



Human Skin Detection using Combination of Color Spaces in Color Images

¹Dr. Ravi Subban, IEEE Member, and ¹Richa Mishra, Research Scholar

¹Department of Computer Science

Pondicherry University

Puducherry

India

Abstract: Enhancing the performance of human face detection, tracking and recognition has been done by skin detection considering it as the fundamental step for the several decades. Of the evolved skin detection techniques, skin cluster classifier based on the human skin tone color are considered along with the concept of combination of two color spaces. This paper presents a novel method of combining more than one color space for human skin segmentation based on the piecewise linear decision boundary classifier and provides an analogous study on the use of color spaces for the segmentation of human skin regions under inconsistent illumination conditions, basically altering skin tone color and varying lighting conditions. The color spaces that are used for this study are: HSV, HSL, LMS, LSLM, XYZ, XyEz, YCC, YPbPr, and YDbDr. Combinations of two color spaces are used for the analysis of success rate for the human skin detection region. Finally, the comparison is made between single and combinations of color spaces to find out the best possible color space(s) either single or combination of two color spaces that has given clear discrimination between skin and non-skin pixels in color image. The successfulness of the color space(s) or combination of color space(s) depends on the false positive and false negative rate obtained after the extensive experimental evaluation over the commonly used sample face database.

Keywords: Colour Spaces, Combination of two colour spaces, Face detection, Skin cluster classifier, Skin detection.

I. Introduction

Skin detection is one of the two-class classification problems taken as the fundamental step for improving the performance of human face detection, tracking, recognition and other applications of computer vision. The analogous of skin detection totally depends on the appropriateness of the selected color spaces, skin modeling, and the classification of skin and non-skin pixels. Human skin color is one of the unique and distinct colors among all the available colors. Therefore, it is considered for the detection of human face skin region. The primary color space used for the computer vision is RGB. It has been commonly used for skin detection under static conditions but under altering illumination conditions, the results have been totally affected due to the delocalization of skin color cluster in its subspace. In order to improve the results under varying illumination conditions, variety of color spaces has been evolved which are obtained by the linear and non-linear transformation of RGB color components, namely YUV, YIQ, YCbCr, HSV, HIS, etc. These color spaces are capable of separating the luminance and chrominance components very effectively in their color subspaces and thus getting less affected by altering lighting conditions.

Some of the color spaces experimented with skin cluster classifier are less in number (Mahmoud et al. 2011; Lei et al. 2011) to the best of our knowledge. The color spaces used with piecewise linear decision approach are: HSV, HSL, LMS, LSLM, XYZ, XyEz, YCC, YPbPr, and YDbDr. Changing lighting conditions and complex backgrounds containing surfaces and objects close to the human skin like color are major problems and limit the skin detection use in practical real-world applications [Yasir et al. 2012]. For solving the above specified challenges, the motive of the research is to analyze the effects of color spaces against diversifying human face skin tone color as well as lighting conditions and to find out which one of the color space has won the task of skin segmentation of human faces effectively in color images. For the comprehensive experiment the whole task is classified into three categories: analysis of single color spaces, analysis of combination of two color spaces, and comparative analysis between these two. In the first category, the effects of single color spaces along with the piecewise linear decision boundary approach are analyzed. After that, all the unique and distinct possible combination of two color spaces is found. The combinations of two color spaces are then experimented with the same skin classifier model taken one at a time, individually and independently as the second category. Finally, comparative analysis is made on the results obtained by the first and second categories and specifies which one of the color space or combination of color spaces has achieved the goal of skin detection. The winner has been selected on the basis of success rate of skin classification as well as on the rate of incorrectly detected or missed skin and non-skin pixels of the human face skin region in color images.

The rest of the paper is organized as follows: Section 2 relates with the work related to the discussed research. Section 3 describes the presented work with the concept of combination of two color spaces and the outputs

obtained by all the possible color spaces are discussed in Section 4. Finally, the conclusion has been made in the last section.

II. Related Work

Selection of skin modeling has been made on the basis of effectiveness of them in the classification of skin and non-skin pixels. Various researchers have evolved and experimented to implement skin segmentation effectively with different techniques namely Gaussian model, Bayesian model, neural network (Wu et al. 2012; Luh 2012), genetic algorithm (Babu et al. 2011), color constancy (Lee et al.), etc. Yasir et al. (2012) has presented a real-time skin region detection method for the detection of region of interest for high resolution video on embedded platforms. Leyuan et al. (2011) have presented a method for skin color detection under rapidly changing illumination conditions using Bayesian decision framework. Skin detection has been used for various applications like face detection, tracking, recognition, etc. Lin et al. 2008 have proposed an improved version of the face detection based on skin color segmentation as well as neural networks. For the verification it has used support vector machine. The concept of color information has been commonly used in face detection (Wang et al. 2012) and other applications of computer vision. Xiahua Wang et al. (2011) has proposed a skin detection technique using combination of RGB and YCbCr color space and then has used the texture information to detect skin areas.

III. Presented Work

The effects of the color spaces with the skin cluster classifier on the segmentation of human face skin region in color images have been presented. Skin classifiers are responsible for labeling the pixel whether it is skin pixel or a non-skin pixel. Piecewise linear decision boundary approach is used for human skin classification. This approach explicitly defines a decision boundary(s) of the human skin color class in the subspace of color space based on the set of sample images used for training of skin-colored and non-skin colored pixels. First, the color spaces with skin cluster approach are used individually and independently to find the skin cluster range of them under varying conditions. From the variety of families of color spaces, two or three color spaces have been selected from each one. For finding the appropriate range, number of iterations is performed on the training database containing images of different skin races as well as lighting conditions. The color space descriptions with the experimentally obtained decision boundary are discussed below:

A. HSV

This is one of the perceptual color spaces, popularly used for skin detection as well as for the human perception. It is made up of three components: the hue H, the saturation S, and the brightness V. It is obtained by the non-linear transformation of RGB color space. The purpose of using this color space is that it allows users to intuitively specify the boundaries of the skin tone color class in terms of hue and saturation. The brightness component is very much affected by varying lighting conditions and thus dropping this helps to reduce the illumination dependency of skin color. The decision boundaries obtained by using the training database are as follows:

$$0 < H < 40, 0.27 < S < 0.6, 0.4 < V < 1 \quad (1)$$

B. HSL

This color space belongs to the family of HSV color space. The properties of both the color spaces are the same except the brightness component. The skin cluster obtained by extensive iterations is given as follows:

$$H < 38, S > 0.25, L > 0.55 \quad (2)$$

C. LMS

It is commonly used when performing chromatic adaptation i.e. estimating the appearance of a sample under a different illuminant. It is represented as the response of three types of cones of the human eye, and is further named based on their sensitivity at long, medium and short wavelengths. The cluster having skin tone color is experimentally bounded by the following boundaries:

$$L < 210, M > 115, R > 178 \quad (3)$$

D. LSLM

This color space belongs to the family of LMS color space. The experimentally obtained skin cluster boundaries are given as follows:

$$65 < L < 240, 85 < LM < 220 \quad (4)$$

E. XYZ

Using the skin cluster classifier the threshold boundaries are experimentally obtained as follows:

$$67 < Y < 220, 120 < X < 225 \quad (5)$$

F. XYEz

The XYZ and XYEz belong to the same family. The skin cluster obtained by using the trained image set at the time of experiment is as follows:

$$X > 120, Y > 110, Ez < 180 \quad (6)$$

G. YCC

This color space is basically used in digital photography video and belongs to the YCbCr color space. The clustering of skin tone color has been obtained by the successive iterations of experiment and is given as follows:

$$Y > 55, C1 > 85, C2 > 145 \quad (7)$$

H. YDbDr

This color space is used in the analog terrestrial color television broadcasting standard. Db and Dr are the chrominance components that are representing red and blue color differences. The experimentally obtained skin tone color cluster boundaries are shown as follows:

$$115 < Db < 240, 85 < Dr < 180 \quad (8)$$

I. YPbPr

This color space is used in the video electronics. It is the analog version of YCbCr color space as it is used in the analog systems whereas YCbCr is intended for digital video. The explicitly trained thresholds are as follows:

$$Y > 125, Pb > 25, Pr > 13 \quad (9)$$

J. Combination of color spaces

The purpose of the combinations is to enhance the performance of skin detection rates under unconstrained situations like illumination conditions, different skin races. The combinations may or may not have the capability to overcome or override some of the challenges that have faced at the time of execution of color spaces individually and independently. The combinations of two color spaces with the explicitly defined, successively trained and experimented threshold values are defined as shown the table II. The training set contains sort of images of different human skin races as well as under varying illumination conditions.

IV. Experimental Results and Discussions

Single color space will be in general used for skin detection using skin cluster method. In this paper some color space are used individually and as a combination of two color spaces using the skin cluster method. The researcher will try to use two color spaces using a combination of two colors. But a large number of two color combinations have used for skin detection. The color spaces like XYZ, XYEz, YCC, YPbPr, and YDbDr are not used by any of the researchers in past. That is the novel idea tried in this paper. The whole experiment is concise on the determination of the accurate classification of skin and non-skin pixels in images using skin classifiers. The accurateness refers the finding of appropriate upper and lower bound of color components which are invariant with the varying lighting and skin-tone races of human faces. The chrominance components of each color spaces are only considered for the execution process as the luminance component is greatly affected by changing the lighting conditions. At the time of execution of the experiment, some errors occur due to the different illumination conditions. These errors are named as false positive and false negative. False positive refers to the incorrectly identified non-skin pixels as skin pixels. False negative refers to the images that have been mistakenly identified skin pixels as non-skin pixels.

The experiment is started with the implementation of color spaces using piecewise linear decision boundary approach individually and independently. For the sake of the simplicity in the description of yielded results by the variety of color spaces, the whole experiment is discussed in following order: outputs obtained by single color spaces, outputs obtained by the combination of color spaces, and a comparative analysis on the results of single and combination of color spaces. The observation is commenced with the analysis of color spaces individually and independently taken one at a time. HSV and HSL color spaces are commonly used for human perception as it produces good results for the extraction of human facial features. The experimental output has proven this fact by yielding the separation between skin and non-skin pixels with the clear appearance of facial features. The outputs obtained by both the color spaces are shown in figure 1(i) and the rates of skin classifiers are also described in the table I. HSV and HSL have produced good results under varying illumination conditions but still some incorrectly and mistakenly identified pixels are detected. Unlike HSL, HSV has pleasantly identified skin and non-skin pixels with less rate of false positive and false negative in images having different skin races and lighting appearance.

LMS color space is very much affected by changing the lighting conditions only. It has produced good result for different races of human face skin color. The challenges it has mainly faced because of the complex background, skin-like appearances, etc. Unlike LMS, LSLM color space has produced better results under both

Table I Skin Classifier Rates of Single Colour Spaces

Name of the colour spaces	Percentage of Success Rate	False Positive Rate	False Negative Rate
HSV	96	0.05	0.02
HSL	98	0.07	0.16
LMS	96	0.2	0.11
LSLM	91	0.18	0.11
XYZ	77	0.2	0.1
XYEz	82	0.2	0.18
YCC	96	0.05	0.00
YDbDr	77	0.18	0.07
YPbPr	96	0.05	0.05

varying lighting conditions as well as different races of people. The challenges it has faced are just because of the presence of complex background.

XYZ has not produced the results up to the above discussed color spaces accuracies. The results obtained by using this color space get affected by skin-like appearance present in the background, clothes, hair, etc. Like XYZ, XYEz color space has very much affected the skin detection process for skin-like appearance as well as lighting variations.

YPbPr and YCC have produced better results in both the specified conditions. Unlike YPbPr, YCC color space has not faced challenges in the identification of skin as non-skin pixels in images. YDbDr has not produced good results as compared to these twos. It is also affected by the textures present in the images. After completing the extensive analysis of all the single color spaces, the conclusion has been made that the YCC color space has produced better result as it has not faced the challenge of mistakenly identified skin as non-skin problem and the incorrectly identified non-skin as skin pixels are also less in number.

Table II Threshold boundaries of different combinations of color spaces

Name of the combination of colour spaces	Threshold Boundaries
HSV-HSL	$0 < H < 40, 0.27 < S < 1.2, 0.5 < V < 1$
HSV-LMS	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, M > 80, S < 180$
HSV-LSLM	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, 65 < L < 240, 85 < LM < 235$
HSV-XYZ	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, 120 < X < 225, 67 < Y < 220$
HSV-XYEz	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, 120 < X < 230, 90 < Ez < 190$
HSV-YCC	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, Y > 55, C1 > 85, C2 > 145$
HSV-YDbDr	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, 120 < Db < 240, 85 < Dr < 180$
HSV-YPbPr	$0 < H < 40, 0.27 < S < 0.6, 0.5 < V < 1, Y > 125, Pb > 25, Pr > 13$
HSL-LMS	$0 < H < 40, 0.27 < S < 1.2, M > 80$
HSL-LSLM	$0 < H < 40, 0.27 < S < 1.2, 65 < L < 240, 85 < LM < 235$
HSL-XYZ	$0 < H < 40, 0.27 < S < 1.2, 120 < X < 225, 67 < Y < 220$
HSL-XYEz	$0 < H < 40, 0.27 < S < 1.2, 120 < X < 230, 90 < Ez < 190$
HSL-YCC	$0 < H < 40, 0.27 < S < 1.2, Y > 55, C1 > 85, C2 > 145$
HSL-YDbDr	$0 < H < 40, 0.27 < S < 1.2, 120 < Db < 240, 85 < Dr < 180$
HSL-YPbPr	$0 < H < 40, 0.27 < S < 1.2, Y > 125, Pb > 25, Pr > 13$
LMS-LSLM	$100 < L < 210, M > 115, S > 100, 65 < LSLM[0] < 240, 85 < LM < 235$
LMS-XYZ	$110 < Y < 210, 90 < Z < 185, 50 < L < 200, 110 < M < 255$
LMS-XYEz	$100 < L < 210, M > 115, 100 < S < 188, 120 < X < 230, 90 < Ez < 190$
LMS-YCC	$100 < L < 210, M > 115, 100 < S < 188, Y > 55, C1 > 85, C2 > 145$
LMS-YDbDr	$100 < L < 210, M > 115, 100 < S < 188, 120 < Db < 240, 85 < Dr < 180$
LMS-YPbPr	$100 < L < 210, M > 115, 100 < S < 188, Y > 125, Pb > 25, Pr > 13$
LSLM-XYZ	$0 < Y < 210, 70 < Z < 200, L < 240, 85 < LM < 235$
LSLM-XYEz	$120 < X < 230, 90 < Ez < 190, 65 < L < 240, 85 < LM < 235$
LSLM-YCC	$65 < L < 240, 85 < LM < 235, Y > 55, C1 > 85, C2 > 145$
LSLM-YDbDr	$65 < L < 240, 85 < LM < 235, 120 < Db < 240, 85 < Dr < 180$
LSLM-YPbPr	$65 < L < 240, 85 < LM < 235, Y > 125, Pb > 25, Pr > 13$
XYZ-XYEz	$120 < X < 225, 67 < Y < 220, 120 < XYEz[0] < 230, 90 < Ez < 190$
XYZ-YDbDr	$120 < X < 225, 67 < Y < 220, 120 < Db < 240, 85 < Dr < 180$
XYZ-YPbPr	$120 < X < 225, 67 < Y < 220, Y > 125, Pb > 25, Pr > 13$
XYEz-YCC	$120 < X < 230, 90 < Ez < 190, Y > 55, C1 > 85, C2 > 145$
XYEz-YDbDr	$120 < X < 230, 90 < Ez < 190, 120 < Db < 240, 85 < Dr < 180$
XYEz-YPbPr	$120 < X < 230, 90 < Ez < 190, Y > 125, Pb > 25, Pr > 13$
YCC-YDbDr	$Y > 55, C1 > 85, C2 > 145, 120 < Db < 240, 85 < Dr < 180$
YCC-YPbPr	$Y > 55, C1 > 85, C2 > 145, Y > 125, Pb > 25, Pr > 13$
YDbDr-YPbPr	$120 < Db < 240, 85 < Dr < 180, Y > 125, Pb > 25, Pr > 13$

As nine color spaces are used and analyzed above, so thirty six distinct and unique possible combinations of two color spaces are formed mathematically. Combining two color spaces does not implies that it always evaluates better results as compared to the color spaces involved in the combination. There is a possibility that on going to overcome the challenges the better result may be override on combining the two color spaces. Therefore, this concept may or may not succeed depending on the capability of color spaces in discriminating the human skin

tone color under different illumination conditions. On analyzing this fact sort of combinations of color spaces are used to determine the combination that has given better result under all conditions.

The table III has clearly described that on combining the two color spaces the rate of the false positives is not varying as compared to the false negative rates. The commencement of the analysis of combination of two color space is initiated by the combinations having HSV color space as one of its color spaces. The possible combinations using this color spaces are HSV-HSL, HSV-LMS, HSV-LSLM, HSV-XYZ, HSV-XYEz, HSV-YCC, HSV-YDbDr, and HSV-YPbPr. The experimentally obtained skin classifier rates of all possible combinations have described in table III. Among the combinations having HSV as one of the color space, HSV-YCC has yielded better result in terms of skin races as well as lighting conditions. The results with other color spaces are shown in figure 1(ii).

Now, the features of the combinations of color spaces are commenced having HSL as one of the color space. All the combinations have produced equivalent results to the HSV combinations of color spaces that can be clearly shown in figure 2. The experiment is now further preceded with the combinations having LMS as one of the color spaces. Some combinations like LMS-XYZ, LMS-XYEz, and LMS-YDbDr have faced texture problem at the time of skin segmentation. All the combinations shown in figure 3 have faced problems with slight lighting challenges. But the LSLM color space belongs to the same family of LMS has not faced challenges related to the elimination of texture appearance. The combinations with the LSLM color space have slightly affected by lighting conditions. The combination LSLM-YCC has yielded comparatively better results as compared to the other combinations having LSLM and the results are shown in figure 4.

Table III Skin Classifier Rates of Combination of Two Color Spaces

Name of the colour spaces	Percentage of Success Rate	False Positive Rate	False Negative Rate
HSV-HSL	96	0.05	0.09
HSV-LMS	96	0.05	0.07
HSV-LSLM	96	0.05	0.18
HSV-XYZ	96	0.05	0.14
HSV-XYEz	98	0.02	0.22
HSV-YCC	96	0.05	0.14
HSV-YDbDr	93	0.05	0.2
HSV-YPbPr	96	0.05	0.09
HSL-LMS	96	0.05	0.05
HSL-LSLM	96	0.05	0.07
HSL-XYZ	96	0.05	0.11
HSL-XYEz	93	0.02	0.16
HSL-YCC	96	0.05	0.02
HSL-YDbDr	91	0.02	0.09
HSL-YPbPr	96	0.05	0.07
LMS-LSLM	91	0.09	0.18
LMS-XYZ	77	0.02	0.18
LMS-XYEz	80	0.18	0.14
LMS-YCC	96	0.02	0.14
LMS-YDbDr	77	0.05	0.11
LMS-YPbPr	96	0.05	0.11
LSLM-XYZ	80	0.18	0.18
LSLM-XYEz	91	0.02	0.16
LSLM-YCC	96	0.00	0.02
LSLM-YDbDr	93	0.05	0.11
LSLM-YPbPr	96	0.05	0.09
XYZ-XYEz	77	0.18	0.11
XYZ-YCC	96	0.05	0.14
XYZ-YDbDr	77	0.05	0.2
XYZ-YPbPr	77	0.05	0.18
XYEz-YCC	96	0.02	0.11
XYEz-YDbDr	77	0.2	0.09
XYEz-YPbPr	93	0.05	0.18
YCC-YDbDr	93	0.05	0.14
YCC-YPbPr	96	0.05	0.00
YDbDr-YPbPr	96	0.05	0.09

Except the combination of XYZ-YPbPr, the rest of all combinations have faced slight texture challenges having XYZ as one of the color space. The success rate of each combination has less as compared to the above discussed combinations and the result yielded at the time of execution has been shown in figure 5.

Like XYZ-YDbDr, XYEz-YDbDr has faced the challenges due to the texture available in the image. It implies that the intensity of the light does not fall in the cluster representing the non-skin pixels. The results yielded by the experiment have shown in figure 6(i).

Figure 1 Results Obtained by (i) Single and (ii) Combination of Colour Spaces.



Figure 2 Results Obtained by Different Combinations of Color Spaces with HSL.

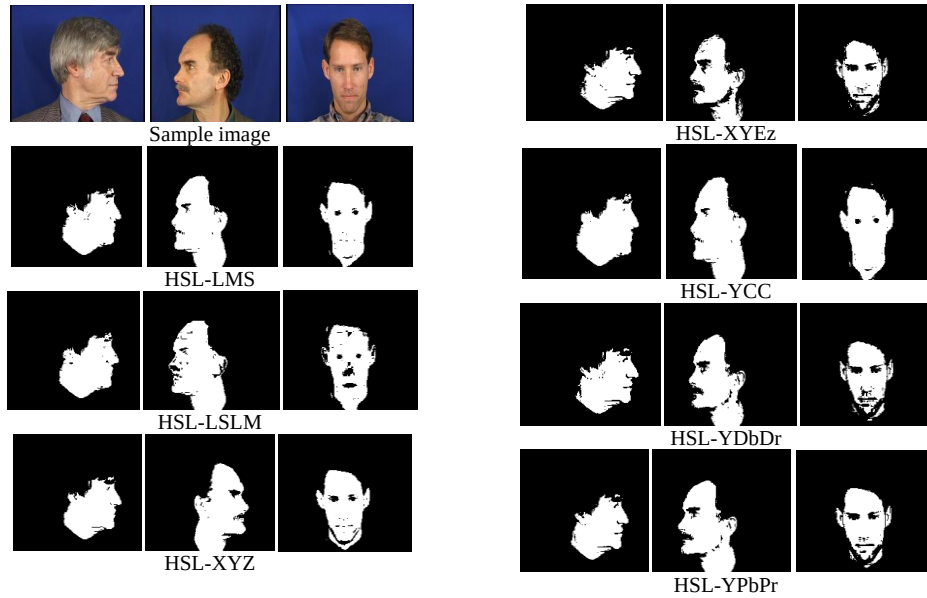
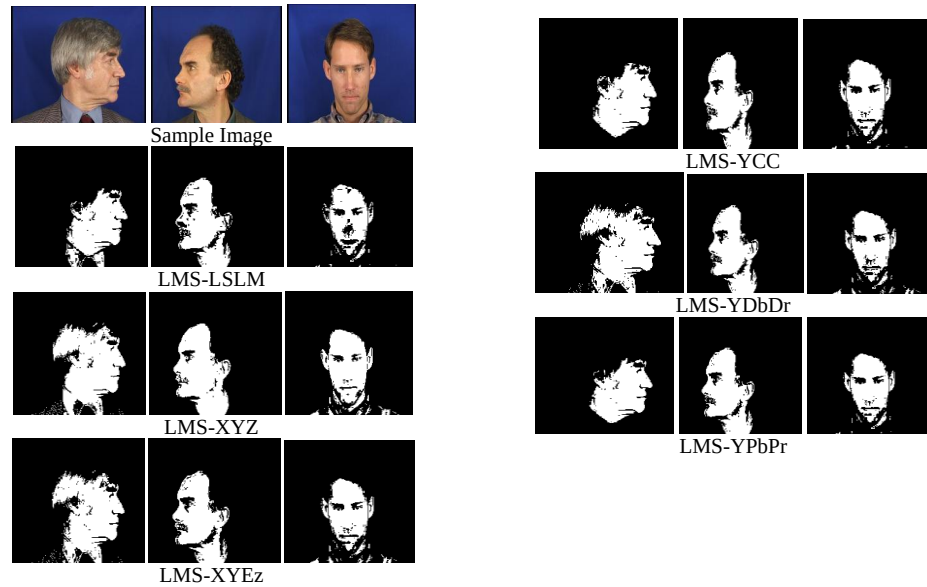


Figure 3 Results Obtained by Different Combinations of Color Spaces with LMS.



Lastly, the three combinations are experimented whose results have shown in the figure 6(ii). The combination YCC-YPbPr has shown the better result as compared to the other discussed combinations as well as the single color spaces YCC and YPbPr. Both the single color spaces have false positive and false negative rate as compared to their combination.

V. Conclusion

The paper has made a comparative analysis on the single and combinations of two color spaces using skin cluster classifier with the aim of enhancing the segmentation of human skin color region effectively. During the experiment YCC color space has performed better as compared to the other single color spaces. On observing the combinations of color spaces skin classifier rates, it has been seen that YCC-YPbPr has performed well as the rate of mistakenly identified skin pixels as non-skin pixels is zero and also the rate of incorrectly identified non-skin pixels as skin pixels is approximately negligible. Thus, this combination can be further used as a new color spaces by different applications of computer vision.

Figure 4 Result Obtained by Different Combination of Color Spaces with LSLM.

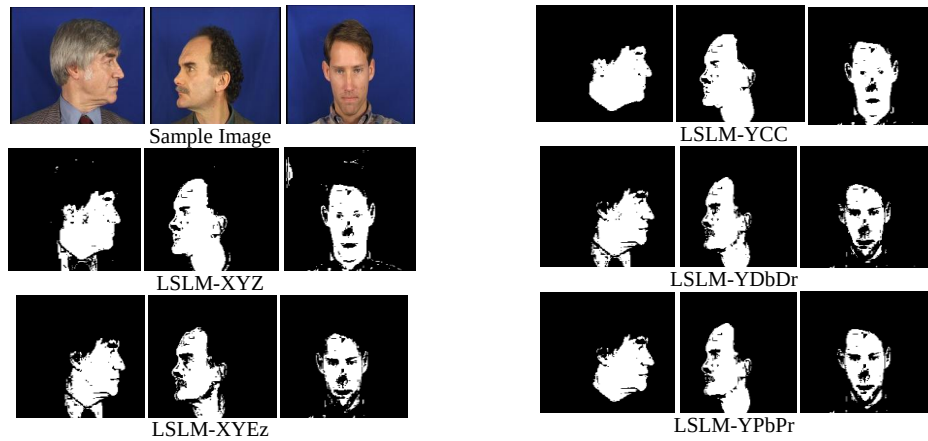


Figure 5 Results Obtained by Different Combination (a) Sample Images; (b) XYZ-XYEz; (c) XYZ-YCC; (d) XYZ-YDbDr; (e) XYZ-YPbPr.

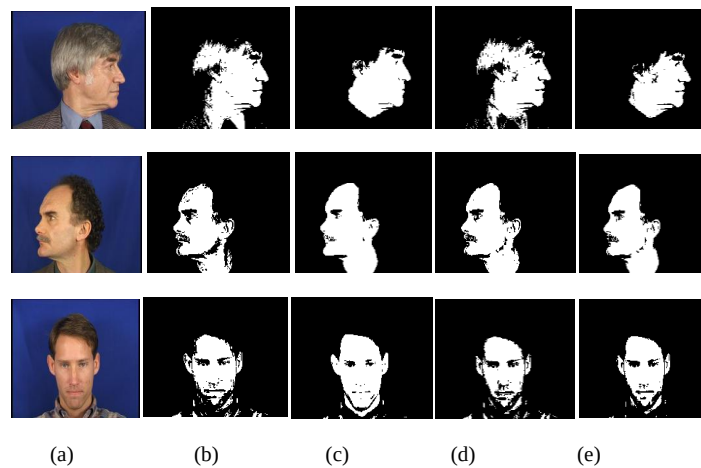
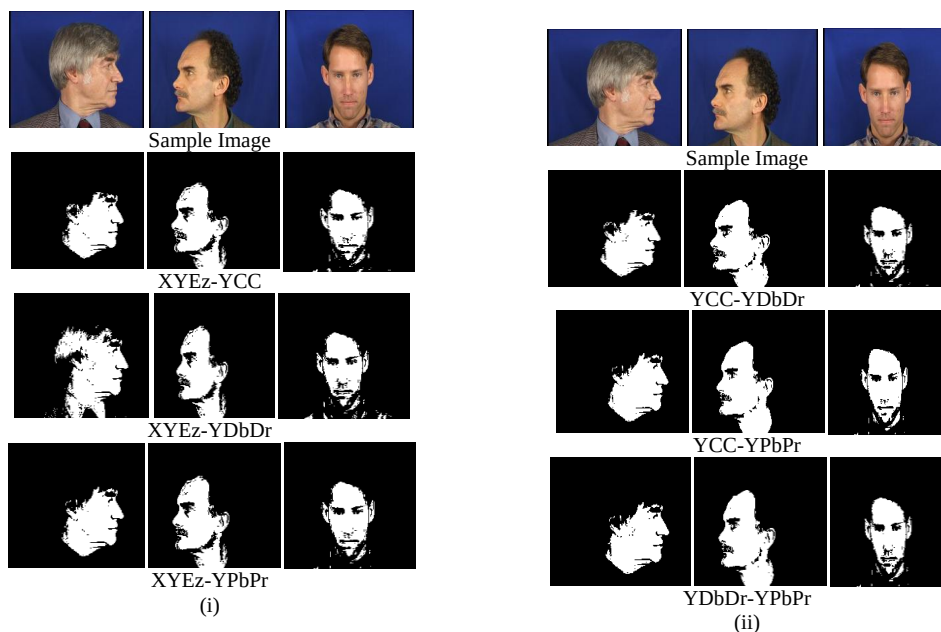


Figure 6 Results Obtained by Different Combinations (i) Combinations having XYEz color space; (ii) Combinations having YCC and YDbDr color spaces.



Acknowledgements

This work is supported and funded by the University Grant Commission (UGC), India under Major Research Project to the department of Computer Science of Pondicherry University, Puducherry, India.

References

- [1] Yasir M. Mustafah, and Amelia W. Azman, "Skin Region Detector for Real Time Face Detection System", International Conference on Computer and Communication Engineering (ICCCE2012), 2012, pp. 635-58.
- [2] QingXiang Wu, Rongtai Cai, Lijuan Fan, Chengmei Ruan, and Gang Leng, "Skin Detection using Color Processing Mechanism Inspired by the Visual System", Proc. IEEE, 2012, pp. 1-5.
- [3] Guan-Chun Luh, "Skin Color Detection using Artificial Immune Networks", Proc. 2012 International Conference on Machine Learning and Cybernetics, 2012, pp. 1807-13.
- [4] Leyuan Liu, Nong Sang, Saiyong Yang, and Rui Huang, "Real-Time Skin Color Detection under Rapidly Changing Illumination Conditions", IEEE Transactions on Consumer Electronics, vol. 57(3), 2011, pp. 1295-1302.
- [5] T. Ravindra Babu, K. Mahalakshmi, and S.V. Subrahmanya, "Optimal Skin Detection for Face Localization using Genetic Algorithms", Proc. IEEE, 2011, pp. 668-73.
- [6] Woo-Ram Lee, Dong-Guk Hwang, and Byoung-Min Jun, "Comparison of Color Constancy Methods for Skin Color under Colored Illuminants", pp. 80-83.
- [7] Hwei-Jen Lin, Shwu-Huey Yen, Jih-Pin Yeh, and Meng-Ju Lin, "Face Detection based on Sin Color Segmentation and SVM Classification", Second International Conference on Secure Integration and Reliability Improvements, 2008, pp. 230-31.
- [8] Mahmoud A. Mofaddel, and Samy Sadek, "Adult Image Content Filtering: A Statistical Method Based on Multi-Color Skin Modeling", Proc. IEEE, 2011, pp. 366-70.
- [9] Lei Yang, Hui Li, Xiaoyu Wu, and Dewei Zhao, "An Algorithm of skin Detection Based on Texture", 4th International Congress on Image and Signal Processing, 2011, pp. 1822-25.
- [10] Rong Wang, and XiaoGang Yang, "A Face Detection on Color and Geometry Information", Proc. IEEE, 2012, pp. 1960-63.
- [11] Xiaohua Wang, Xi Zhang, and Jingliang Yao, "Skin Color Detection under Complex Background", International Conference on Mechatronic Science, Electric Engineering and Computer, 2011, pp. 1985-88.