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A Systematic Survey of Skin Detection Algorithms, Applications and Issues

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ABSTRACT

In the current era of World Wide Web, human skin detection is a critical parameter in computer vision and image processing applications. With diverse range of applications in forensic sciences, medical imaging, pornography filtering, image retrieval, video surveillance etc., skin detection algorithms are to face many challenges. The major problems in detection of human skin color are varying shades of human skin, color spaces, skin color daily life objects, and illumination conditions. This paper is a systematic study of human skin color detection methods and their classification. Moreover different domains of application are also discussed. The work presented in this paper is a survey of algorithmic techniques proposed so far, their implementation, numerical evaluation results, comparative analysis and discussion on complications.

KEYWORDS*:* Skin detection; computer vision; image processing; issues; color spaces; algorithms; Asian skin.

1 INTRODUCTION

Detection of human skin color in images is pretty hot research areas in graphics, computer and image processing domain. It means detecting those pixels and regions from an image that contain human skin tone color in an image. Skin color detection has extensive applications in different disciplines of life such as entertainment world, advertisement, medical system, porn image filtering, defense systems, and robotics and in various other industries. Use of color information as a feature for skin detection enables fast processing and brings robustness to such application. Research in this direction has three major concerns. Firstly, colorspace selection, secondly, modeling of skin color distribution and thirdly what procedures to adopt for color segmentation [1,3]. This paper covers the first two problems as skin detection methods use color as a primary element in processing, so major issues in this area are also relevant to color representation. Skin detection problem can be further categorized as Color Classification and Skin Color Modeling.

This paper is aimed at collecting information about skin detection techniques in literature and to summarize key ideas, advantages, disadvantages and issues in skin detection. In subsequent sections section 2 highlights some of the skin detection application in multiple disciplines. Section 3 describes skin detection methods. Section 4 is devoted to description of color spaces classification. Section 5 describes the current skin color modelling techniques. Section 6 describes issues with human skin detection and in section 7 issues specific to the detection of sub-continental skin are described. In Section 8 conclusions are drawn.

2. MULTIDISCIPLINARY APPLICATIONS OF SKIN COLOR DETECTION.

Human skin detection is quite rigorous part of state of the art applications in various disciplines. In [9] human skin detection technique is providing aid to augmented reality application. And in [7] and [8] researchers have made use of skin detection approaches for biometric identification applications. Moreover researchers have used skin detection to detect facial wrinkles and fixes to affected areas of face. Such application could be quite useful in cosmetic surgery [10]. In [10] researcher has introduced an algorithm for wrinkles curves and pattern matching for the purpose of face recognition. In [11] skin detection technique is used for body part and gesture identification.

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Some major applications of skin color detection are described in the table 1.

Sr No	Application	Domain
1	Assessment of facial wrinkles	soft biometric, use in cosmetic surgery
2	Facial analysis	Person Detection etc
3	Gesture analysis	Gesture Recognition, Robotic Control, Other Human Machine Interaction
4	Video surveillance Biometric Face Demonstrator	security in homes, banks, offices etc
5	un ethical online social networking, porn image detection porn video filtering etc	Cybercrime prosecution
6	Image content filter Content aware video compression	multiple uses in web and mobile platform
7	phothography tools	Entertainment, Showbiz, Advertisement industry

Table 1. Skin Color Detection Application Domains

3.SKIN DETECTION METHODS

Skin detection methods can be further classified as region based methods and pixel based methods. pixel based skin detection methods are primary focus of this paper. [1]

3.1.**Region Based Methods.** It is established on the basis of pixel based approach. It takes the spatial arrangement of neighboring pixels to improve performance of skin pixel detection. Moreover in this approach other information such as texture etc.. are also required. [1,2].

3.2.**Pixel Based Methods.** In this method each pixel is categorized in form of skin pixel and non-skin pixel apart from neighboring pixels. It is a standard binary classification problem where the input is a color vector and the output is a Pallet of skin and non-skin pixel groups, hence skin detection falls in the category of pattern recognition problems. Three major approaches for pattern recognition are statistical, neural and symbolical. Amongst three of these Statistical approach has been studied and applied most widely in skin detection based on color information [1]. Pixel based methods are fast in processing and more appropriate for different geometric patterns in skin color. Moreover as they are more sensitive to resolution changes hence they don't need the use of artificial colour signs in image.

4.COLOR CLASSIFICATION.

There are a couple of issues associated with color classification such as separation of skin and Non-skin areas, Illumination variation, variation in skin tones within and across individuals, color blurring due to object movement, different out put produced due to shadow or camera limitations [1,5,6]. Because there are a number of colour spaces available hence, the first and foremost problem is the selection of appropriate color space in an image processing domain i.e. what color space to be used? [1]. Popular color spaces groups are presented in following table 2.

Most of the research in detection and localization of faces is done using color of skin based on RGB, YCbCr and HSI color spaces. A brief detail of the most known is presented in the following sections.

SrNo	Colour Space Group	Colour Space Examples
1	RGB	RGB, Normalized RGB, XYZ, CIE
2	Perceptual Colour Spaces	HIS, HSV, HSL, TSL, TSV
3	Orthognal Colour Spaces	YCbCr, YIQ, YES , YUV
4	Perceptually Uniform Colours	CIELAB, CIELUV,CIE XYZ, CIE-xyY

Table 2. Popular Colour Spaces

4.1. **RGB.** It is most common color space for image representation. It was developed with CRT. RGB color space contains three additive primary colors, red, green and blue. These colors combine in different ratios additively to produce other colors. The RGB model has a 3 dimensional cube representation with red green and blue colors on corners of each axis as shown in Figure 1. In colored systems, 24 bit graphics contains 8 bits per color channel. In RGB color cube, red (255,0,0) is (1, 0, 0), blue (0,0,255) is (0,0,1) and green (0,255,0) is (0,1,0). Though RGB model is simplest and easiest method in implementation and also most widely used in image display devices but high association between its color components red, green and blue, increase difficulty in image processing algorithms. A lot of image processing techniques, for example histogram equalization works with the intensity component of an image. Hence due to mix chrominance and luminance data, it is not preferred for analysis and recognition of color in algorithms. [3,4,7]

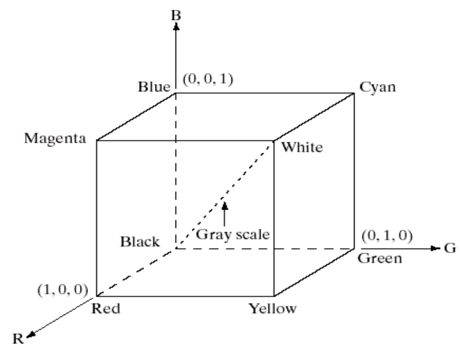

Figure 1. Schematic RGB Color Cube [17]

Chrominance is the color information and Luminance is the measurement of the brightness of light i.e. black and white image. In [2] Rehg and Jones have used this color space to study the possibilities of separation of the color space. But it is not preferred approach because of its high correlation between the color channels [3].

4.2. **Normalized RGB.** By normalizing luminance is separated from chrominance that is essentially required in color space detection. Normalized RGB is obtained by normalizing RGB value to their first normalization using the following equation. [1]

r= R/R+G+B , g=G/R+G+B, b=B/R+G+B [16]

4.3. **HSV, HSI, HSL (hue, saturation, value/intensity/luminance).** Hue describes the central color in pixle for example pink, green, purple etc. Saturation means the thickness of color i.e. measures the colorfulness. Hue & saturation taken together are called chromaticity and I or V is the intensity value associated with brightness. In figure 2 HIS model is shown. Agle from axis gives hue, length of vector gives saturation value. And height shows the resultant color.

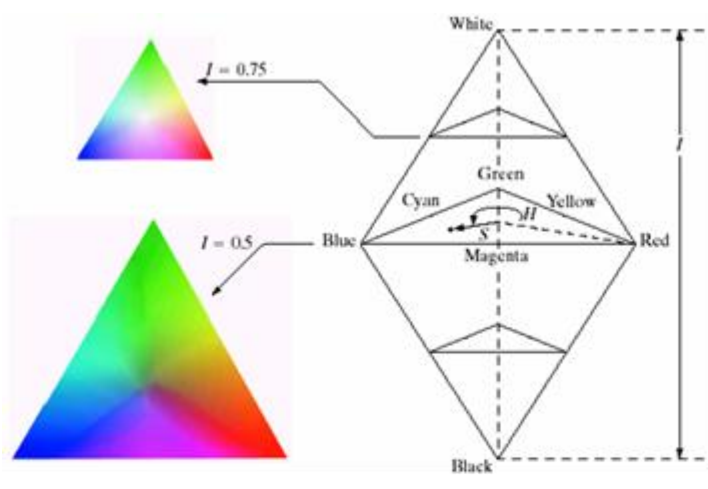

Figure 2. Double Hexcone Model of HSV[17]

The conversion of RGB to HSV is given by the following equations.

$$
\begin{aligned}
H &= \arccos \frac{\frac{1}{2}((R-G)+(R-B))}{\sqrt{((R-G)^2+(R-B)(G-B))}} \\
S &= 1-3\frac{\min(R,G,B)}{R+G+B} \\
V &= \frac{1}{3}(R+G+B)
\end{aligned}
$$

It is obvious that is has high cost of conversion. Secondly pixel with large and small intensities is rejected becuse HS becomes unstable and removing illumination component might make it 2D. It is separable in chrominance and luminance and it is invariant to highlight, surface orientation etc.[1] there is no standard way to convert rgb to hsv. A no of equations exists to serve this purpose. Using this color space Qiong Liu et al [5] developed an algorithm for face detection with different sizes, angles and expressions under diverse illumination settings. And their approach was observed fast and accurate.

4.4. **Orthogonal Color Spaces (YCbCr,YIQ,YUV,YES).** These color spaces isolates RGB channels into chrominacity and luminancity information. YCbCr color space was defined in response to increasing demands for digital algorithms to handle video information, and is commonly used by European TV system. Luminance (Y) and chrominance (Cb and Cr) are used to represent this color space. It is popular due to explicit separation in chrominance and luminance and are useful in compression applications. YCbCr is digital color system, whereas YIQ and YUV fall in analog space category.[1,3,4]

Y= 0.299R+0.587G+0.114B.
Cb= B-Y
Cr= R-Y.

Equations above are referred from [1]

4.5. **Perceptually Uniform Color Spaces.** CIE-XYZ and CIE-xyY and CIE CUV and CIE LAB are most popular in this group. Both are device independent and Luminance and chrominance are also well separated, but are not preferred in skin detection due to its complexity and computational cost. [1]

5. SKIN COLOR MODELING

The purpose of any skin detection system is to differentiate between skin and non-skin pixels. So how exactly the colour distribution has to be modelled? it is done by defining a decision rule to discriminate skin and non-skin pixels. For this purpose usually a metric is defined, which is based in general on measurement of distance between pixel color and skin tone. Such a metric is defined by the skin color modelling methods. [1,4]. Most commonly used methods in this direction are described in this section.

5.1. **Explicitly Defined Skin Region:** This method explicitly defines the boundaries of skin cluster in some color spaces. Multiple ranges threshold values for each component of a color space are defined. Simplicity of this method attracts researchers. Many researcher have used this method due to its simplicity like [M.R. Tabassum. 2009], [Peer and others. 2003], [Ahlberg 1999], [Jordao and others. 1999] have used this technique [13,14,15]. The main challenge to this technique is to to find both good colorspace and adequate decision rules so that high recognition rates could be achieved. However this problem has been tried to solve by using machine learning algorithms to find both suitable colorspace and a simple decision rule that achieve high recognition rates [Gomez and Morales 2002]. M.R. Tabassum [5] has also used this method with a range table of threshold values to identify Asian sub-continental skin.

5.2. **Non Parametric Methods.** In this method skin distribution is estimated by training data without developing explicit model for skin color. As a result they are independent to the distribution shape in just theory. Normalized lookup tables based on Histogram model, Bayes classifier and Self Organizing Map (SOM) classifier are the popular examples. Main advantage of this technique is that it takes less time in training, and are theoretically independent of shape of skin distribution in contrast to parametric skin modelling. But it has very high storage requirements in data training process and its performance is highly dependent upon representativeness of the training images set [4]

5.3. **Parametric Methods.** These require less training with data. Most popular methods are the single Gaussians model, mixture of Gaussians and Elliptical boundary model.[1,3,4]

In addition to parametric and non parametric some dynamic skin distribution models have been proposed in literature for face detection task in video because image analysis in video is different from static image analysis in many aspects. Most researchers have preferred paramtric methods as a base for dynamic skin models because it is fast and it is capable to adopt according to variation in distribution change, and requires less storage space. [1,4]

6. IDENTIFIED ISSUES WITH SKIN DETECTION

One major issue in skin detection is that most of methods produced are not intelligent enough to differentiate skin color like background or skin like objects in the image from human skin. If an approach detects some portions of non-skin images as a skin area then this phenomena is called False Positives. Similarly if some skin areas could not be detected correctly as skin by a selected algorithm, then these are called False Negatives.[5]

Choice of an optimal Color space is a serious concern in color space but is very often addressed by researchers. A good skin classifier is needed for this purpose. A diversity range of classification techniques have been used by researchers for skin classification task. A skin classifier is used to establish a boundary to decide a skin color class in a chosen color space. If color of any pixel falls inside the skin color class boundary is labeled as skin. Hence, the selection of skin classifier is strongly effected by the skin class in the color space. If skin shape is more simple and regular then color classifier is also very simple and vice versa.[3,4]

Most convenient method to identify a pixel as skin is to explicitly define a boundary. Brand and Mason [7] proposed one-dimensional easy skin classifier. According to their method a lower and upper bound is defined and if the ratio between R and G channels of a pixel is between defined lower and an upper bound then pixel is categorized as skin pixel[17].

In [1] C. Prema has generated a table for performance evaluation for different skin classifiers is given that evaluates performance using True Positive Rate named as (TPR), True Negative Rate called (TNR), False Positive Rate named as (TPR), and False Negative Rate as (FNR). Moreover C. Prema summarized literature based on color space transformation, classification method and the true and false positives (TP & FP) [1]. Survey presented in [1] resulted that when preprocessing is not needed then hybrid approach is better. In table 3 comparison of most three popular color spaces is presented.

Color Space	Advantages	Disadvantages
RGB	1. Simplest method 2. suitable for video display	1. Sensitive to illumination intensity. 2. High correlation between color channels 3. Device Dependent
HSV	1. Good with histogram operations 2. Separates the chromatic part from achromatic part 3. Easy human perception	1. perceptual relevance for computation speed 2. User oriented-Device dependent 3. sensitivity to value RGB value deviation 4. un stable hue, because of the angles
YCbCr	1. Separated chrominance and luminance 2. Good for image compression	1. Device Dependent 2. Depends on the RGB primaries

Table 3. Comparison of Color Spaces

7. IDENTIFIED ISSUES WITH SUB-CONTINENTAL SKIN DETECTION

Human skin comprises of substantial level of red color and Yellow color for melanin[5]. Density plots of African, Asian and Caucasian skin is not same in a selected color space. That's why different color ratios are used to detect skin of different human races.

Brand and Mason [7] concluded from their experiments that combinations of color ratios (R/G + R/B = G/B) provide better result than individual ratios. Similar research in this direction concluded that the combinations of HSV-rgb-TSL are more useful to detect a mixture of Asian, Caucasian and Black skins and excluding glass and hair.

M.R. Tabssum [5] describes that most of the research completed in skin detection domain is performed on data sets of Black, European or East Asian skin, but South Asian skin especially skin from the region of sub continent is heavily ignored in experiments[5].

In [5] researchers have performed a comparative analysis between HSV, YUV, YIQ methods. Further they have tested these approaches using image sets of sub-continental skin images. They have tried to enhance the detection criteria, and have find out little bit effective parameters for skin area detection in indian skin images. Further researcher concluded through experiments that HSV color model based approach yielded better result for Indian sub-continental skin detection. They resulted true positives in 91.1% whereas true negatives were 88.1%. In table 5 I have summarized the performance evaluation of different researchers with different color spaces for skin detection combined with the criteria type of the skin. Besides these a lot of literature was found with skin detection evaluation but experiments with Asian skin color detection are very few.

Researchers work is summarized and classified based on skin type, True and Fals positive rates and color space used in following table 4.

Sr No	Researcher	Color Space	Skin Types	TP	FP
1	Jones and Rehg [1999]	RGB	Non-Asian	80%	8.5%
2	Brand and Mason [2000]	RGB	Non-Asian	93%	19.8%
3	M.R Tabassum et al [2010]	YIQ HSV YUV	Asian		
4	S. Singh et al [2003]	RGB HIS YCbCr	Asian	-	25.45% 14.5% 12.82%
5	Jones & Rehg [2002]	RGB	Non-Asian	-	-

Table 4. Performance Overview of Researchers On Different Skin Detection Methods

```
function [ output_args ] = samplehsv( f, T1,T2 )
        W = imread(f);
        W=double(W);
        k = imfinfo(f);
        for a = 1 : k.Height
        for b= 1 : k.Width
          mx = max(max(W(:,:,1), W(:,:,2)), W(:,:,3));
          mn = min(min(W(:,:,1), W(:,:,2)), W(:,:,3));
          lemda = mx- mn;
          if (mx == W(a,b,1))
            h = (W(a,b,2) - W(a,b,3));
          else if ( mx == W(i,j,2))
            h = 2 + (W(a,b,3)- W(a,b,1))/lemda;
          else
            h = 4 + (W(a,b,1)- W(a,b,2))/lemda;
           end
          end
          h = h* 60;
          if(h<0)
            h = h + 360;
          end
          if( T1 <= h && h <= T2 )
            segment(a,b)=1;
          else
              segment(a,b)=0;
          end
          end
        end
        im(:,:,1)=W(:,:,1).*segment;
        im(:,:,2)=W(:,:,2).*segment;
        im(:,:,3)=W(:,:,3).*segment;
        figure,imshow(uint8(im));
        end
```

```
function [ output_args ] = sampleyuv( f, T1,T2,T3,T4,T5,T6 )
        W = imread(f);
        W=double(W);
        k = imfinfo(f);
         y = 0.257 * W(:,:,1) + 0.504 * W(:,:,2) + 0.098*W(:,:,3) + 16;
         u = -0.148* W(:,:,1) - 0.291* W(:,:,2) + 0.439* W(:,:,3) + 128;
         v = 0.439* W(:,:,1) - 0.368* W(:,:,2) - 0.071* W(:,:,3)+128;
        for a = 1 : k.Height
        for b = 1 : k.Width
         if ( T1 <= y(a,b) && y(a,b) <= T2 && T3 <= u(a,b) && u(a,b) <= T4 && T5 <= v(a,b)&& v(a,b) <= T6 )
             segment(a,b)=1;
          else
             segment(a,b)=0;
          end
        end
        end
        % imshow(segment);
        im(:,:,1)=W(:,:,1).*segment;
        im(:,:,2)=W(:,:,2).*segment;
        im(:,:,3)=W(:,:,3).*segment;
        figure,imshow(uint8(im));

        end
```

Table 5. Matlab Skin Detection Code based on technique presented in [5]

In table 5, I have presented matlab code presented in [5] and after testing with different skin image sets HSV based approach outperformed as compared to YUV based approach for sub-continent skin type. Improvement in skin detection filters is required to detect Pakistani and indian skin as results are shown in figure 3.

Figure 3. Sample output images of HSV based technique

8. CONCLUSION

In the current era of internet advancement in skin detection methods is needed in multiple disciplines. In this paper, application areas are highlighted and techniques of color based skin tone detection are also presented. A good classifier plays vital role to differentiate skin and non skin pixels in variety of skin images with different skin types such as pink, yellow, white, dark brow and light brown. A lot of work is done in all skin types but experimental shortcoming is observed with subcontinenetal skin type detection. Moreover in real time applications, issues of computational cost and memory requirements are also extremely important. Researcher from Tabassum [5] have shown remarkable results regarding detection of sub-continenetal skin detection. But still a lot of experimental evidence and improvement is required as subcontinent is a crowded region of earth with millions of applications and internet users. To work on the robustness of the sub-continental skin color detection methods is the need of the time in existing circumstances and a room of improvement is required in this domain.

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