Real-time Human Skin Color Detection Algorithm using Skin Color Map

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Abstract— Human computer interface (HCI) system requires a skin color detection algorithm in it's first step of designing. Skin color detection algorithm faces two major problems one is variable Human skin tone and second one is complex background. Human skin tone variation can be easily seen from person to person within same ethnic group or different ethnic groups. And the background used in real time is usually complex with variable lightening conditions. Hence a good skin color detection algorithm is required to work well under these conditions. In this paper a skin color detection algorithm using skin color map is proposed which gives promising results in complex background. Color space used here is YCbCr color space and skin color model used is explicitly defined regions. This model has certain advantages over parametric and non parametric models in terms of implementation and memory usage and color space chosen is good for video processing applications.

Keywords— Computer Vision, Skin color detection, Color space, Thresholding, Skin color model

I. INTRODUCTION

In many computer vision applications, human skin color detection plays a very vital role. Human skin tone varies from person to person and region to region over the globe. Sometimes skin color also resembles with non skin materials like wooden articles, wall-paint etc. which increases the complexity of designing and implementation of real time computer vision applications. Skin color information, motion cues, texture and edge features are combined to track and detect human skin in applications like Human Computer Interaction systems (HCI), face detection, hand gesture recognition and video surveillance etc. [1]

Skin color detection becomes very challenging task under the variable visible spectrum of light with complex background as an image is receptive to various factors as stated below:

1) *Illumination*: The inconsistent color profiles of indoor, outdoor and shadows affect the performance of human skin detection.

2) *Ethnicity*: Across the globe there exist different ethnic groups. Their skin color varies tremendously from one person to another within their own ethnic group and also with respect to other ethnic groups too.

3) *Imaging Devices characteristics:* Webcam or digital camera is one of the most widely used imaging devices in numerous vision based applications. The distribution of skin color for same person can be different using different imaging devices, as it also depends upon camera sensor properties and calibrations.

4) *Human Physical characteristics*: such as age, gender and other body parts too shows variable skin-color profile for the same person.

5) *Other Factors*: impact of factors like makeup, hairstyle and glasses, background colors, shadows and motion is greatly observed on skin-color profiles [1].

Fig 1 represents two important features that have to be kept in mind while designing skin color detection algorithm, these are color space selection and skin color model. A variety of color spaces are available in visible spectrum like RGB, HSV, HIS, YCbCr, CIE-Lab, CIE-Luv etc and so skin color models available are Gaussian Classifiers, Histogram based, Bayesian classifier NN's and Explicitly defined.[6]

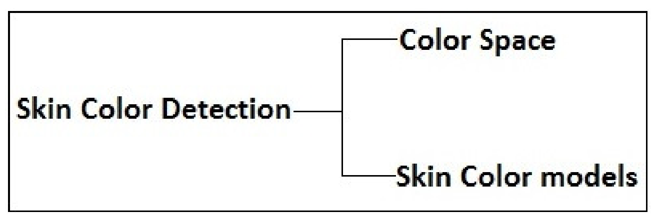

Fig.1. Features of Skin color detection algorithm

This paper focuses on real time human skin color detection and segmentation using skin color map. Color space chosen for this purpose is YCbCr as it has great adaptability to video coding and skin color model is explicitly defined model. The technique used in the color space model is pixel based segmentation. In order to reduce computational consumption we ignore Luminance factor Y and the range for Cb and Cr channels are selected in order to get desired results [5], [6]:

Further this paper is organised as section II deals with brief introduction about color spaces and skin color models, Section III explains proposed skin color detection algorithm, section IV discusses experimental set up and results, Section V conclusion.

II. COLOR SPACES AND SKIN COLOR MODELS

A. Color Spaces

When a set of colors are represented using mathematical expression it is called color space. In the literature many different color spaces are employed like RGB, HSV, HSI, YCbCr, CIE-Lab, CIE-Luv. The initial step is to select the color space which helps in efficient discrimination of skin and non-skin pixels. Opting YCbCr color space helps to a greater extent in this regard [2]. Fig 2 shows the color space available. RGB is termed as basic color space whereas YCbCr is termed as orthogonal color space and HSI is termed as perceptual color space. RGB is also known as primary source of light color as all other color spaces are derived using RGB color space model.[3]

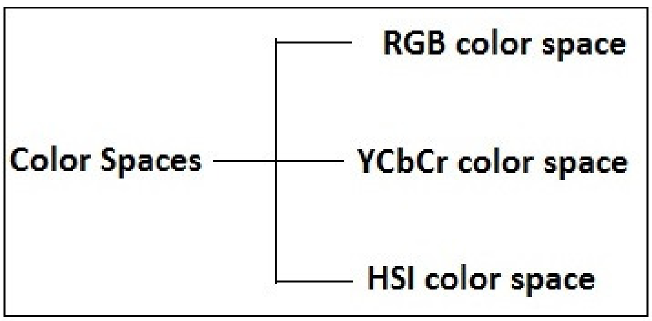

Fig.2. Different color spaces available

1) RGB Color-space

RGB corresponds to basic color space and mostly used to represent digital images, since most of the imaging devices like camera provide information as RGB. It is also known as primary colors of light as RGB stand for R- Red, G- Green and B- Blue. In order to reduce the affect of lightening, the components of RGB color space are normalized as follows:

$$r = \frac{R}{R+G+B} \qquad g = \frac{G}{R+G+B} \qquad b = \frac{B}{R+G+B}$$

Equation 1: Represents normalized RGB color space values

It gives the resultant sum of normalized components as unity(R+G+B = 1). This signifies that third component have no significant role and it can be dropped to reduce dimensionality. Under lightning conditions skin color of different persons from different ethnic group have less difference in their skin pixel values and RGB color space can be advantageously used as color space for human skin detection task. [1], [4]

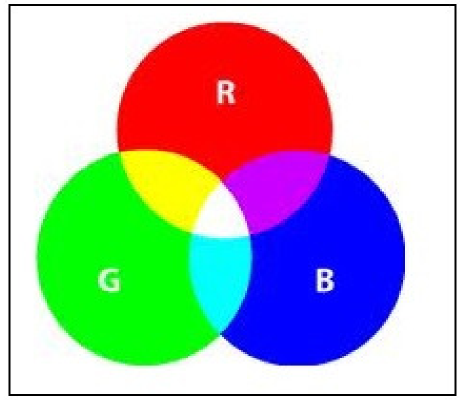

Fig.3. RGB color space

2) YCbCr Color-space

In YCbCr color space, Y refers to Luminance, Cb refers to Chromatic blue and Cr refers to Chromatic red. Being orthogonal color space it reduces the redundancy present in RGB color space and thus representing the components statistically independent. The difference of luminance component B and R give rise to chromatic components i.e. Cb and Cr and sum of RGB components computes luminance of color Y [1], [4]. The conversion from RGB color space to YCbCr color space can be done using equation 2. For skin detection problems, the most opted color space is YCbCr color space and is used by various researchers like Hsu et al. Chai and Bouzerdoum, Chai and Ngan, Wong et al. [1], [10]. Also for video coding and compression techniques, this color space is largely used now days. [3]

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2290 & 0.5870 & 0.1140 \\ -0.1687 & -0.3313 & 0.5000 \\ 0.5000 & -0.4187 & -0.0813 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + 128$$

Equation 2: RGB to YCbCr color space conversion

3) HSI Color-space

Hue-Saturation-Intensity (HSI) represents perceptual features of color. This color space is designed in a manner as human eye perceives to color. In order to map RGB on to these perceptual features many non-linear transformations have been developed. In this color space Hue is defined as property of color that varies from red to green, Saturation is defined as property that ranges from red to pink whereas Intensity also known as Brightness or value as the property of color which varies from black to white. [1], [4] In order to obtain transformation from RGB to HIS color, normalized the value of Intensity in the range [0,1] and express hue and saturation as per equation 3 given below:

$$H = \frac{R + G + B}{3}$$

$$S = \frac{1 - \min(R,G,B)}{I} = 1 - \frac{3}{R + G + B}$$

Equation 3: RGB to HIS color space conversion

For functions like convolution, equalization and histograms and so on referred as traditional image processing functions, HSI color space is best suited. [4]

B. Skin Color Models

Second feature of skin color detection algorithm is designing skin color model. Skin color models are used to distinguish between skin colored and non skin colored objects as the real time skin color detection has to go through complex background. Another major challenge faced by these models are variable lightning conditions like daylight, indoor light, and foggy light condition etc. Large range of skin color for human is present in the world and also the objects showing ambiguity in color with these skin color of human is also present .[10]

Skin color models are further classified into three categories: pixel based, Edge based and Region based models. Fig 4 shows pixel based skin color models. These are explicitly defined skin color region, parametric methods and non-parametric methods. Further parametric methods are divided into two parts one is Gaussian model and second is mixture of Gaussians (MOG) model.[9] Similarly Non-Parametric methods are divided as Look up table and Baye's skin probability map model. [8].

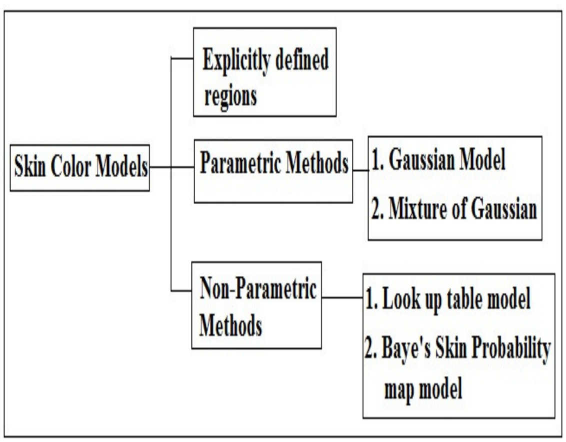

Fig.4. Skin color models

Explicitly defined skin region approach has advantage over parametric and non parametric methods in terms of simplicity and non-rational classification rules. Which results in comprehensively easy implementation and less storage space is required. Whereas parametric methods require less storage space and at the same time training and classification rate is slow. In comparison of this Non-Parametric methods requires more storage space and training and classification rate is fast. [7]

III. PROPOSED WORK

In developing computer vision applications namely Human Computer interaction system and Hand Gesture based system, skin color detection plays a crucial role. This is the first step in developing these systems. But this step becomes challenging due to the factors like variable lightening conditions, complex background, skin colored textured objects etc. So skin color detection algorithm must be designing with the capability to work well under these circumstances. Broadly classifying skin color detection algorithm comprises of two aspects namely: skin color representation and skin color model. Further skin color can be represented as basic color space or perceptual color space or orthogonal color space or perceptually uniform color space. Similarly skin color models are classified into three broad categories namely Pixel-based, Edge based and region based skin segmentation. Pixel based models include Gaussian classifier, histogram based, Bayesian classifier explicitly defined region. Similarly, edge based models are watershed regions, Laplacian of Gaussian, canny edge detector. Finally region based models are region splitting, region merging and region growing techniques [6].

The proposed work is based on the explicitly defined region model based on pixel based skin segmentation and color space used here is YCbCr. Real time human skin color detection suffers from mainly two problems: complex background and lightning factors. In order to remove complex background a Skin map is created to protect skin color pixels from background, known as foreground representation and then apply background subtraction to obtain the segmented skin colored image as a desired output. Fig 5 shows the proposed algorithm for Human skin color detection using skin map is given in figure 7.

Step 1: The first step in this algorithm is to acquire an image frame from live video stream. Adjust the size of the output image.

Step 2: Now acquired image frame is in RGB color space. So change the color space of acquired image frame from RGB to YCbCr color space. YCbCr color space is chosen as it is most suitable for video processing with reduced computational time [6].

Step 3: In the next step identify the skin pixels using thresholding technique. Threshold value used for the detection purpose is given in the table 1 [6] [5]. Now mark the detected pixel as skin pixel value equivalent to 1 (white) and for rest of the pixels assign the value 0 (black). In this way the detected area i.e. skin will be white and background area will be black.

Step 4: Next step is to apply morphological operation as binary image obtained in the previous step contains some imperfection and noise. So in order to remove these defects morphological operations like erosion followed by dilation to construct the region of interest. This step is followed by filtration process to remove some of the background noise. Median filter, a class of non-linear digital filtering, is used here to remove the noise.

Step 5: find the area containing pixels with pixel value equal to 1. Find the centroid point of this area. Draw the bounding rectangle around this area to show the output skin colored detected image.

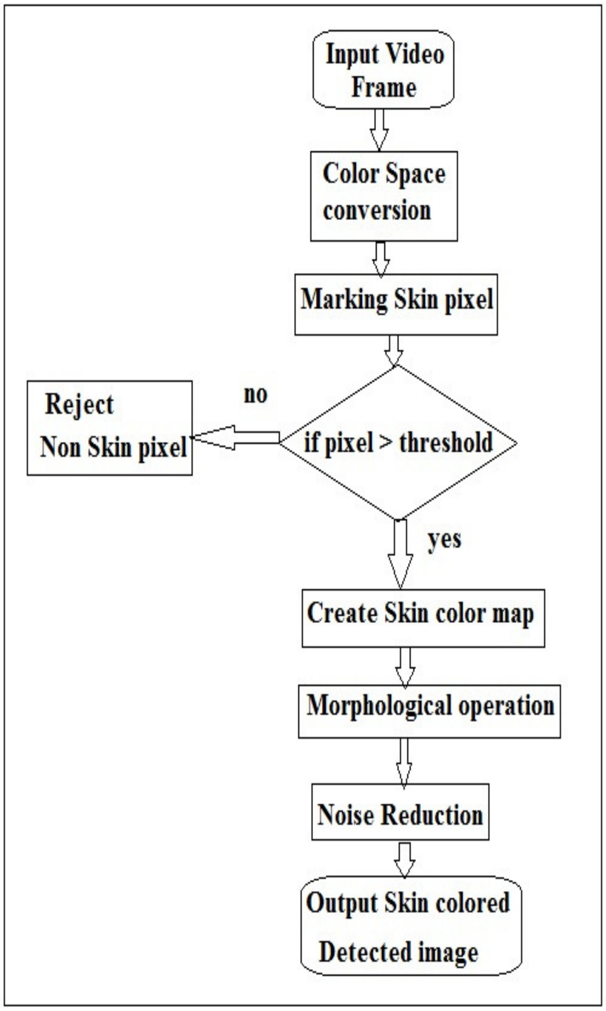

Fig.5. Proposed algorithm for skin color detection

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed algorithm is implemented using Matlab R2012B, USB 2.0 webcam (4Mp), 3Gb RAM, 32-bit windows operating system; image resolution is set as 640x480. The results obtained by using different values of threshold for creating skin map and correspondingly skin colored detected image for indoor environment is shown in Fig 6.

TABLE I. DIFFERENT VALUES OF THRESHOLD

S.No	Cb	Cr
1. [5]	77, 127	130, 173
2. [6]	105, 135	130,170
3.	100, 127	130, 175

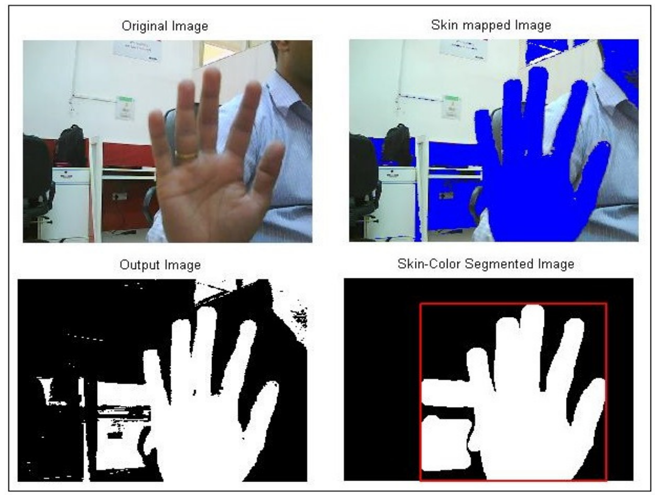

Fig 6a.The results of skin color detected image threshold value Cb [77, 127] and Cr = [130, 173]

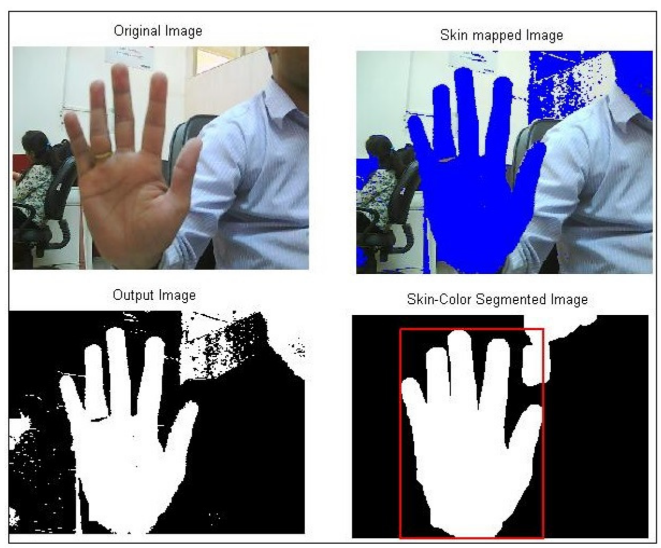

Fig 6b.The results of skin color detected image threshold value Cb [105, 135] and Cr = [130, 170]

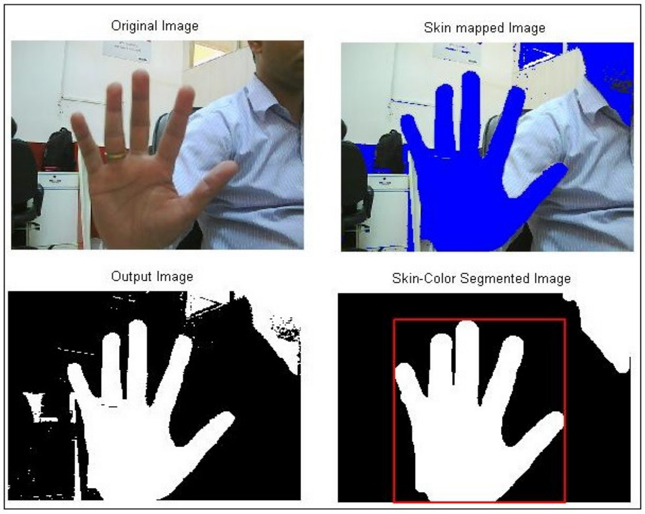

Fig 6c. The results of skin color detected image threshold value Cb [100, 127] and Cr = [130, 175]

V. CONCLUSION

Real time human skin color detection is required in most of the vision based applications. This paper focuses on detecting human skin color on real time basis using skin color map for the complex background. The color space chosen here is YCbCr color space as this is more suitable for video processing applications and the skin color model used is explicitly defined region skin color model. This model has certain advantages over parametric and non-parametric methods in terms of easy implementation and low storage space requirement with good processing speed. This algorithm is tested in indoor complex background environment for different values of threshold as mentioned in table 1. This algorithm gives promising result for the threshold value of Cb = [100, 127] and Cr = [130, 175].

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