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Skin Segmentation based on Gaussian Model by Combining Color Spaces

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Abstract: This paper proposes a novel idea of combining the color spaces as a pair in getting the improved results in the human skin detection. Skin detection methods that can be used in various applications of image segmentation are evaluated. The performance of the three pixel based classification algorithms are analyzed. The color images of human faces are segmented into skin regions on the basis of piecewise linear decision boundary, Gaussian model to detect human skin regions, and finally, the concept of combinations of two color images are used to configure and analyze the effect of them on the segmentation of human skin regions. The extensive set of experiments is performed over the commonly used face color images using color spaces, namely YCbCr, YUV, YES, YIQ, and XYZ. The color spaces are combined together in using the Gaussian Color Model. The experimental results shows that the method of combining more than one color space with the Gaussian model produces better results than the ordinary skin cluster and Gaussian model with highest skin detection rates of 100%.

Keywords: Linear decision Boundary Classifier, Gaussian Color Model, Skin detection, Color Spaces, Combination of two color spaces.

I. Introduction

For the image segmentation or classification, like detection, tracking, localization, and recognition of human faces in color images, skin detection methods are widely studied. It is also used to find and confirm the location and size of the human face in the digital color image. This technique basically helps to discriminate the skin and non-skin color present in the color image. As the skin color and the shape of human races are different in different regions, the concept of pixel based classification algorithm using color spaces are used based on their luminance and chrominance information. Convention of color is the most fundamental step in detecting human skin segmented region as it helps to differentiate the human skin region from the relatively complex background, and other objects present in the sample image. The color in the digital color image is represented by the brightness values of the color components of the RGB color space. As the lighting conditions or illumination conditions change, the brightness values get affected [1]. The information of brightness values of color components are used with different classification algorithm to get the binary images for the extensive set of the sample images considered.

The concept of piecewise linear decision boundary algorithm is used to detect the binary segmented region of the color images. According to this algorithm, each pixel of the image is taken one at a time sequentially, independently, and individually to detect whether it is skin or non-skin pixel. Each pixel is processed to compare it with the threshold values explicitly specified for each color space to detect skin region, if the value of pixel falls in the range of the threshold values then the pixel is considered as skin pixel, else non-skin pixels. The threshold is determined by observing the extensive set of sample images that explicitly defines the cluster of skin which is further called as skin locus for the respective color space [1]. The whole set of sampled images are reconsidered to yield binary segmented image using the Gaussian model with the information of brightness of the color spaces individually. This model basically operates on the color space chrominance plane, ignoring the luminance information [11]. It describes the probability of the pixel of the sampled image belonging to skin. The consideration of combinations of color spaces are used to configure and analyze the effect of it on the detection of skin segmented region using Gaussian color model. The impression of comparison of different color spaces using different methods are dealt with in [2].

The rest of the paper is arranged as follows: Section 2 focuses on the work related to the color spaces and classification algorithms. The methods used in this paper along with the information of color spaces are elaborated in Section 3 and how they are used to detect the skin segmented region are presented. Section 4 deals with the analysis and comparison of the experimental results obtained by using the three skin classification algorithms. Finally, the last section concludes about the paper.

II. Related Work

The concept of combination of color spaces to detect skin areas are presented by Wang et al. [3] and then compare the results with the color spaces used. The color spaces taken into account are commonly used by most of the researchers in the applications of image processing. Skin detection methods are widely affected by the brightness values of color images so various color spaces are used to detect the skin region effectively. Color spaces considered in this paper are YCbCr [8], [12], YUV [5], [9], YES [6], YIQ [9], [10], and XYZ [7]. The methods tested in this paper are only based on the information obtained from the pixels of the sampled color images. Piecewise linear decision boundary method is used for the long period of time in the detection of skin regions [13] because of its simplicity to implement, whereas the Gaussian model [14] is required for the compact representation of skin model for certain applications of image processing. Vladimir et al. [11] has discussed several methods of skin detection in their paper in which explicitly defined skin region and Gaussian model are included. Like Nada et al. [12] proposed an adaptive skin modeling and detection technique based on face skin tone color, this paper basically considers the skin tone color of human faces to segment the sampled images into binary images.

III. Proposed System

The crucial idea of the segmentation of skin region is to make a clear segregation between skin and non-skin regions, thus different methods are presented using traditional color spaces. The skin detection methods used are based on the pixel based classification algorithms. They can be classified into two categories: explicitly defined skin region and parametric methods. The first method falls into former category whereas the rest of the two falls into the latter category. Explicitly defined skin region method defines number of rules that will explicitly make the boundaries of skin cluster in color spaces. The color spaces discussed in this paper are commonly used in the applications of computer vision. A parametric skin-color model has a specific functional form with adjustable parameters chosen to fit the model to the sample set [14].

A. Piecewise Linear Decision Boundary Approach

This approach deals with the classification of pixels into skin and non-skin based on the information of the brightness value of the color images, if the value falls in the range of skin color cluster which is explicitly defined by observing the sample images, then the pixel is considered as skin pixel, otherwise non-skin pixel. As different color spaces have different range that shows the skin color cluster, thus explicitly defined range for each color spaces varies. This approach is effectively used as it is simple and easy to implement and having fast computational speed.

In this approach, a series of rules can be applied on the color components of the color space to obtain skin pixel in color images. The chroma components of this YCbCr color space are capable of discriminating skin and non-skin pixels very efficiently as there are a clear separation between luminance and chrominance components. The rule that is experimentally obtained by examining the sampled images to separate skin and non-skin regions are as follows [8] [12]:

$$85 < Cb < 135, 135 < Cr < 180, \text{ and } Y > 80 \quad (1)$$

The skin color is only clustered in some small areas of color space. This method helps to determine that small areas to segregate the skin and non-skin region from each other. YUV color space is basically employed for digital video. Variations appear in skin color is due to variations in brightness values not the color. The chromaticity information of the color information is stored in U and V components. The rules that help to cluster the skin color in YUV color space are as follows [5] [9]:

$$75 < U < 200, 30 < V < 110 \quad (2)$$

The major advantages of YES color space is that it can reduce variations in chrominance due to changes in luminance and it can be efficiently computed from RGB components by shifting bits rather than multiplication. It is free of singularities [6]. The inequalities that help to determine the skin color cluster of YES color space are as follows:

$$Y > 80, \text{ and } E > 167 \quad (3)$$

YIQ color space is basically used for human perception as human vision is more sensitive to changes in luminance. I and Q color components carry more information as compared to luminance component Y. The area that surrounds the skin color cluster can be determined by following rules [9] [10]:

$$110 < I < 170, \text{ and } 75 < Q < 200 \quad (4)$$

The advantage of this method is to construct a classifier that can rapidly discriminate skin and non-skin regions of human faces in color images. The rules that can help to make the discrimination using XYZ color space are defined as follows [7]:

$$125 < Y < 220, 40 < Z < 175 \quad (5)$$

B. Gaussian Model

This method falls into the category of parametric method that follows machine learning approaches. According to this approach, the skin detector is trained by using training set to solve the skin detection problem. The motive of the method is to calculate the probability that a pixel of the color image with the color be a skin pixel. This probability is used to create the skin likelihood image of the sample image. Using the threshold technique, the skin probability map can be easily converted into the binary map. The threshold technique specifies that if the pixel values are greater than the applied threshold then they are considered as skin pixels and others are considered as non-skin pixels [4]. The general form of Gaussian model [14] is given below:

$$p(c|s) = (2\pi)^{-d/2} |\Sigma_s|^{-1/2} e^{-\frac{1}{2}(c-\mu_s)^T \Sigma_s^{-1}(c-\mu_s)} \quad (6)$$

Here, c represents the color vector, and d is their dimensions. μ_s represents the mean vector, and Σ_s represents the covariance matrix of the skin class.

C. Combination of Two Color Spaces

In this approach, one color space is combined with another color space to analyze their effect on the detection of skin region in terms of metrics of the skin detection. This method follows the steps of Gaussian model with the two color spaces individually. The advantage of using Gaussian model is its generality and interpolating capability to stimulate the development of skin distribution model for the training data [11]. After getting the binary images with different color spaces, they are combined using AND operator to yield the final binary segmented image, and compared it with the binary segmented image of the involved color spaces respectively.

IV. Experimental Results and Discussions

The algorithms discussed here are trained by using commonly used face databases containing images having single human face. The images are downloaded from the web services. The selected images were included extensive variety of skin tones of human skin. The metrics that were used to ascertain the accuracy of skin segmentation are faithful rate, false acceptance, and false rejection. The faithful rate is ratio of the number of correctly identified human skin images to the total number of actual images used. The false acceptance ratio is the ratio of the number of images in which non-skin pixels accepted as skin pixels to the total number of actual images used. The false rejection ratio is the ratio of the number of images in which skin pixels are rejected by considering it as non-skin pixels to the total number of actual images used.

The methods are considered for skin detection with their utmost accuracy. The piecewise linear decision boundary method is easy to implement and produce the result but does not produce good accuracy with the varying lighting conditions. In the presence of the normal lighting conditions it has produced acceptable results which are shown in table I.

Table 1 Metrics obtained by using Piecewise Linear Decision Boundary Approach

S. No.	Name of the Color Space	Percentage of faithful rate	False Acceptance	False Rejection
1.	YCbCr	96	0.04	0.00
2.	YUV	96	0.04	0.04
3.	YES	96	0.06	0.00
4.	YIQ	96	0.09	0.02
5.	XYZ	80	0.09	0.15

Using of large number of facial images from different databases, the threshold boundary of each color spaces has required changes each and every time. This may need much time for detecting skin regions of the respective images. But this constraint does not come in the Gaussian model. The false acceptance and false rejection rates interprets that the brightness values of some objects appear in the sample image falls into the range of skin color explicitly defined by the method. YCbCr color space produce better results in terms of all the metrics. All of the color spaces produce better results in the classification of skin and non-skin regions except for XYZ color space.

The graphical representation of false acceptance and false rejection rates are shown in figure 1 and the sample images along with their corresponding binary segmented images are shown in figure 2. By seeing the graph, the rate of false acceptance and false rejection of each color spaces can be easily compared among them.

Figure 1 Graphical representation of false acceptance and false rejection over color spaces using piecewise linear decision boundary classifier method.

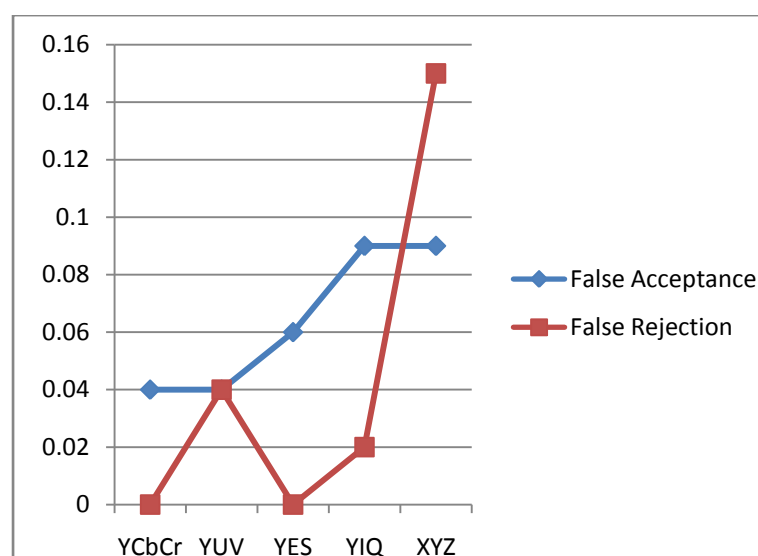
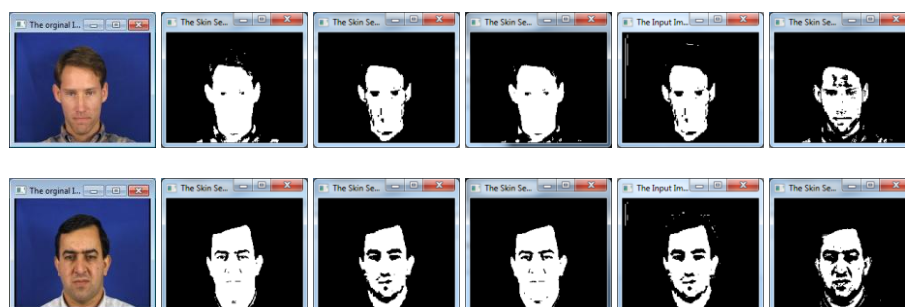


Figure 2 Sample images with their corresponding binary images using YCbCr, YUV, YES, YIQ, and XYZ color spaces based on Piecewise Linear decision Boundary Approach

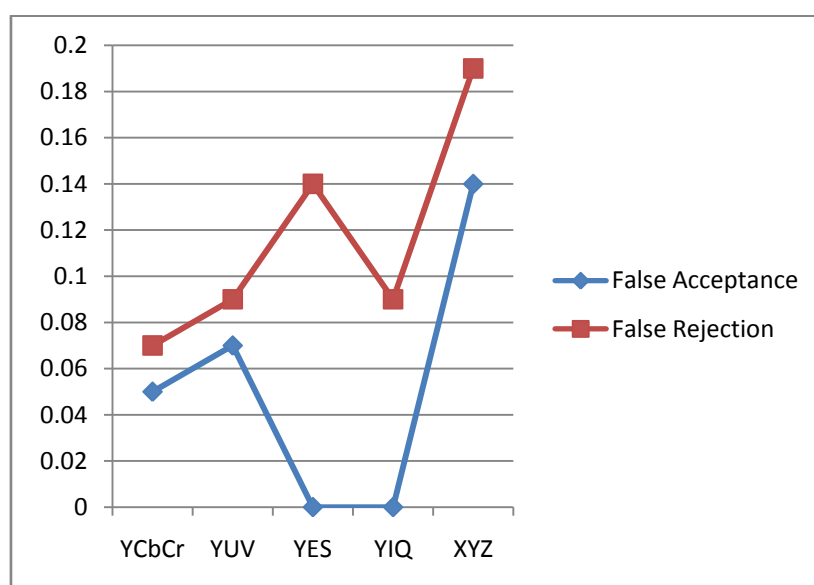


The images were stored in various formats based on the color spaces and can be reconsidered for testing the effect of the second method. Here, images were segmented into binary images based on their skin probability maps yielded. Some of the researchers have used RGB, YCbCr and Normalized rgb color space with the Gaussian color model. In addition the color spaces YIQ, YES and XYZ have not been used by the other researches and a comparative analysis is made by using the color spaces. The analysis on the color spaces made using Gaussian model are shown in table II. Fig. 3 shows the graph for false acceptance and false rejection ratios. The results have yielded using this method and the binary segmented image along with the skin likelihood image of the corresponding used sampled images in figure 2 are shown in figure 5. By seeing the graph, the rate of false acceptance and false rejection of each color spaces can be easily compared among them. Now, the last method is under consideration for the analysis from the experimental perception. The hypothesis of combination of two color spaces are taken to improve the detection of skin and non-skin pixels from the training data on the basis of information of skin probability map obtained by the two color spaces involved in the combination. The different possible combination of five color spaces are shown in table 3 along with the outputs of metrics yielded during examination moment. The concept is diagrammatically shown in fig. 4 and the graphical representation of metrics is shown in fig. 6. By seeing the graph, the rate of false acceptance and false rejection of each combination can be easily compared.

Table 2 Metrics obtained by using Gaussian Model

S.No.	Name of the Color Space	Percentage of faithful rate	False Acceptance	False Rejection
1.	YCbCr	96	0.05	0.07
2.	YUV	93	0.07	0.09
3.	YES	86	0.0	0.14
4.	YIQ	96	0.0	0.09
5.	XYZ	73	0.14	0.19

Figure 3 Graphical representation of false acceptance and false rejection over color spaces using Gaussian model.



The combination of YIQ and YUV color spaces produce the excellent result in the environment of the metrics of the skin detection methods. The diagrammatic representation of result is shown in figure 4. As the figure clearly shows the detection of cloth and hair as skin pixels by YIQ color space is overcome after combining it with the YUV color space and the detection of facial features are also clearly shown which is not effectively detected by the YUV color space.

Figure 4 Sample image with their corresponding binary images using combination of two color spaces (YUV + YIQ)

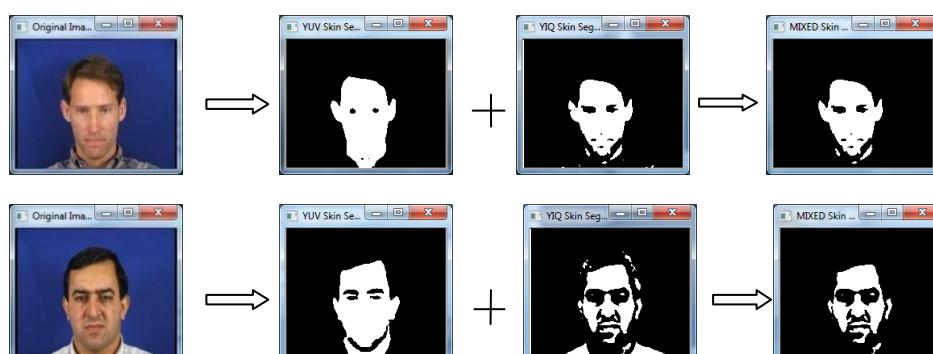


Figure 5 Sampled image with their corresponding binary images using (a) YCbCr, (b) YUV, (c) YES, (d) YIQ, and (e) XYZ color spaces

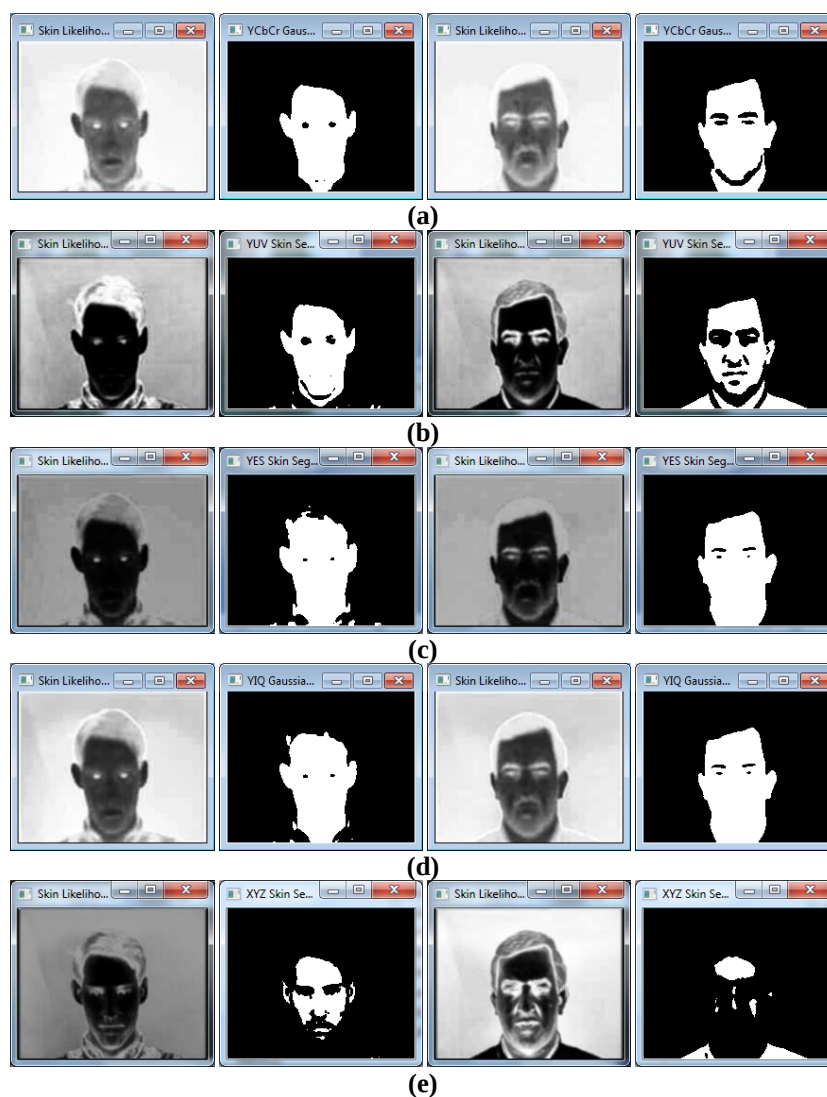


Figure 6 Graphical representation of false acceptance and false rejection rates of color spaces using Gaussian model for combinations of two color spaces.

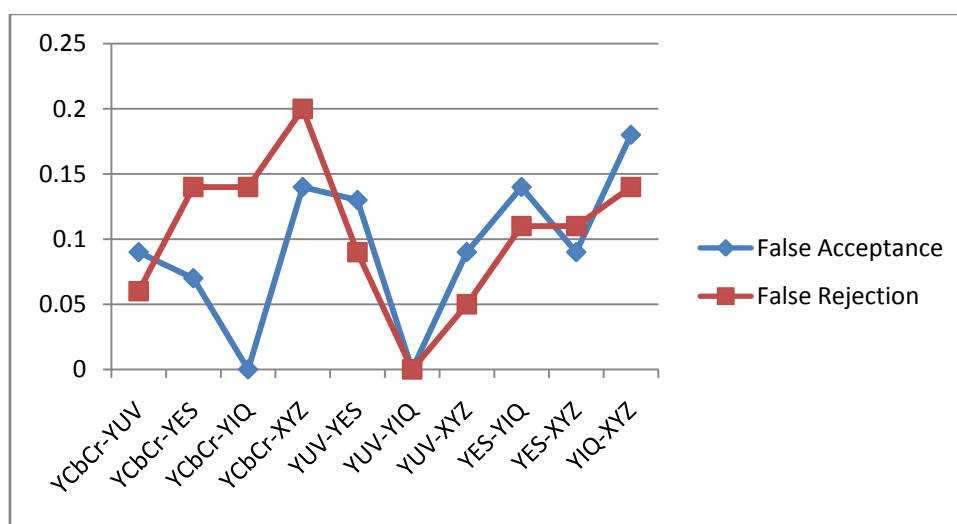


Table 3 Metrics obtained by using Gaussian model for the combination of two color spaces

S. No.	Name of the Color Space	Percentage of faithful rate	False Acceptance	False Rejection
1.	YCbCr-YUV	96	0.09	0.06
2.	YCbCr-YES	86	0.07	0.14
3.	YCbCr-YIQ	80	0.09	0.14
4.	YCbCr-XYZ	77	0.14	0.2
5.	YUV-YES	91	0.13	0.09
6.	YUV-YIQ	100	0.00	0.00
7.	YUV-XYZ	96	0.09	0.05
8.	YES-YIQ	89	0.14	0.11
9.	YES-XYZ	86	0.09	0.11
10.	YIQ-XYZ	91	0.18	0.14

Some more results related to each color combination with their intermediate binary images are also shown in figure 7 and 8. The combination of each color spaces with other ones shows their own effective role in the detection process of human skin region in color images. They can be considered in future work of the applications of computer vision.

Figure 7 Combination of two color spaces with their corresponding binary images

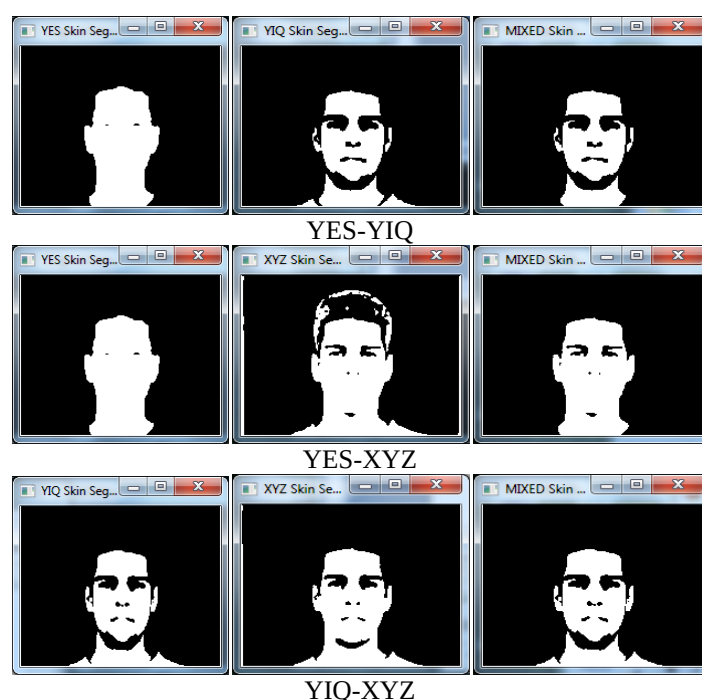
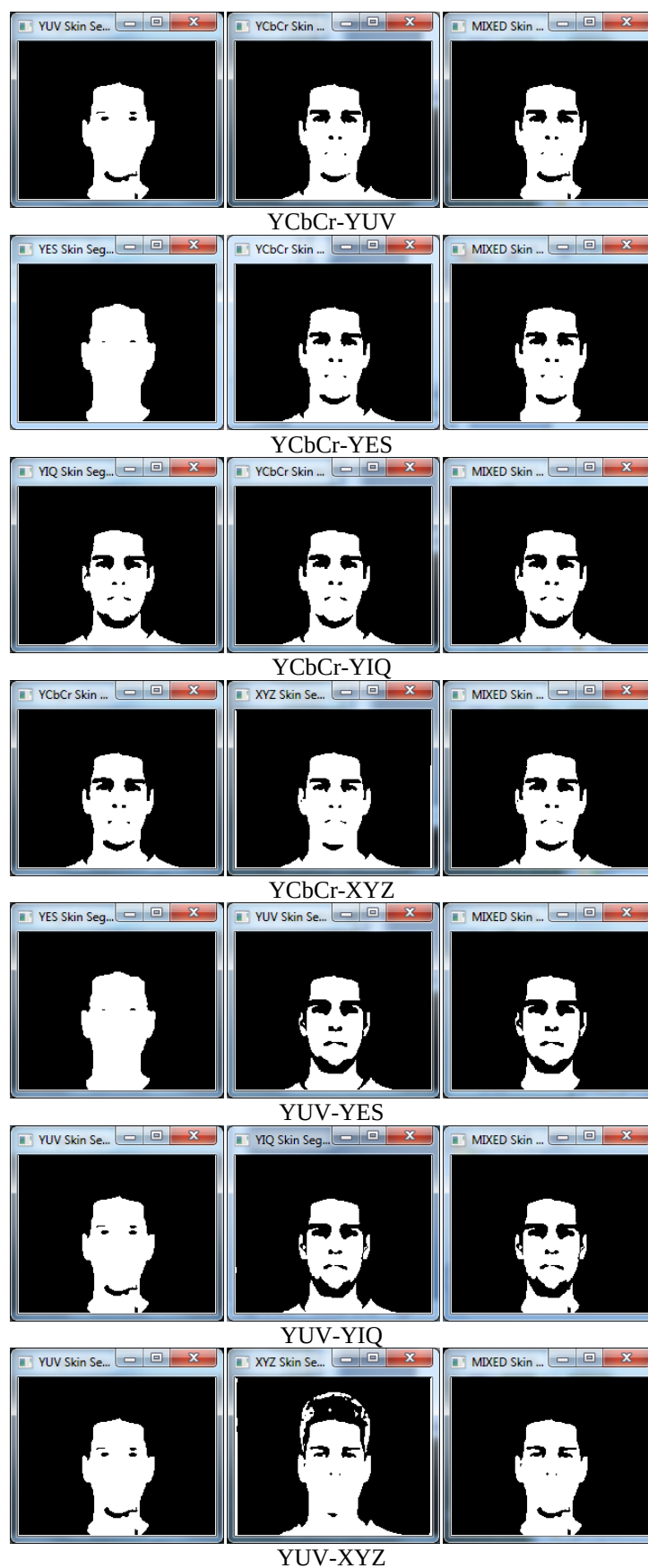


Figure 8 Continuation of figure 7



V. Conclusion

Detection of skin regions are carried out by using three different classification algorithms over the commonly used color spaces, namely YCbCr, YUV, YES, YIQ, and XYZ. The piecewise and Gaussian model has yielded 96% highest detection rate whereas the third method has yielded 100% detection rate. The combination of YIQ-YUV has clearly identified the skin and non-skin pixels in the sampled images by overcoming the obstacle occurred by them individually.

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