colour space very popular. The simplest model is to define a region of skin tone pixels using Cr;Cb values, from samples of skin color pixels. With carefully chosen thresholds, [Cr1; Cr2] and [Cb1; Cb2], a pixel is classified to have skin tone if the chromaticity values (Cr;Cb) fall within the ranges, i.e., $Cr1 \leq Cr \leq Cr2$ and $Cb1 \leq Cb \leq Cb2$. The separation between skin and non-skin colors depends on the chosen color model. The color of objects and scenes change dramatically when placed under different lighting condition. "Fig. 2" shows the human skin chromatic distribution. Besides YCbCr , HSI and TSL (Tint, Saturation, Lightness), several other linear transformations of the RGB space are employed for skin detection.

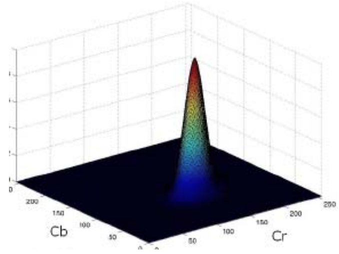

Figure 2. The human skin chromatic distribution

III. EDGE DETECTION

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Edges characterize boundaries and are therefore a problem of fundamental importance in image processing and an important tool for image segmentation [5]. The concept of edge is highly useful in dealing with regions and boundaries as an edge point is transition in gray level associated with a point with respect to its background. Edges typically occur on the boundary between two regions. The gradient points in the direction of most rapid increase in intensity.

The image gradient is given by

$$\nabla f = \left[\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right]$$

The *edge strength* is given by the gradient magnitude:

$$\|\nabla f\| = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 + \left(\frac{\partial f}{\partial y}\right)^2}$$

The gradient direction is given by:

$$\theta = \tan^{-1}\left(\frac{\partial f}{\partial y} / \frac{\partial f}{\partial x}\right)$$

A. Robert's Cross Edge Detection

The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point. The operator consists of a pair of 2×2 convolution kernels as shown below. One kernel is simply the other rotated by 90°

+1	0
0	-1

0	+1
-1	0

Gx **Gy**

B. Canny Edge Detection

The Canny method finds edges by looking for local maxima of the gradient of image. The gradient is calculated using the derivative of a Gaussian filter. The method uses two thresholds, to detect strong and weak edges, and includes the weak edges in the output only if they are connected to strong edges. This method is therefore less likely than the others to respond to noise, and more likely to detect true weak edges. As canny edges detect weak edges also we are using a combination of Canny and Prewitt to eliminate unwanted weak edges and retain strong boundary edges.

The Canny method applies two thresholds to the gradient: a high threshold for low edge sensitivity and a low threshold for high edge sensitivity. Edge starts with the low sensitivity result and then grows it to include connected edge pixels from the high sensitivity result. This helps fill in gaps in the detected edges.

Canny's edge detection algorithm performs better than other under almost all scenarios and performs well even under noisy conditions [6]. It has been observed that Canny's edge detection algorithm is computationally more expensive compared to LoG(Laplacian of Gaussian), Sobel, Prewitt and Robert's operator. Canny yields thin lines for its edges by using non-maximal suppression [6].

C. Prewitt Edge

Prewitt is used for detecting vertical and horizontal edges in images. It returns edges at those points where the gradient of image is maximum. The kernels used by Prewitt are as shown below.

-1	-1	-1
0	0	0
1	1	1

-1	0	1
-1	0	1
-1	0	1

Gx Gy

IV. Challenges

Several challenges are encountered while segmenting skin-tone images as compared to images with non-skin regions. Segmentation using any one single color space results in mainly two kinds of faulty detections i.e. false detection, where a non-skin region is detected as skin region and failed detection, where an actual skin region goes undetected by the algorithm.

"Fig. 3a", "Fig. 3b", "Fig. 3c" & "Fig. 4a", "Fig. 4b", "Fig. 4c" demonstrate these issues. Some regions which are segmented as skin region in HSI color space ("Fig. 3c", "Fig. 4c") are not segmented as skin regions in YCbCr colour space and vice-versa (Figure 3-c, 4-c). Hence use of combination of colour spaces to overcome such problems is the preferred approach.

Figure 3a Input image

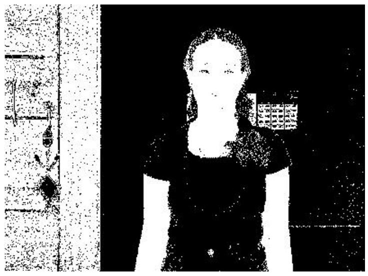

Figure 3b Segmented regions using HSI colour space

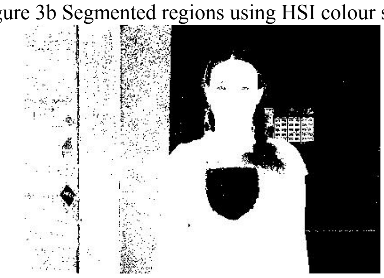

Figure 3c Segmented regions using YCbCr colour space

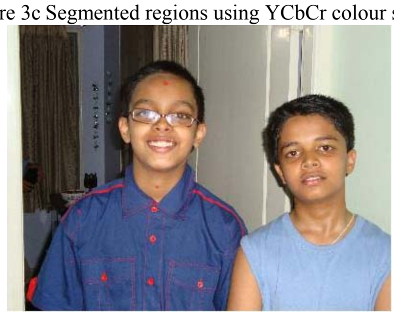

Figure 4a Input image

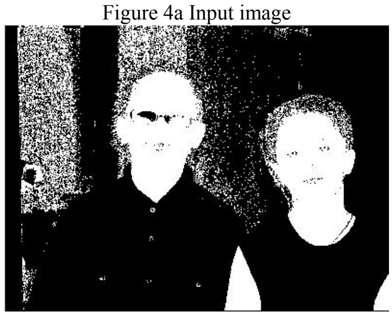

Figure 4b Segmented image using HSI colour space

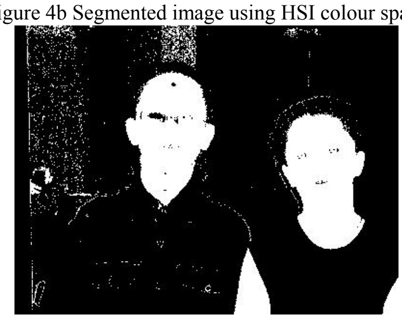

Figure 4c Segmented image using YCbCr colour space

Most of the detection algorithms have considered images having non-skin tone background, people wearing non-skin tone dresses etc. If images contain skin tone background, then the entire region is identified as skin region ("Fig. 5a" and "Fig. 5b"). In order to locate faces present in the segmented regions calls for additional face localization process. While segmenting faces of people wearing skin-tone dresses ("Fig. 6a" and "Fig. 6b") using skin pixel segmentation pre-processing technique, the entire image of the person with skin-tone dress is detected as the face region and hence requires a further face localization step. Besides, overlapping face regions also add additional constraints while segmenting the faces. Due to variation in illumination, skin regions may not be properly identified as skin during skin segmentation. Locating faces in these circumstances is more complex as opposed to localising faces with uniform, non skin-tone background.

Figure 5a Input image with skin tone background

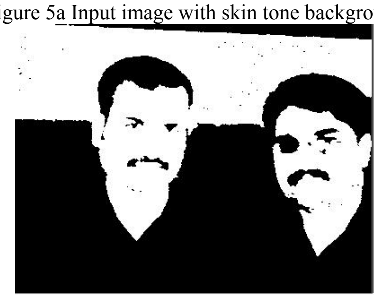

Figure 5b Segmented image using HSI and YCbCr combination

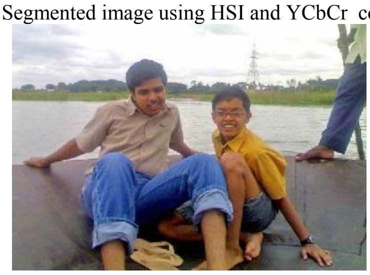

Figure 6a Input image with skin tone dress

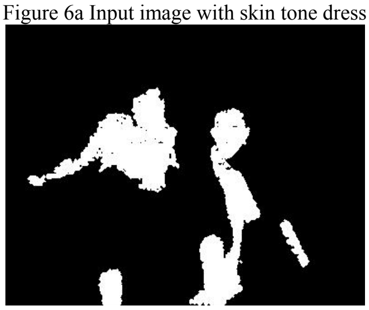

Figure 6b Segmented image using HSI and YCbCr colour space

In spite of using combination of different colour spaces during segmentation, it is tedious to demarcate region boundaries between skin and pseudo skin regions and also eliminate these regions from searching process. The use of colour space alone sometimes fails to segment the boundary regions of the image as shown in the following "Fig 7b".

Input image shown in "Fig 7a" after skin segmentation using single colour space such as YcbCr, results in a skin segmented image as shown in "Fig 7b". It is quite clear from "Fig 7b" that just segmentation based on skin chromaticity is not sufficient to segment image boundaries. In order to demarcate the region boundaries, the skin segmented image is combined with the edges of the input image obtained using Robert cross edge detection algorithm followed by different morphological operations. While performing morphological operations, erosion with structuring element disk with disk radius less than 3 fail to shrink irrelevant details. The use of disk type structuring element with higher radius to separate image component results in thicker edges. These thicker edges pose problems while segmenting faces of people wearing spectacles.

The use of single colour space such as YCbCr for extracting skin regions based on chromaticity combined with edge detected image using Robert cross edge followed by the morphological operations like erosion and immediate operations for extracting image boundaries with structuring element of disk radius 1, results image segmentation as shown in "Fig 7c". From this figure it is quite evident that the structuring element with smaller disk radius fails to close the object boundary correctly. The small openings which are not closed completely fails to segment correctly during connected component analysis. The disk radius is set to 3 in order to close the object boundaries correctly. This results in thicker boundaries as shown in "Fig 7d".

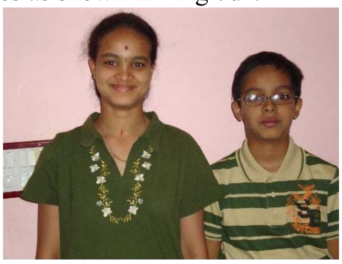

Figure 7a Input image

Figure 7b Segmented Image using YCbCr Colour space

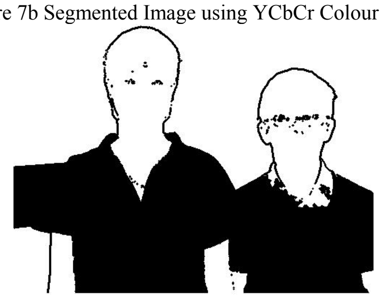

Figure 7c

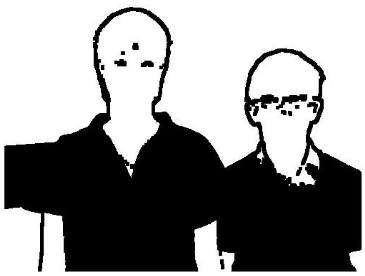

Figure 7d

V. PROPOSED APPROACH

A. Algorithm

In this paper, a combination of colour 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: The input image is skin segmented first using HSI colour space. On this skin segmented regions various morphological operations such as erosion and dilation with suitable structure element is carried out.

Step-2: The input image is also skin segmented using YCbCr colour space. On this skin segmented regions various morphological operations such as erosion and dilation with suitable structure element is carried out.

Step-3: Segmented images obtained in Step-1 and Step-2 is combined into single segmented image. On this image connected component analysis is carried out to obtain a Combined-Segmented image. Regions larger than certain threshold area (in our case greater than 600 pixels), satisfying certain aspect ratio, containing holes are selected.

Step-4 : The input colour 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-5: Region boundaries obtained in step-4 is multiplied with the Combined-Segmented image obtained in Step-3. After performing relevant morphological operations such as erosion and dilations as in Step-3 we get the final segmented image.

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 [3], as even non-face regions can also contain holes located at positions similar to those of facial components like eyes and mouth.

VI. RESULTS

In the proposed method, image boundary generated with structuring element of disk radius 1 using Canny in combination with Prewitt edge detection algorithm results in thinner boundary edges when compared with the boundary generated using Robert Cross edge algorithm with the same structuring element. The details of black and white pixel count for the edge detected images of “Fig 8”,”Fig 9”,Fig 10” using proposed methodology and using YCbCr colour space are tabulated in Table-1.

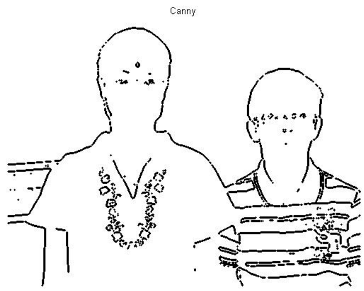

Figure 8a Canny & Prewitt Structuring Element with Disk Radius 1

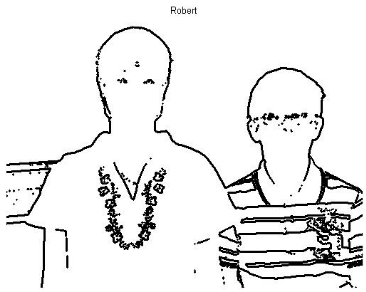

Figure 8b Robert Cross Edge Structuring Element with Disk Radius 1

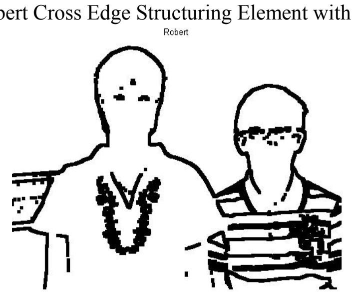

Figure 8c Robert Cross Edge Structuring Element with Disk Radius 3

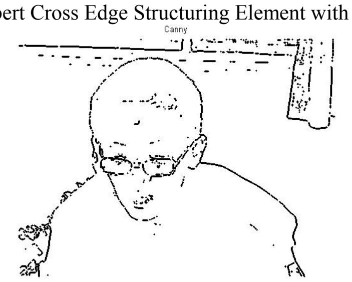

Figure 9a Canny & Prewitt Structuring Element with Disk Radius 1

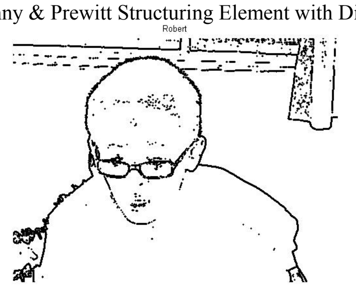

Figure 9b Robert Cross Edge Structuring Element with Disk Radius 1

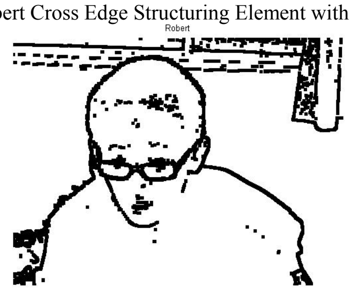

Figure 9c Robert Cross Edge Structuring Element with Disk Radius 3

The segmentation using combination of colour spaces combined with Canny and Prewitt edge detection for obtaining the region boundaries segment better when compared with the combination of YCbCr colour space and Robert Cross edge [4, 7]. If the input image contains multiple faces of different sizes with overlapping faces, proposed segmentation approach segments better as shown in “Fig 11a”, “Fig 11b”, “Fig 11c”. Robert cross edge segments faces of people wearing spectacles into two face partitions as shown in “Fig 12b”, “Fig 12c”, “Fig 13a”, “Fig 13b”. This is because Robert cross edge detection followed by morphological operations like erosion and dilation results in thick edges.

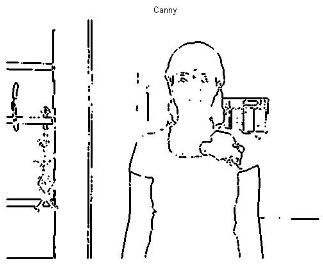

Figure 10a Canny & Prewitt Structuring Element with Disk Radius 1

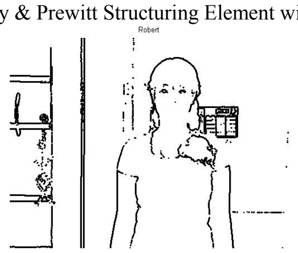

Figure 10b Robert Cross Edge Structuring Element with Disk Radius 1

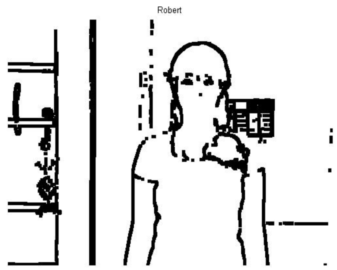

Figure 10c Robert Cross Edge Structuring Element with Disk Radius 3

TABLE 1

Figure	Proposed Method Structuring Element with Disk Radius 1				YcbCr colour space Structuring Element with Disk Radius 3	
	Black Pixel Count		White Pixel Count		Pixel Count	
	Canny	Robert	Canny	Robert	Black	White
8	12976	16838	174524	170662	30874	156626
9	9119	13584	178381	173916	27715	159785
10	10969	13876	176531	173624	25586	161914

Figure 11a Input Image

Figure 11b Segmented using proposed approach

Figure 11c Segmented using YCbCr and Robert edge approach

Figure 12a Input image

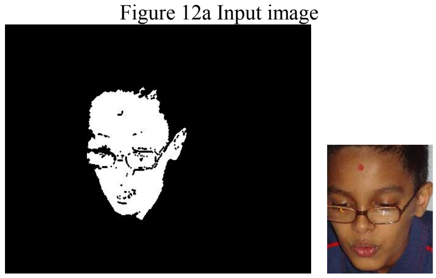

Figure 12b Segmented using proposed approach

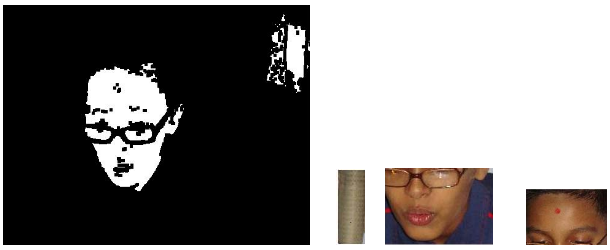

Figure 12c Segmented using YCbCr and Robert edge approach

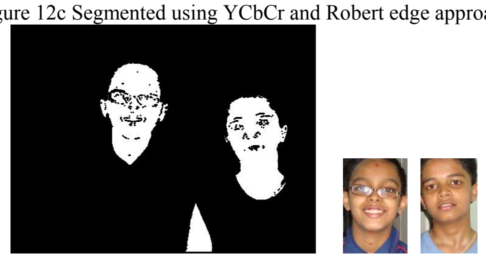

Figure 13a Segmentation of Figure-4a using proposed approach

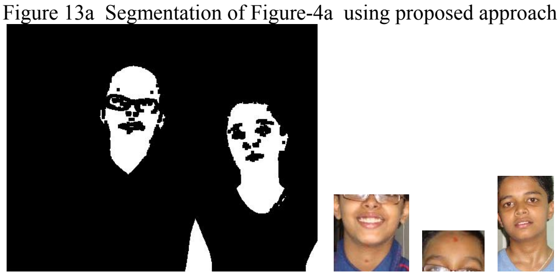

Figure 13b Segmentation of Figure-4a using YCbCr Robert edge approach

Figure 14a Segmented using proposed approach

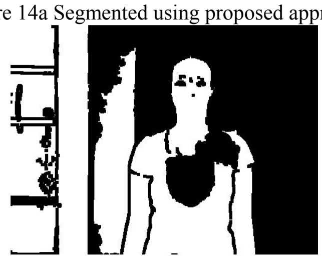

Figure 14b Segmentation of Figure-3a using YCbCr Robert edge approach

VII. Conclusion

In this paper, a segmentation algorithm for face detection in color images with skin tone regions is proposed. It is demonstrated that edge detection when used along with the skin segmentation based on skin chromaticity values from combination of multiple color spaces gives a better segmentation result. Specifically, combination of HSI and YCbCr colour spaces with Canny edge detection algorithm in combination with Prewitt edge detection algorithm is found to segment the input image better when compared to previous attempts by researcher who used single color space in combination with Robert Cross edge technique. The proposed segmentation procedure is found to reduce the search space for face detection step. This is evident from the segmented images "Fig 14a" and "Fig 12b" of respective input images "Fig 3a" and "Fig 12a" using the proposed approach.

References

[1] D. Petrescu and M. Gelgon "Face detection from complex Scenes in colour images" *Eurasip/Proceedings/Eusipco2000.*.

[2] F Fritsch, S Lang, M Kleinehagenbrock, G A Fink and Sagerer, "Improving Adaptive Skin Colour Segmentation by incorporating Results from face detection", *Proceedings of IEEE International workshop on Robot and Human Interactive Communication (ROMAN)*, Berlin , Germany, September 2002.

[3] H.C. Vijaylakshmi, S. PatilKulakarni "Face Localization and Detection Algorithm for Colour Images using Wavelet Approximations " *International Conference ACVIT-09 16th – 19th December 2009, at Aurangabad. India.*

[4] Mohamed A. Berbar Hamdy M. Kelash, and Amany A. Kandeel "Faces and Facial Features Detection in Color Images " Proceedings of the Geometric Modeling and Imaging— New Trends (GMAI'06) 0-7695-2604-7/06

[5] Rafel C. Gonzalez, Richard E Woods "Digital Image processing" Second edition Prentice Hall India.

[6] Raman Maini & Dr. Himanshu Aggarwal "Study and Comparison of Various Image Edge Detection Techniques "International Journal of Image Processing (IJIP), Jan-Feb 2009, Volume (3) Issue (1)pp.1-11.

[7] Son Lam Phung, Abdesselam Bouzerdoum, and Douglas Chai "Skin Segmentation Using Colour and Edge Information" Perth, Western Australia, Australia Proc. Int. Symposium on Signal Processing and its Applications, 1-4 July 2003, Paris, France. 0-7803-7946-2/03

[8] V. Veznevets, V Sazonov, nad A Andreeva, "A survey on pixel-based skin color detection techniques", in *Proceedings Graphicon-2003 pp85-92.*

[9] Y. Ming-Hsuan, D J Kreigman, and N Ahuja, " Detecting Faces in images: a survey" Pattern Analysis and Machine intelligence, IEEE Transactions on Vol 24, pp. 34-58, 2002.Eric