

Face Detection Based on Robust Algorithm of Skin Color

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Abstract— In the current research, an experimental study of algorithms of face detection that are based on “Color of Skin” has been carried out in details. The three color spaces RGB, YCbCr and HSV were of the main concern of the study. The algorithms depend on these color spaces were compared and they have been combined to get a new skin color depend on algorithm of face detection, which gave higher ratio of accuracy. In the result part, the proposed approach is applied on FEI database and the accuracy rate reached 96.25%.

Index Terms— Face Detection, Skin Color, Color Space, Thresholding.

1 INTRODUCTION

Nowadays, human face perception became a very interested research subfield in the community of computer vision. Localizing and detecting a human face is considered the first step in any application for instance human computer interface, video surveillance, image database management and face recognition. Localizing and tracking a human face is a precondition to recognize any face and/or analyze any facial expression, despite assuming the availability of the normalized face image. However, to locate any human face, the system has to take an image by using a camera and a frame-grabber to start processing this image, it has to search for the important features and then it has to use these features to decide the face location [1].

Several algorithms including that depend on skin color are used to detect the face. The color is considered the most important feature of any human face. In addition, using the skin color to track any face has many merits such as processing the color is much faster than other facial features processing. The color orientation is invariant under specific lighting conditions, which makes the estimation of the motion too much easier because motion estimation needs a translation model only [2, 3].

Therefore, the color is not a mere physical phenomenon; it is a perceptual, which is linked with the spectral features of the electro-magnetic radiation of the visible wavelengths that strike the retina [4].

Following up the human face depending on color has its own problems such as the face color of an image captured by a camera is affected by several factors like object movement, and ambient light etc.), different color values are obtained when different cameras are used, even for the same person and the same lighting conditions, besides skin color differs from person to another. Hence, to use color as a face feature tracking, these problems have to be solved. Colors are also very sensitive

against any change in scaling and orientation, and can tolerate well occlusion. Color cue demerit is its sensitivity to change of illumination color especially in the RGB case, and the sensitivity to intensity of illumination. The only way to increase the tolerance towards any change in intensity of any image is to convert the RGB image into a color space one, whose chromaticity and intensity are separated; the chromaticity part only is used for detection [5].

This paper presents a comparative study of algorithms to localize and detect three well-known skin colors of face, besides proposing a new algorithm depends on classifying skin color in RGB, YCbCr, and HSV color patterns. This paper results show that each algorithm has some pros and cons. The three results were combined to locate the skin region and then on the skin region several algorithms have been done to obtain the face from the skin region. The results illustrated that the face can be effectively localized using the suggested algorithms.

The 2nd section of this paper explains the color spaces (RGB, YCbCr, and HSV) that were used to classify skin color. While the the suggested algorithm that depend on RGB, YCbCr, and HSV color spaces were explained in the 3rd section. The experimental results of the proposed algorithm were discussed in the 4th section and the conclusions are presented in the 5th section.

2 COLOR PATTERNS OF SKIN COLOR CLASSIFICATION

In the recent years, the field of classification of skin color has attracted many researchers attention because of content-based image representation active research, for example image object such as face can be located and then used in image editing, indexing, coding, or any other interactive purposes. Furthermore, localizing face is considered a stepping stone for many facial expression studies. It is worth to mention here that the color information is used in most common algorithms, in which the first pivotal step is skin color areas estimation. However, classification of skin color became very necessary task [6]. RGB, YCbCr, and HSV color spaces are very important for face localization and detection based on skin color,

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and many researches depend on them. These color spaces are described as follows:

2.1 RGB Color Space

This color space includes three basic colors red, blue, and green. These colors spectral components are additively combined to result a new color.

Its model is often represented by 3D cube with red, green and blue at three corners of three adjacent axes, Figure 1[7]. The black color is found at the origin where $r=0, g=0,$ and $b=0,$ whereas the white color found at the opposite corner of the black color of the cube. In this cube the grey color keeps track of the diagonal line which starts in black corner and ends in white corner. In the (24-bit) color graphics system whose (8 bits) for each color channel, the green color equals (0, 255, 0) Despite the fact that RGB pattern represents the design of computer graphics system in a simple way[4,8].

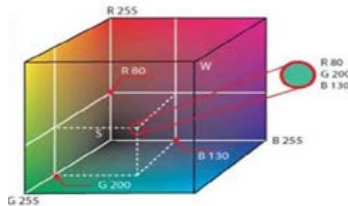


Fig.1. Cube of RGB Colors

2.2 YCbCr Color Space

This color space was found to satisfy the increasing demands for digital algorithms that handle video information, so it became a very widely used pattern in the digital video, Figure 2.

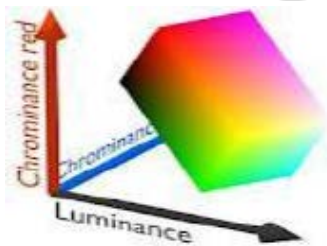


Fig.2. YCbCr Color Space

YCbCr belongs to television transmission color spaces family, which includes other color spaces like YIQ and YUV. It is considered a digital color space, whereas YIQ and YUV are considered analog spaces used in PAL and NTSC systems. These color spaces detach the Red, Green, and Blue into chrominance, and luminance information, and they are effectively used by compression applications, yet the specification of colors is somewhat unintuitive [9, 10].

2.3 HSV Color Space

Since hue, saturation and value are three properties used to describe color, it seems logical that there be a corresponding color model, HSV. When using the HSV color space, you don't

need to know what percentage of blue or green is required to produce a color. You simply adjust the hue to get the color you wish. To change a deep red to pink, adjust the saturation. To make it darker or lighter, alter the value [11].

Many applications use the HSV color model. Machine vision uses HSV color space in identifying the color of different objects. Image processing applications such as histogram operations, intensity transformations and convolutions operate only on an intensity image. These operations are performed with much ease on an image in the HSV color space. For the HSV being modeled with cylindrical coordinates, Figure 3[8]. The hue (H) is represented as the angle θ , varying from 0 to 360. Saturation (S) corresponds to the radius, varying from 0 to 1.

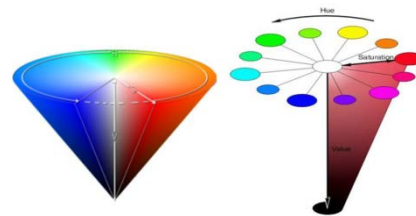


Fig.3. HSV Color Space

3 THE FACE DETECTION PROPOSED ALGORITHM

Face detection is the essential stage. The efficiency recognition is heavily dependent on the accuracy of face detection technique being used. In this work, face detection based on skin color and pixel-based model, Face detection stage includes many steps and in each step several algorithms have been used to detect accurate face as illustrate in figure 4, and it will be explain as follows:

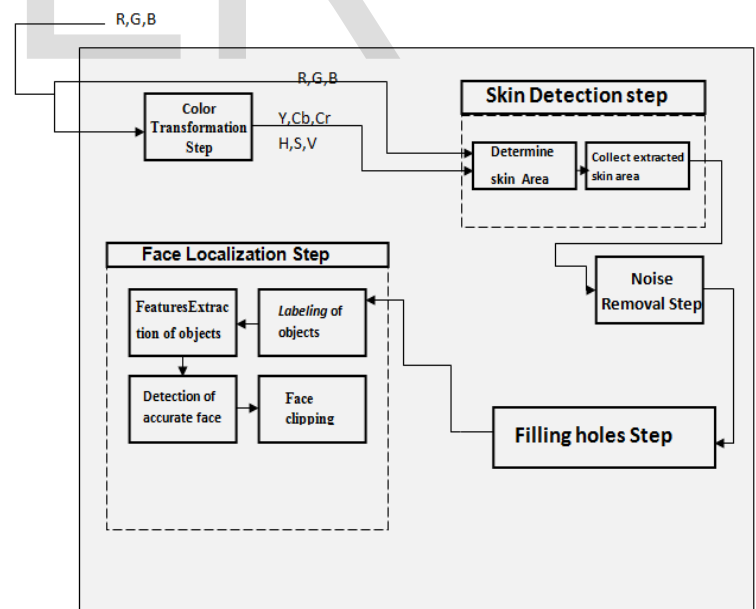


Fig.4. the Face Detection Proposed Algorithm

3.1 Color Transformation

In this step the Red, Green, and Blue arrays are transform first into the YCbCr color space to get the Y, Cb, and Cr arrays and second transform into the HSV color space to get the H, S, and V arrays .This transformation is doen by using Equation(1)[12] and (2)[11] respectively.

$$\begin{aligned} Y &= [0.257 \quad +0.504 + 0.098] \cdot [R] \quad + [+ 16] \\ Cb &= [0.148 \quad -0.291 - 0.439] \cdot [G] \quad + [+ 128] \\ Cr &= [0.439 \quad -0.368 + 0.071] \cdot [B] \quad + [+ 128] \end{aligned} \quad \dots\dots(1)$$

$$H = \begin{cases} \left(\frac{G-B}{\text{Max}-\text{Min}} \right) / 6 & \text{if } R = \text{Max} \\ \left(2 + \frac{B-R}{\text{Max}-\text{Min}} \right) / 6 & \text{if } G = \text{Max} \\ \left(4 + \frac{B-R}{\text{Max}-\text{Min}} \right) / 6 & \text{if } B = \text{Max} \end{cases} \quad \dots\dots\dots (2)$$

$$S = \left(\frac{\text{Max}-\text{Min}}{\text{Max}} \right)$$

$$V = \text{Max}$$

3.2 Skin Detection

In this section a new algorithm which represents a combination of the three algorithms have been depicted, which depend on RGB, YCbCr, and HSV, respectively. It has been explained that those three algorithms function splendidly under only one condition, which the image must contain only one face. Implementation of these algorithm consists of two main steps; in the first step the skin region will be classified in the color space and the rsulted image of applying the skin color statistics will be subjected to binarization by applying suitable threshold, in the second step combining the detected regions that obtained from all the three mentioned color spaces.

3.2.1 Determne Skin Area

Determine skin area is done by classifying the pixels for each color space resulting from color transformation step separately into skin as white color pixel and non-skin as black color pixel.

A. Determine Skin Area in RGB Color Space

One of the most unpretentious algorithms used to detect skin pixels uses an algorithm of skin color .The human color varies accordingly as a relative direction function to the illumination. The skin region pixels can be easily detected in RGB color model by classified image pixel as skin when the following conditions are hold [7, 13].

$$R > 95 \text{ and } G > 40 \text{ and } B > 20 \text{ and}$$

$$\text{Max}(R, G, B) - \text{min}(R, G, B) > 15 \text{ and} \quad \dots\dots\dots (3)$$

$$|R - G| > 15 \text{ and } R > G \text{ and } R > B$$

B. Determine skin Area in YCbCr Color Space

An algorithm of skin color classification has been implemented with color statistics gathered from YCbCr color spacean image pixel is classified as skin when the following conditions are hold [14].

$$\begin{aligned} &(Y > 50) \text{and } (Y < 175) \text{ and} \\ &(Cb > 90) \text{and } (Cb < 120) \text{ and} \quad \dots\dots\dots (4) \\ &(Cr > 140) \text{and } (Cr < 165) \text{ and} \\ &(Cr > Cb) \text{and } (Cr - Cb > 15) \end{aligned}$$

C. Determine skin Area in HSV Color Space

Skin color classification in HSV color space is the same as YCbCr color space but here the responsible values are hue (H), saturation (S) and value(V) . The pixel is classified as skin when the following conditions are hold [14].

$$\begin{aligned} &(H > 0) \text{and } (H < 25) \text{and} \\ &(S > 70) \text{and } (S < 150) \text{ and} \quad \dots\dots\dots (5) \\ &(V > 90) \text{and } (V < 220) \end{aligned}$$

3.2.2 Collect Extracted Skin Areas

It is supposed that skin region can be extracted by combining the detected regions that obtained from all the three mentioned color spaces. Hence, when these results combined,it is suggested that this combination will give the skin region from the three skin detected images. The assumption here is "if the skin image was detected by certain algorithm(s) and other algorithm gives a false resul for the same image;then the face will be extracted by using the combination of the three algorithms.Therefore, the result obtained from RGB color space is **A**,the result obtained from YCbCr color space is **B**, and there-sult obtained from HSV color space is **C**, accordingly, if any of these results contains a skin image then the combination of these three algorithms will certainly be a skin image. This idea can be more explained as:

Let $A = \{a, b, c, d\}$, $B = \{b, e\}$ and $C = \{b, f\}$.

If $a = \text{"skin image"}$, then the first algorithm result will be "true", but the next two will fail. Yet if the combination of the three was taken then $D = (A \cup B \cup C) = \{a, b, c, d, e, f\}$ and if either of a, e or f was skin image, so this algorithm will be able to detect it. When all the three algorithms gave the same result, then this is the case if $b = \text{"skin image"}$, then even D will have b element. Hence, the skin region will be detected from any color image. Figure 5 shows the proposed algorithm steps to classify skin color.

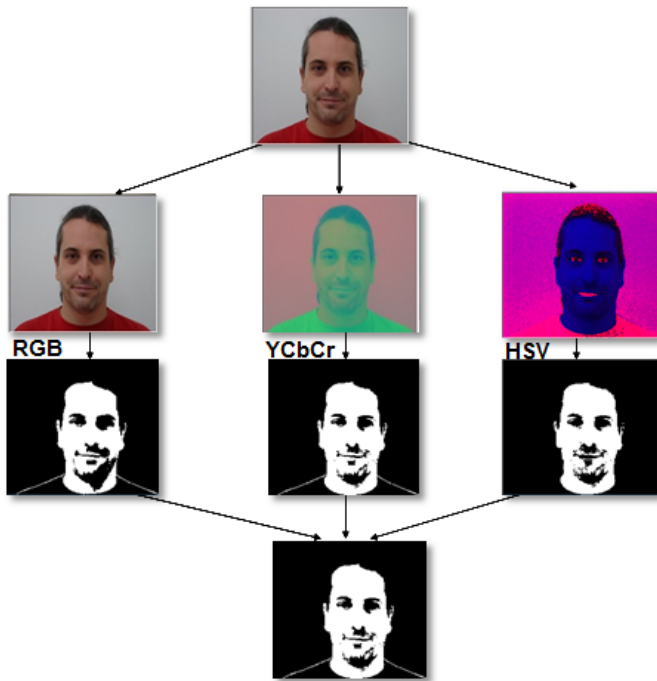


Fig.5. Skin color detection step from proposed algorithm

3.3 Noise Removal

Noise pixels may be appear in the image that result from Skin Detection area step and For reducing that noise pixels, Median filter with (3 x3) kernel is applied and it is applied tow times to get best result,figure 4.

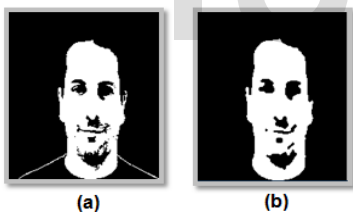


Fig.6. Noise Removal

3.4 Filling Holes

The image that is resulted from Noise Removal Step, may contain a Set of holes in the outer boundary of some regions for example Person wears glasses as it is illustrated in Figure 7 , These holes produce unclosed regions. This problem may be affect the possibility of Labeling candidate face regions using Connect Component Labeling method(CCL) [15] as it is illustrated in Figure 8, To solve this problems, the advantage of the close morphological operation has been taken which is represented to remove small holes from boundary of candidate face regions to ensure closing it region.

The close operation is implemented by applying Dilate operator and then applying erode operator [16].



Fig.7. Sample of candidate face regions with holes



Fig.8. effect of Filling Holes:

(a) filling holes;(b) Labeling of objects by CCL without applying filling holes of (a);(c) Labeling of objects by CCL with applying filling holes of (a).

3.5 Face Localization

At this step, a several substeps have been used to detect accurate of face, these substeps are described as follows:

3.5 .1 Labeling of Objects

The process at this supstep is Labeling of objects within close regions by Connect Component Labeling method(CCL) [15].This method is used to perform labeling of objects and built an array of these labels.All pixels with values equal to (0) labelled as background, others are treated as object's pixels.

3.5 .2 Features Extraction of Objects

Features are Extracted of objects that Labeled in the previous supstep.These features include (x, y) coordinates of objects as well as the width, height, area and perimeter for each object .

3.5 .3 Detection of Accurate Face

The resulting image of the previous supstep contained a Set of white closed areas on a black background, one of these areas represents an accurate face if all rules are true, otherwise it is not face, these rules are area and connected component operators(Compactness, Solidity and Orientation)[16,17].It is applied over each region to decide whether it represent a face or not.A t first,the area rule is applied with experimental threshold(≥ 1000) for all region, if the region pass from this rule,it will examin by the others rules to decide the accurt face and then by drawing a bounding box that surrounding the face region as described in the Algorithm(1) and the result is shown in Figure 9.



Fig.9. Detection of Accurate Face

Algorithm (1) : Detection of Accurate Face

Input
 image with Mark each object
 ObjectsCount and FeaturesObjects // count of object and array of features objects that resulted from Features Extraction of Objects supstep

Output
 image with Mark only the face object

Begin
Step : For j ← 0 to ObjectsCount loop

Width ← FeaturesObjects [j][Width]
 height ← FeaturesObjects [j][height]
 Area ← FeaturesObjects [j][area]
 perimeter ← FeaturesObjects [j][perimeter]
 xs ← FeaturesObjects [j][x1]
 ys ← FeaturesObjects [j][y1]

if area >= 1000 then

Compactness ← $\frac{\text{FeaturesObjects}[j][\text{Area}]}{\text{FeaturesObjects}[j][\text{perimeter}^2]}$ eq (6)

Solidity ← $\frac{\text{FeaturesObjects}[j][\text{Area}]}{\text{FeaturesObjects}[j][\text{width}] + \text{FeaturesObjects}[j][\text{height}]}$ eq (7)

Orientation ← $\frac{\text{FeaturesObjects}[j][\text{height}]}{\text{FeaturesObjects}[j][\text{width}]}$ eq (8)

If compactness < 0.025 and Object solidity > 0.5218 and 0.9 ≤ object orientation < 2.10 then

face ← Mark (xs,ys,width,height, ErodeImg)
 End if

End if

End For

End

3.5 .4 Face clipping

The purpose of this supstep is to obtain face clip from the original image (color image) Depending on the new coordinates of the face, which was discovered from the previous supstep as in figure 10.



Fig.10. Face clipping

4. EXPERIMENTAL RESULTS

A detailed comparison of the above mentioned algorithms is presented in this section of the paper, the proposed approach is applied on FEI database and the following equation is used to obtain the accuracy for all cases.

$$\%S = \frac{\text{The Number of Pixel Correctly Classified}}{\text{Total Pixel in the Database}} \times 100 \dots \dots \dots (9)$$

% S equals the correct skin detection percentage.

The Experiments show that RGB color space accuracy equals (74.55%) and the Experiments that have been carried out on the YCbCr color space is equals (84.18%); this result is much better than that of RGB color space and the Experiments show that HSV color space is also good in classifying the skin color region, the accuracy is found to be (80.5%) which is nearly equivalent to results from YCbCr color space.

The experimental good results of the suggested algorithm were shown in Table 1. These results were obtained by using the previously mentioned threshold and conditional probabilities values and the accuracy here equals (96.25%).

TABLE (1)
 THE RESULTS OF SKIN COLOR CLASSIFICATION FOR EACH COLOR SPACE AND SKIN COLOR MODEL

No.Images	Color Space Type	Correct Detection Rate (%)
500	RGB	74.55%
500	HSV	80.5%
500	YCbCr	84.18%
500	Skin Color Model RGB, HSV and YCbCr	96.25%

Comparison of Algorithms

A comparison among of all algorithms used in this paper is presented. Table (1) demonstrates this comparison, which shows that the suggested algorithm leads to good results .Sample results from proposed algorithm are shown in Figure 10.

5 CONCLUSION

In following all conclusions are presented; they are derived from the investigations done on this paper applied on FEI database. They can be summarized as follows:

1. Combination of three color space RGB ,YCbCr and HSV was performed to detection skin region in face detection stage, It gave better results than using each color space separately, from the experiments the Correct detection Ratio for each color space was :RGB ,YCbCr and HSV, 74.55%, 84.18%, 80.52% Respectively, when combination of three color space RGB ,YCbCr and HSV the result was 96.25%.
2. Use the median filter twice gave better results.

3. The Morphology Operation is an effective process to deal with face with glasses because it solved the problem of face split into several areas because of the glasses.

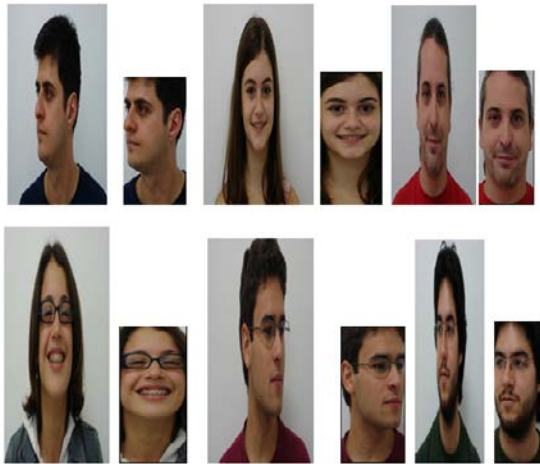


Fig.11. Sample Results of Proposed Face Detection Algorithm

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