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An Improved Probability Density Function (PDF) for Face Skin Detection

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Abstract

Face Detection by skin color in the field of computer vision is a difficult challenge. Detection of human skin focuses on the identification of pixels and skin-colored areas of a given picture. Since skin colors are invariant in orientation and size and rapid to process, they are used in the identification of human skin. In addition features like ethnicity, sensor, optics and lighting conditions that are different are sensitive factors for the relationship between surface colors and lighting (an issue that is strongly related to color stability). This paper presents a new technique for face detection based on human skin. Three methods of Probability Density Function (PDF) were applied to detect the face by skin color; these are the Extreme Value Distribution Function and the Exponential Distribution Function methods, in addition to a new proposed model, over the HSV (Hue, Saturation, and Value) color space. The suggested technique aims to enhance skin pixel detection and improve the detection accuracy of a colored region in the human skin in a specific photo. The new model has proved to be **96.05%** more accurate than the Extreme value distribution function and Exponential distribution function according to the selected region of the face during experiments. The images used in this paper were **380** color images from **Caltech (California Technology Institute)** dataset.

Keywords: Skin color, HSV, PDF, Extreme value distribution function, Exponential distribution function, Face detection

تحسين دالة الكثافة الاحتمالية (PDF) لاكتشاف بشرة الوجه

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الخلاصة

يشكل اكتشاف الوجه بواسطة لون البشرة في رؤية الكمبيوتر تحديًا صعبًا. كما أن اكتشاف الجلد البشري يركز على تحديد نقاط البكسل والمناطق الملونة للجلد، وبسبب ألوان الجلد التي هي ثابتة في الاتجاه وفي الحجم وسرعة في المعالجة، تستخدم أيضا في تحديد الجلد البشري، فضلا عن خصائص العرق، والمستشعر، البصريات والإضاءة ذات عوامل حساسة مختلفة للعلاقة بين ألوان السطح والإضاءة، وهي مشكلة ترتبط بشدة باستقرار الألوان. تقدم هذه الورقة طريقة جديدة لاكتشاف الوجه استناداً إلى الجلد البشري. تم تطبيق ثلاث

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طرق لدالات كثافة الاحتمال لاكتشاف الوجه بواسطة لون الجلد: دالة توزيع القيمة القصوى، دالة التوزيع الأسي، والنموذج الجديد المقترح، على مساحة ألوان HSV. تهدف الطريقة المقترحة إلى تعزيز الكشف عن بكسلات الجلد في هذه الصور. لتحسين الدقة في اكتشاف الوجه لمنطقة لون بشرة الإنسان في صور معينة. تم تحقيق النموذج الجديد بدقة أكبر **(96,05%)** من وظيفة توزيع القيمة القصوى، ووظيفة التوزيع الأسي, وفقًا لذلك للمنطقة المحددة للوجه أثناء التجارب. وكان عدد الصور المستخدمة في هذا البحث **380** صورة ملونة من مجموعة بيانات **Caltech** (معهد كاليفورنيا للتكنولوجيا).

1. Introduction

Over recent decades, interest in face recognition concepts and algorithms has grown rapidly. In today's fast context of life, an action is required by technology in the beginning or early stages. Prediction of human skin needs to be conducted accurately[1]. Methods of skin detection are applied to recognize parts of the human body, for example, facial expressions, image classification, etc.

Skin detection is also considered as an important technique in a wide range of image processing studies, such as face detection, online face monitoring, motion tracking, content-based image retrieval (CBIR), and most human-computer interaction (HCI) applications [2].

RGB (Red, Green, Blue), YCbCr (Luminance, Chrominance), and HSV (Hue, Saturation, Value) are the three key color models parameters for identifying a skin pixel.[3] These can help in locating skin pixels in images [3][4],.

Therefore, the standard red, green, blue (RGB) color space of the image was applied in the current study. And since skin detection is very difficult with variables such as lighting and contrast, it is better for the image to be converted to other color spaces, such as HSV and YCbCr [3, 4]. For this purpose, various sensitivity, lighting, and contrast changes are taken into consideration in this research.

2. Literature Review

Interest is progressively growing in the context of developing various approaches that deal with different applications related to face detection, facial expression detection, and hand motion detection [5]. Also, there is research that focuses on enhancement methods to achieve more accurate segmentation based on human body, such as applied histogram equalization, and variable enhancement degree by adjusting parameters to restore the skin color of a human [6],[7]. Other methods for skin detection are based on statistical functions, such as Probability Distribution Function (PDF), to obtain objects in image with less noise and better color contrast. In [8], PDF was computed using Parzen function and applied to images. The results was compared with stochastic watershed. In [9], the researchers classified fruits based on converting the RGB to Hue, Saturation, and Intensity (HSI) color space and applying median PDF to avoid mismatching the similarity. While in [10] the researchers proposed a new "high performance face recognition system" constructed on the PDF of the equalized and segmented face images in different sub-band images in diverse color channels.

By reducing the KLD between the PDF of a given face and the PDFs of faces in the database, these PDFs were used as feature vectors to recognize faces. In [11], researchers proposed a high-performance face recognition method (Local Binary Pattern (LBP) depending on the (PDF). The method is proposed for pixels within various color channels that are mutually independent. Kullback-Leibler was used as a metric in the identification of the combined PDFs of a given face collected by LBP and the combined PDFs of every face of the dataset.

3. MATERIAL

3.1 RGB Color Space

RGB Color Space is a color space created as the co-ordinate system using Red, Green, and Blue colors. In RGB color space the arbitrary color can be represented by the concept of the three primary colors [12].

3.2 HSV Color Space

The color space of the RGB is not fully capable of distinguishing perceptual properties like hue, saturation, and intensity. The color that dominates the area or the image is expressed by Hue (H) Saturation (S) that determines a color’s 'thickness,' or we might say the light-to-color ratio controls. The color illumination is related to the intensity (I) or value (V). The color conversion from RGB to HSV is achieved with different nonlinear transformations[13]. Such color spaces became popular with skin color segmentation works because of their intuitive colors and the explicit distinction between their characteristic, and their light.[14].

3.3 Skin color based on HSV

RGB, HSV, and YCbCr are color spaces that are often selected for skin modeling. Due to the high-channel similarities, considerable perceptional uniformity, and a mixture of chrominance data and luminance. On the other hand, RGB color space is not considered effective for color segmentation. Where surroundings light are overlooked and matte surfaces with standard RGB values are represented there will be no effect on values when adjusting surface orientation to the source of light [15]. It is the most important feature of normalized RGB, and shadows and lights could decrease deformities in an image through this color space. The hue and saturation can be changed directly in HSV, and that is why HSV is selected for skin color improvement including detection such as the following example. (1) [16].

$$HSV = \begin{cases} 0 \le H \le 50 \\ 0.2 \le S \le 0.68 \ldots \\ 0.35 \le V \le 1 \end{cases} \quad \ldots.(1)$$

Skin color pixels are distributed between [0°, 50°] and other pixels have less than 3% of skin color pixels distributed between [300°, 350°], these pixels are ignored due to the practicability of the skin detection [16]. It was found that, as it mentioned before, the recognition of skin color is influenced by the intensity (value) and saturation of the image. Consequently, the distribution of value, saturation, and hue was used for skin detection. The value of skin color and the space in Hue/Saturation are shown in Figure 1. After images training, including various ethnic groups, the following rules were obtained for a pixel (H0, S0, and V0) to be classified as skin, where the three components are normalized 0.1 < S0 < 0.68 [16][17],.

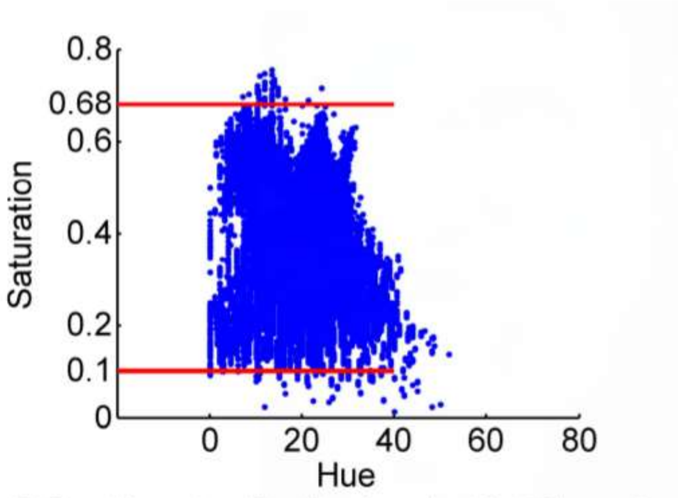


Figure 1: The skin color distribution pixel in Hue/saturation space[16].

The identification of skin color of humans is affected by intensity (value), so the skin colors in an image that contains human skin will show in different intensity. Skin color distribution in HV Panel is shown in Figure 2.

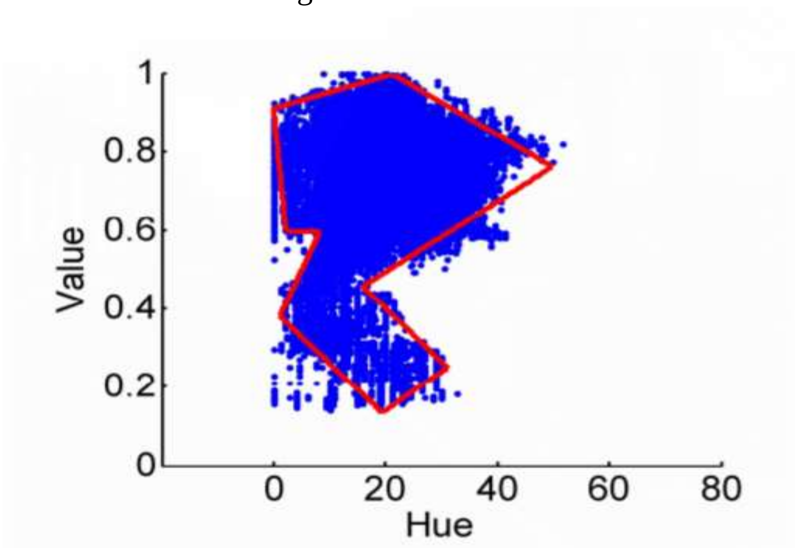


Figure 2: Skin color distribution pixels in hue/value space.[16]

4. Probability Density Function (PDF)

Probability Density Function (or also referred to as PDF), is a statistical function that explains the relative possibility for this variable to take on a given value. The PDF is usually associated with continuous invariant variables to fall under a specific region is found by the integral of this variable's density over the region [18].

In this work, two statistical PDFs were combined: extreme value, and exponential distribution functions. In the following sections, how to obtain a new function, and comparing it with those two functions is discussed

4.1. Extreme Value Distribution Function

The Extreme value object contains parameters, model description, and sample data for a distribution probability of extreme value. The distribution of extreme value is often used to model the smallest or largest value amongst some over-sized number of random values that represent measurement or observations that are equally distributed. The distribution of extreme values is suitable for modeling the minimum values from a distribution where tails descents exponentially rapidly, like the normal distribution. It can also be done using the negative values of the original values to represent the maximum value of a distribution, such as regular or exponential distributions [19].

To define a probability density function for the distribution of the Extreme value with the scale parameter **σ** and location parameter **μ** (2) [19].

$$f(x|\mu,\sigma) = \sigma^{-1} \exp\left(\frac{x-\mu}{\sigma}\right) \exp\left(-\exp\left(\frac{x-\mu}{\sigma}\right)\right) \quad \ldots\ldots(2)$$

Where **x**, is data, μ is mean of **x**, and σ is the standard deviation of **x**.

4.2. Exponential Distribution Function

The exponential distribution is a single-parameter group of curves. The exponential distribution models wait times where the likelihood of waiting for an extended amount of time is independent of how long you have been waiting for. For e.g., the burning of a light-lamp a minute after its use is a relatively independent probability from the number of minutes that have been actually burned. The PDF of the exponential distribution is defined in equation (3)[19].

$f(x|\mu) = \frac{1}{\mu}\exp\left(-\frac{x}{\mu}\right)$ Where **x**, is data, μ is mean of **x**. …(3)

5. Proposed Method

There are two main steps in this work; the first step is the face-detection stage of complex background colored images, which involves converting the color space from RGB to HSV color space. HSV used to decrease the overlapping found between the skin and non-skin pixels. Then, the value intensity pixels of HSV space (V) is considered. The second step is applying improved PDF, which is the mixture of both extreme value and exponential distribution functions, and produce a new method as described in equation (4). This equation contributed to separating the candidate area of the face, specifically the human skin, from the complex background. The implementation of improved PDF facilitated the separation of the face region from other objects like the background and clothing. However, in some instances, because of the overlapping of colors between the neighbor objects, full separation of the face region from other objects cannot be achieved. Therefore, one of the primary morphological processes that are also in the proposed face detection system is dilation. It is one of the morphological processes and can be used to fill in spaces where selection gaps include small pixel numbers. The morphological expansion makes things more visible and bridges small gaps in objects to increase separation effectiveness. As shown in Figure 4, an illustration of the results of segmentation of face appears in dilation and after adding and affects the Improved PDF with the dilation and adds the other morphologies like black and white. The proposed system focuses on using a new formula to achieve greater separation between skin color and background, which means improve the chances of finding a face. As shown in the diagram in Figure 3.

$$f(x|\mu,\sigma) = \sigma^{-1}\exp\left(\frac{x-\mu}{\sigma}\right)\exp\left(-\exp\left(\frac{x-\mu}{\sigma}\right)\right) * \frac{1}{\mu}\exp\left(-\frac{x}{\mu}\right) \quad \ldots.(4)$$

The formula of improved PDF function (Extreme and Exponential) produced satisfactory results when applied on value (intensity) channel of HSV color domain.

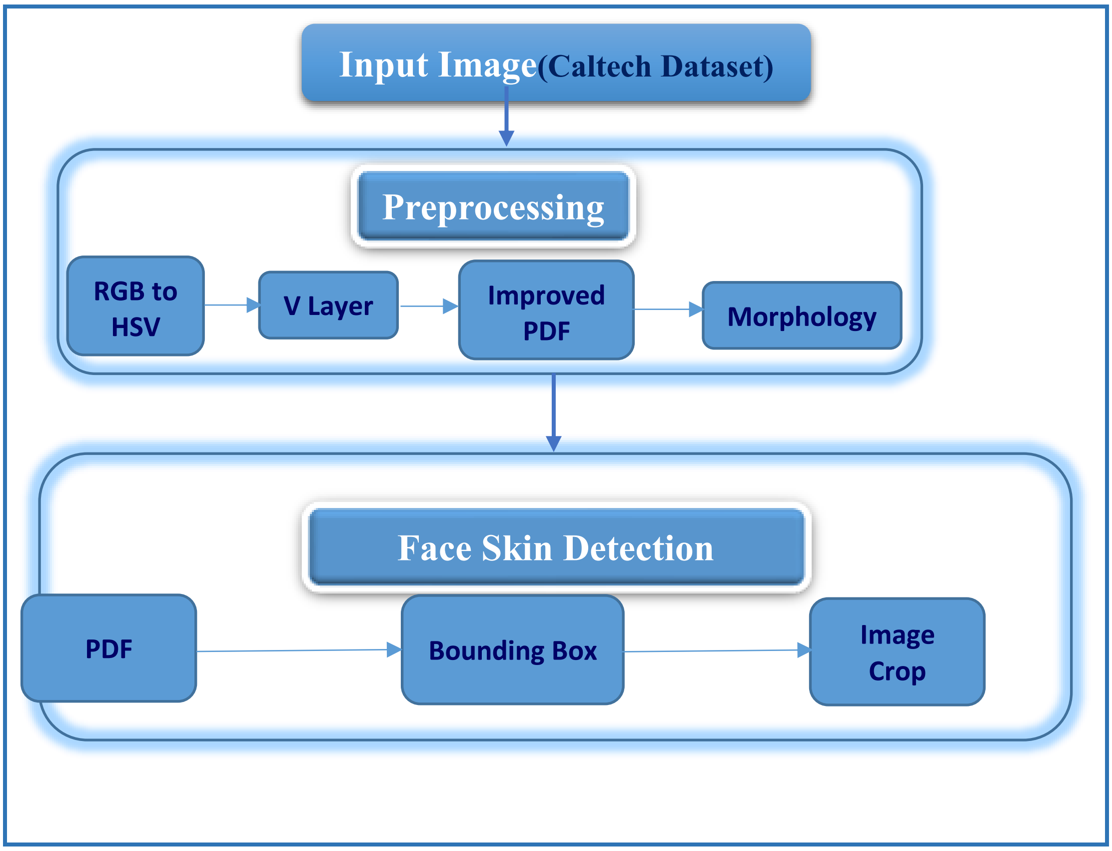


Figure 3-Layout of the proposed face detection system

(A) **(B)**

Figure 4: Illustration of Dilation (A) Face with Dilation (B) Face after add PDF with dilation

6. METHODOLOGY

This section details this study's implementation and the results obtained.

6.1 Training Sample Dataset

The images used in this study to evaluate the performance of the proposed formula were obtained from the **Caltech** dataset. It includes **450** color images from **Markus Weber at the California Technology Institute**[20]. The number of images selected was **380,** with **19** persons, and each person has **20** pictures in different light levels and locations. The size of each image was **896**x**592** and has only one side that also covers the set of variations like different ethnicities and skin colors. The images' skin color regions contained an exposure to varying forms of illumination, such as outdoors illumination, and light was not uniform under dark conditions.

6.2 Experiments and results

Three PDF functions were applied on the intensity value layer after converting the RGB image to HSV color space. Two of the PDFs were extreme value and exponential distribution functions, and the third one was an improved PDF, which occurs by combining these first two PDFs mentioned. Figure 5 shows the preprocessing of five randomly selected samples that contain human face and converted to HSV color space. For this experiment we have used **MATLAB R2019a** 64-bit (win64) Windows10.

Original image	**HSV**	**Intensity layer**
		
		

Figure 5: Samples of image transformed to HSV and select intensity layer

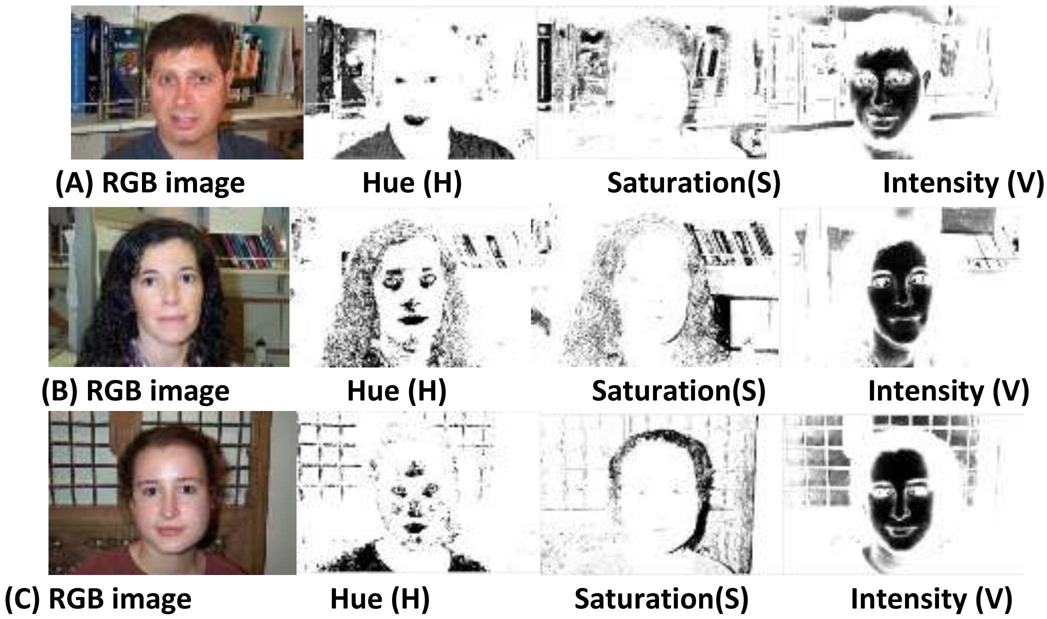


Figure 6: The detection results comparison under different intensity and background.

In Figure 6 a difference is observed between the image layers under different intensities and background. Where (A), (B), and (C) are the original images under medium, high and low light. After using the optimized PDF on the color spaces (H), (S), (V) for each image, it is found that the result on layer **V** gives distinction it is clear in determining the densest area (**the skin**) from the rest of the objects in the image. Thus, this layer will contribute to moving to the next stage and then reaching the final stage, which is face detection by skin color.

Through experimenting on samples from dataset Caltech **(380 sample of which five samples are mentioned here)** ,the following conclusion has been reached : the proposed method based on improving PDF function achieves good verifying results by combining two familiar functions (Extreme Value and Exponential distribution functions). Figure 7 shows the two conventional functions and proposed work.

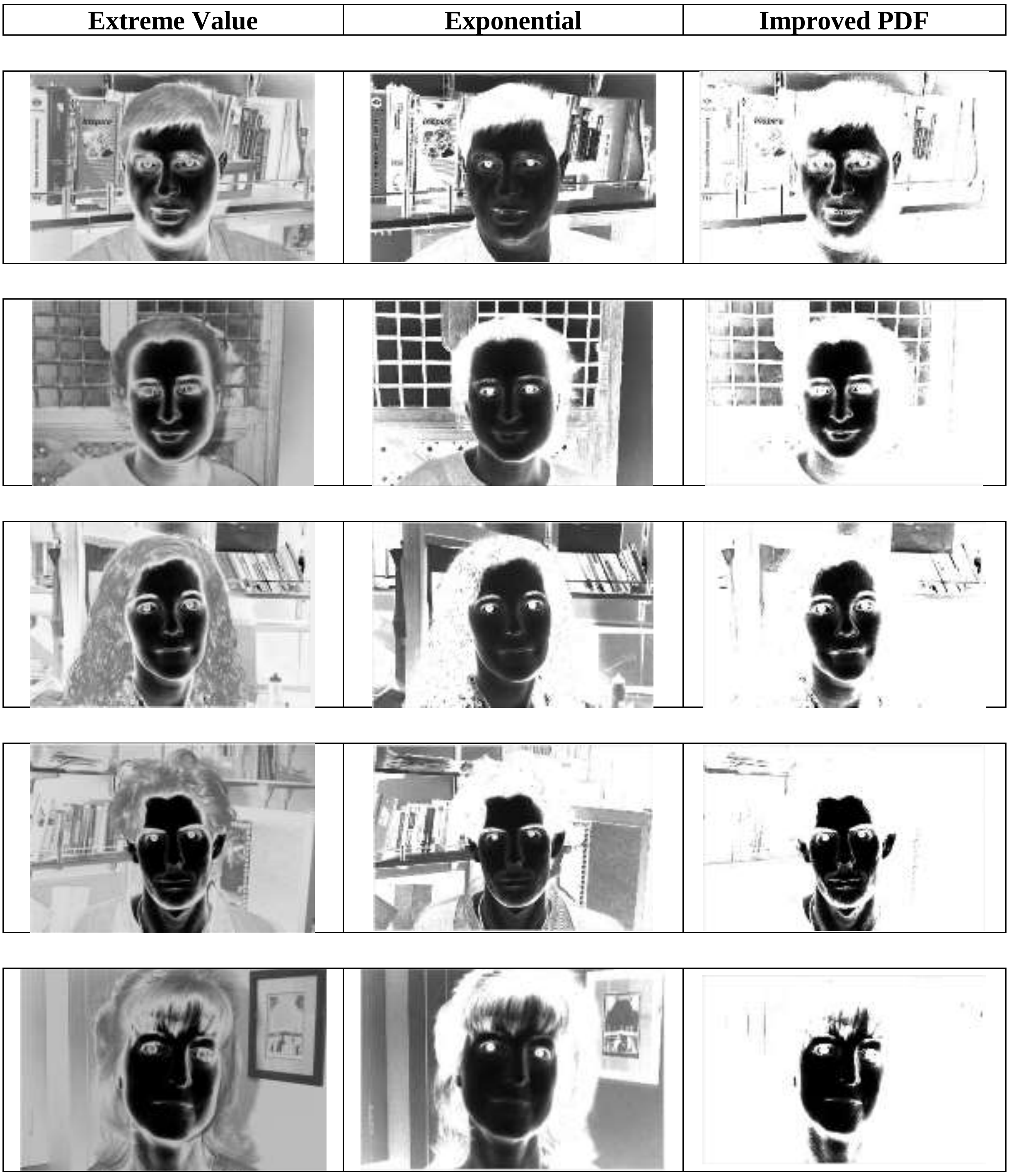


Figure 7: Samples of image comparisons, Extreme Value, Exponential, and improved PDF

The criteria measurement for results (extreme, exponential, and improved PDF) has used 'Goodness of fit' after finding the histogram for each sample shown above. These criteria are Root Mean Square Error (RMSE), Sum Squared Error performance function (SSE), and R^2 or the coefficients of determination (R-square). Below figures show comparisons of these conventional and proposed works by these measurements.

Figure 8 shows the RMSE for two conventional and improved PDFs. In this case, higher RMSE indicates better difference between background and foreground (skin color) which means better separation of the face and any other objects in the background.

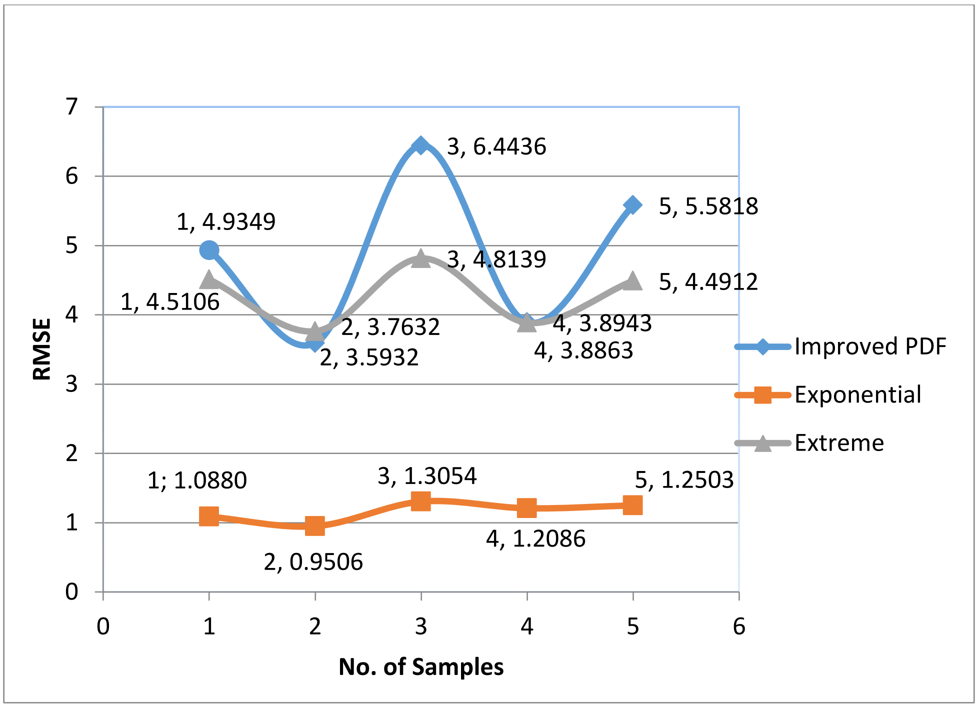


Figure 8: RMSE of Extreme Value, Exponential and improved PDF functions

Table 1: RMSE values corresponding to three functions for five samples

Methods	Image 1	Image 2	Image 3	Image 4	Image 5
Extreme	4.5106	3.7632	4.8139	3.8863	4.4912
Exponential	1.0880	0.9506	1.3054	1.2086	1.2503
Improved	4.9349	3.5932	6.4426	3.8943	5.5818

Figure 9 Shows the SSE for two conventional and improved PDF. For this experiment, higher SSE indicates better difference between background and foreground (skin color) which means better separation of face and other objects found in the background.

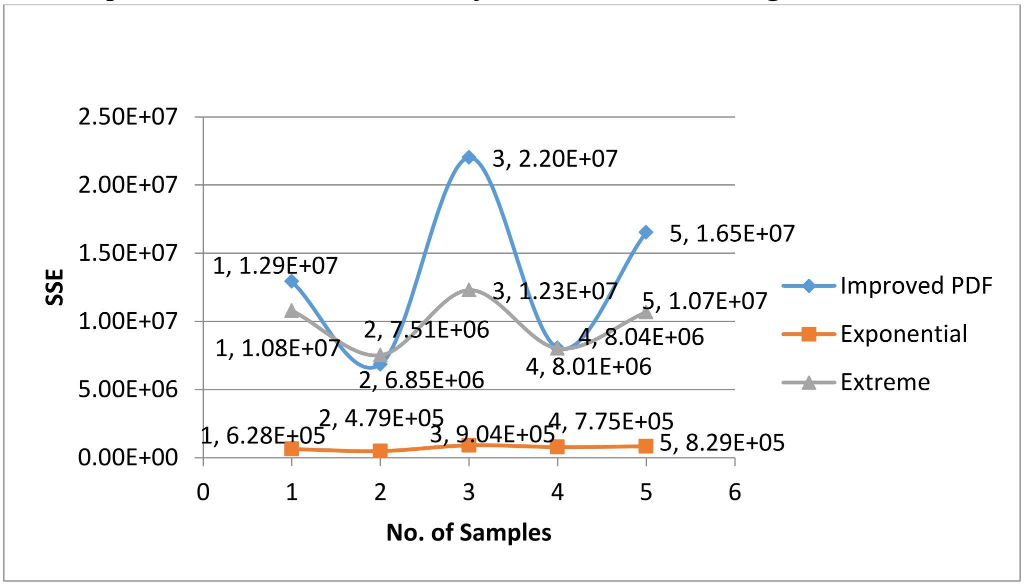


Figure 9: SSE of Extreme Value, Exponential and improved PDF functions

Table 2: SSE values corresponding to three functions for five samples

Methods	Image 1	Image 2	Image 3	Image 4	Image 5
Extreme	1.08E+07	7.51E+06	1.23E+07	8.01E+06	1.07E+07
Exponential	6.28E+05	4.79E+05	9.04E+05	7.75E+05	8.29E+05
Improved	1.29E+07	6.85E+06	2.20E+07	8.04E+06	1.65E+07

Figure 10 Shows the R-square for two conventional and improved PDF. It can be seen that lower R-square indicates high difference between background and foreground (skin color), which mean better separation of face and other objects in the background.

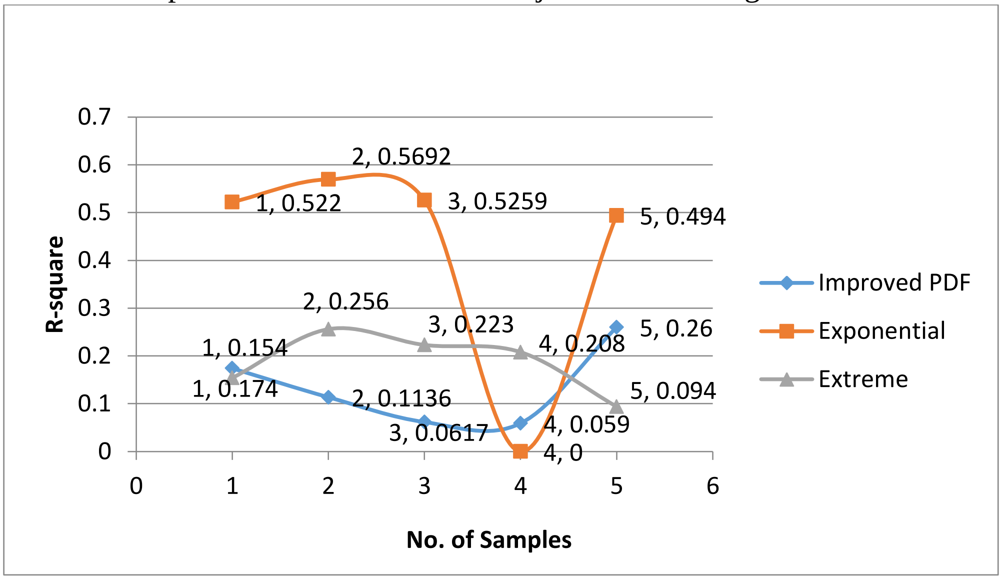


Figure 10: R-square of Extreme Value, Exponential and improved PDF functions

Table 3: R-square values corresponding to three functions for five samples

Methods	**Image** 1	**Image** 2	**Image** 3	**Image** 4	**Image** 5
Extreme	0.154	0.256	0.223	0.208	0.094
Exponential	0.5225	0.5692	0.5259	0	0.4949
Improved	0.1747	0.1136	0.0617	0.059	0.26

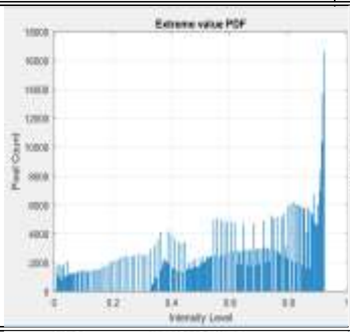
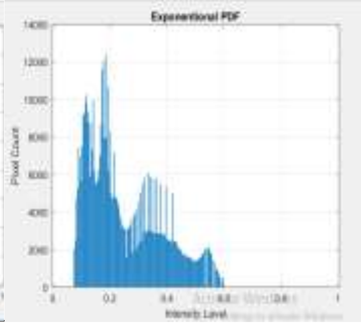
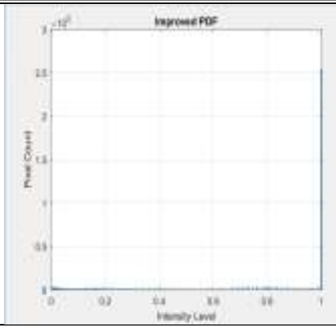
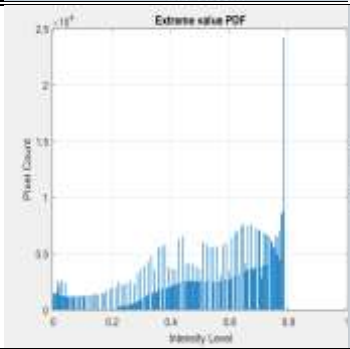
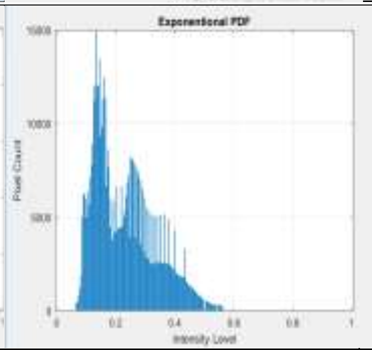
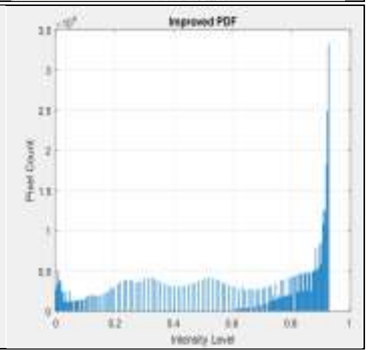
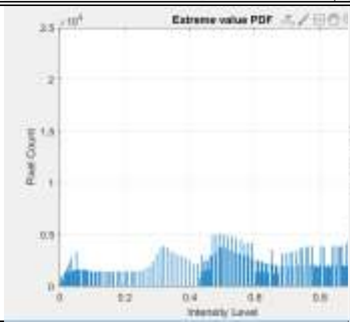
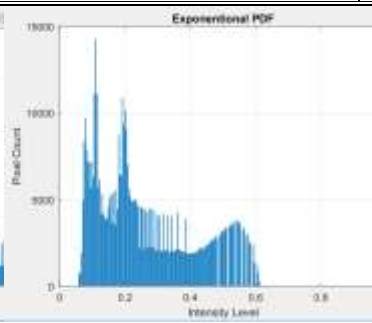
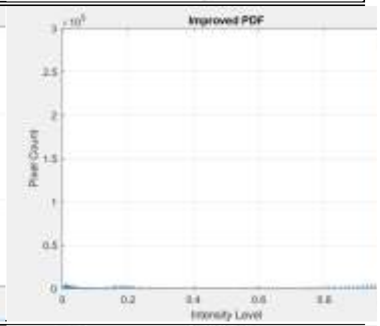
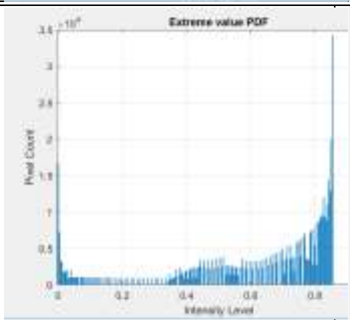
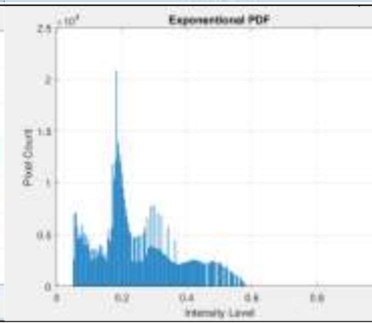
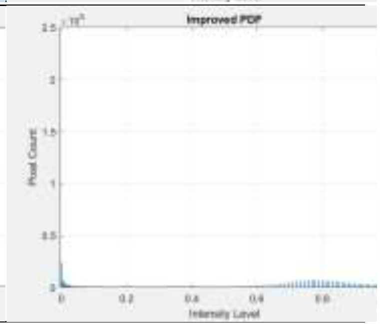
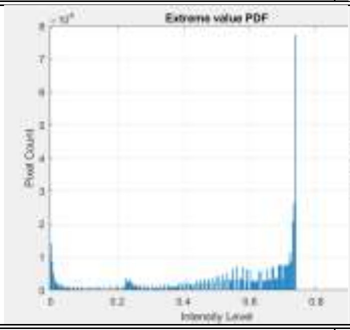
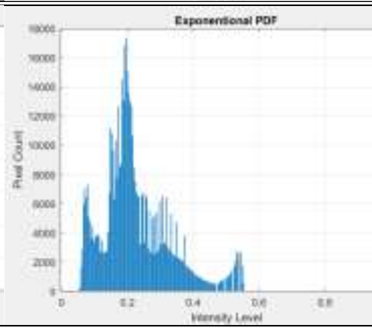
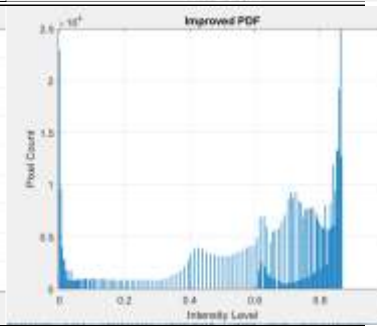
Sample	Extreme value	Exponential	Improved PDF
1			
2			
3			
4			
5			
	(A)	(B)	(C)

Figure 11: Image histogram for (A) Extreme, (B) Exponential, and (C) Improved PDF corresponding to the samples tested in this work

Through the implementation and testing of the proposed method performed on the images, this histogram was produced. It focuses the intensity of the lighting during that the skin color in the image can be accessed, as shown in Figure 11. The improved PDF and the extreme value distribution in (**C**), (**A**) in the graph indicates the presence of areas of high brightness in the image, while on (**B**) a set of dark colors, this is what the exponential method has shown. There are two types of measurement performance used to evaluate the success rate. The first is the Non-Detection Rate (NDR), which calculates the rate of non-facial detection relative to the total number of detection.

$$NDR= \frac{Non-Face\ Detection}{Number\ of\ Faces} \times 100\% \qquad \text{…. (5)}$$

The second type is the Detection Success Rate (DSR) that calculates the correct face detection rate relative to the total number of detections.

$$DSR= \frac{Correctly\ \ Detection\ Face}{Number\ of\ Faces} \times 100\% \qquad \text{…. (6)}$$

The method that used the new equation for the improved PDF in this paper found that the face position can be detected by separating the skin color area from the background in each image using the morphology methods, such as dilation, and black and white. In addition to applying an intensity value channel of HSV depending on bounding box (x, y, width, and height) obtained by improved PDF of each 380 samples as shown below Figure 12. Where it is determined based on the max area in objects in which the lighting is intensive. Depending on this brightness, this determine if a part or an object is a candidate area for the existence of a face. Then the larger object in the image is cropped automatically to achieve the face detection process.

Some samples are shown in Figure 12. Using the above experiment and **Caltech** dataset involved converting the color space from RGB to HSV in color space, the value intensity pixels of HSV space (V) taken into account. HSV is used to decrease the overlapping found between the skin and non-skin pixels, where the intensity value is higher because of (V) equal max(R, G, and B) in the equation of convert RGB to HSV. The detected faces system works better under various lighting conditions and background. Table 4 summarizes the results obtained from the proposed system using the comparisons between the three methods (Extreme value, Exponential, Improved PDF). The accuracy was **96.05%** and indicated better separation between background and foreground (skin color), which means better separation of the face.

Figure 12: Result of correctly detected faces by the suggested system

Some of the results of the suggested face detection method are displayed in Figure 12. Most of the face detections by the system proposed were accurate, as clear from the findings in Table (4), and as a result of using improved PDF, the NDR output was **(3.94%)**.

Table 4: Face detection experimental results

Methods	No. of All samples	No. of Right sample	No. of Error samples	Detection Success Rate (DSR)	Non-Detection Rate (NDR)
Extreme Value distribution function	**380**	**348**	**32**	**91.57%**	**8.42%**
Exponential distribution function	**380**	**178**	**202**	**46.84%**	**53.15%**
Improved PDF Proposed	**380**	**365**	**15**	**96.05%**	**3.94%**

7. Conclusions

This paper proposed a new PDF to enhance the detection of human skin color in **380** images. The improved PDF is based on combining two conventional PDF functions (Extreme Value and Exponential distribution functions) by multiplying both functions. The experiment considered multiple conditions including normal lighting, different background, and different lighting conditions. The improved PDF gives higher RMSE and SSE, and lower R-square than other conventional functions and this indicate a better difference between background and foreground (skin color), which mean better separation of the face and other objects found in the image. The accuracy obtained from the system of face detection based on skin color was **96.05%**.

For future work, one of the methods used to define facial features like eyes, mouth, and nose could be implemented along with the proposed method for increasing the rate of detection in dark image conditions, which could be improved if any morphological methods suggested above were taken into consideration.

References

[1] Y. Kortli, et al., "Face Recognition Systems : A Survey,",*/sensors*, vol. 20, 342, no. 7 January, p. 36, 2020.

[2] H. S. Ã, "Skin detection for single images using dynamic skin color modeling," *Pattern Recognit.*, vol. 43, no. 4, pp. 1413–1420, 2010.

[3] S. Sopasoap, "Facial Space detection and Eyes Surrounded Object detective Technique on Color Image YCbCr and HSV," *IEEE, In proceeding of 5th International Conference on Electrical Engineering Congress, Pattaya, Thailand, 8-10 March 2017*

[4] Z. Youlian, et al, "Face Detection Method Using Template Feature and Skin Color Feature in rgb Color Space,", *IEEE, In proceeding of 27th Chinese Control and Decision Conference (CCDC)* pp. 6133–6137, 2015.

[5] R. Khan, et al, "Color based skin classification," *Pattern Recognit. Letters.*, vol. 33, no. 2, pp. 157–163, 2012.

[6] K. Murahira and A. Taguchi, "A Color Image Enhancement Method with a High Regard for Restoration of Skin Color," *IEEE, In proceeding of International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS)*, pp. 38–42, 2012.

[7] S. K. Rout, et al, "Modified Color Brightness preserving Bi-Histogram Equalization with Variable Enhancement Degree for Restoration of Skin Color," *In proceeding of International Conference on Information Technology*, pp. 88–93, 2015.

[8] U. Polit, et al, "Probability Density Function of Object Contours Using Regional Regularized Stochastic Watershed," *ICIP*, pp. 4762–4766, 2014.

[9] A. Gopal,et al , "Classification of Color Objects like Fruits using Probability Density Function (PDF)," *In proceeding of International Conference on Machine Vision and Image Processing (MVIP)*, vol 1, pp. 1–4, 2012.

[10] [10] H. Demirel and G. Anbarjafari, "Improved Face Recognition System Using Probability Distribution Functions Extracted from Wavelet Subbands," *IEEE*, vol. 0, pp. 94–98, 2009.

[11] G. Anbarjafari, "Face recognition using color local binary pattern from mutually independent color channels," *EURASIP Journal on Image and Video Processing*, pp. 1–11, 2013.

[12] D. R. Q. Liihuhqw *et al.*, "Research and Improvement of Skin Color Segmentation Method Based on Different Color Space," *3rd International Conference on Electronic Information Technology and Computer Engineering (EITCE)*,pp. 112–116, 2019.

[13] A. Shifa, et al, "Skin detection and lightweight encryption for privacy protection in real-time surveillance applications Skin detection and lightweight encryption for privacy protection in real-time surveillance applications ☆," *Image Vis. Comput.*, vol. 94, no. February 2020, p. 103859, 2019.

[14] M. Berbar, "Skin colour correction and faces detection techniques based on HSL and R colour components," *Int. J. Signal Imaging Syst. Eng.*, vol. 7, January, 2014.

[15] A. Amjad,et al, "Multiple face detection algorithm using colour skin modelling," *IET Image Processing*, vol. 7. July, pp. 1093–1101, 2012.

[16] X. Zhang, et al, "Skin Color Enhancement Based on Favorite Skin Color in HSV Color Space," *Transactions on Consumer Electronics*, Vol. 56, No. 3, 1789–1793, 2010.

[17] A. J.-M. 1 ,et al, "Face Detection Based on Skin Color Segmentation Using Fuzzy Entropy," *Entropy*, pp. 1–22, 2017.

[18] D. A. C. ALEXANDER HOLMES THE UNIVERSITY OF OKLAHOMA BARBARA ILLOWSKY and D. A. C. SUSAN DEAN, *Introductory Business Statistics.* 2018.

[19] C. Mathworks, "Statistics and Machine Learning Toolbox ™ User ' s Guide R 2020 a," 2020.

[20] T. H. Le, "Applying Artificial Neural Networks for Face Recognition," *Hindawi Publ. Corp.*, vol. 2011, p. 16 pages, 2011.