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A HYBRID APPROACH TO HUMAN SKIN REGION DETECTION

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Abstract
Face recognition is important in research areas like machine vision and complex security systems. Skin region detection is a vital factor for processing in such systems. Hence the proposed paper focuses on isolating the regions of an image corresponding to human skin region through the hybrid method. This paper intends to combine the skin region detected from RGB and YCbCr color spaces image by the explicit skin color conditions and the skin label cluster identified from CIEL*a*b color space image, which is clustered by Hillclimbing segmentation with K-Means clustering algorithm. Then the resultant image is dilated by arbitrary shape and filtered by the median filter, in order to enhance the skin region and to avoid the noise respectively. The proposed method has been tested on various real images, which contain one or more human beings and the performance of skin region detection is found to be quite satisfactory.

Keywords:
Color Spaces, Dilation, HillClimbing Segmentation with K-Means, Median Filter

1. INTRODUCTION

Skin-color modeling is a crucial task for several applications of computer vision and one of the most successful applications is face recognition which has recently received significant attention, especially during the past several years. Typical applications are Biometrics, Information Security, Law Enforcement and Surveillance, Smart Cards and Access Control [1]. Face recognition research can be based on stills and videos. The factors of challenges associated with face detection are Pose [2], Presence or Absence of structural components [3], Facial expression [4], Occlusion and Image orientation. Morphological Image Processing (MIP) method is needed to satisfy these challenges. MIP refines the image, eliminates noise, cleans up the image. Example: Dilation and Erosion, Hole filling and Shrink. Face recognition can also be used with the Skin-tone approach and Twinkle approach, which follows the statistical approach [5]. Statistical approach uses two independent techniques based on skin color model by histograms and skin color distribution as a Gaussian. By combining color thresholding, skin color density estimation and skin region growing, we can detect the skin color from complex background natural images [6]. Other approaches to detect human skin are thresholding and segmentation-based.

Human skin color has been used and proven to be an effective feature in the applications of face detection and robust visual cue for detection. Skin color model can be mainly categorized into two types namely parametric and nonparametric. Gaussian or mixture of Gaussian distributions and elliptic boundary models are parametric approach. Histogram-based models and Neural networks are nonparametic approach [6].

However, Color plays an important role in the detection of skin color or faces in images. Skin color is often very different than the surrounding colors in an environment. There are a variety of color spaces available. Also, no one color space provides satisfying results for the segmentation of all kinds of images [7]. In that RGB [8], YCbCr [9], [12], CIEL*a*b [10] are most commonly used for face recognition applications. CIEL*a*b color space is used to obtain the improved performance of skin color segmentation among other color spaces. The performance was measured using metrics, single color component, color without luminance and color with luminance in six different color spaces of 40 evaluations [11].

In brief, the following steps are performed in the proposed method. As the first step, the input color image skin color is detected by the (R, G, B) skin color conditions and also input image can be converted into YCbCr and CIEL*a*b color spaces. In the second step, skin color is detected from YCbCr color space by skin color conditions. The third step, HillClimbing segmentation with K-Means clustering can be used to the CIEL*a*b color space, in order to identify the label of the skin color region. The Fourth step, Hybridizes the above segmented outputs. Finally, Dilation and Median filtering are applied to the output segmented image.

This paper is organized as follows: Literature review and color space are described in the second and third section respectively. The fourth section gives the details of the skin region segmentation. The fifth section describes the hybrid method. The sixth section shows the experimental results and discussion. Finally, the conclusion and future work is presented.

2. LITERATURE REVIEW

Reference [2] shows the video based human pose tracking in Monocular sequence using Multilevel Structured Models. In that, three stages of approach was followed and it enables a hierarchical estimation of 3D body poses. In the three stages humans were tracked as foreground blobs, human parts such as face, shoulders and limbs were detected by Skin blobs and 3D body poses estimated by data-driven Markov chain Monte Carlo.

As in [3], an automatic facial feature extraction technique based on the topological properties of the human face was presented. The curvature measure was used to extract the ravine points such as eyes and mouth. The regular surfaces were measured by a linear operator called the shape operator.

Reference [5] is also based on the video based images. The statistical approaches namely conditional probabilities and Bayesian classification were applied to detect the skin. Then the post processing operations of morphological dilation and erosion operation were performed.

Reference [6], Skin seed was detected with histogram. The density of the skin seed's color distribution was estimated by using Mean Shift approach. The experiment was carried out to different illumination conditions of natural images with complex background.

Reference [7], Hybrid color space determined by means of a supervised learning scheme. It lists out the major drawbacks and clearly shows, how to increase the performance of the classification scheme by means of 3D-histogram analysis.

Reference [10], Cluster based technique was built to detect skin areas. K-Means clustering algorithm under cityblock distance measures was applied to cluster the given image. From the resulted labelled image, the skin pixels were identified and then skin pixel objects were identified.

3. COLOR SPACE

A Color space is a method by which we can specify, create and visualise color. As humans, we may define a color by its attributes of brightness, hue and colorfulness. A computer may describe a color by using the amounts of red, green and blue phosphor emission required to match a color.

Nowadays, color processing is a very important tool in image processing and is widely used as a low level feature or as decomposition tool through image segmentation. Image segmentation may be defined as the process of dividing an image into disjointed homogeneous regions. These homogeneous regions usually contain similar objects of interest or part of them. The extent of homogeneity of the segmented regions can be measured using some image property (e.g. pixel intensity [13]). The performance of segmentation methods is based on clustering and is directly related to the shape and the center position of each cluster. Also appropriate color space must be selected.

In this proposed paper, three color spaces namely RGB, YCbCr and CIEL*a*b color spaces are selected for segmentation process. The first two color spaces namely RGB and YCbCr uses the skin color condition to segment the skin region. The third color space called CIEL*a*b color space uses HillClimbing segmentation with K-Means clustering algorithm to segment the regions. The image segmentation algorithm can be treated as a clustering problem where the features describing each pixel correspond to a pattern, and each image region (i.e. a segment) corresponds to a cluster [13]. Therefore many clustering algorithms have widely been used to solve the segmentation problem. The process of segmentation by each color space is clearly explained in the next section.

4. SKIN REGION SEGMENTATION

4.1 RGB BASED SEGMENTATION

To represent colors, the most common color space is probably the RGB color space, where the three primary colors Red, Green and Blue take their values between 0 and 1 or between 0 and 255. The lack of color ("black" color) is symbolized by the triplet (0, 0, 0). On the other hand the point (255, 255, 255) corresponds to the maximum of color ("white" color). The representation of the colors in this space gives us a cube (Fig. 1).

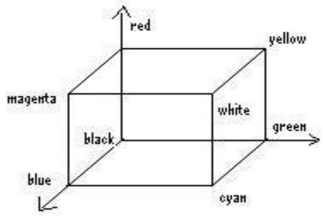


Fig.1. The RGB color space

This space is widely used in color histograms [14] where the pixels are distributed on the three axes R, G and B. RGB color space is far from perceptual homogeneity and, as such, its quantization produces perceptually redundant bins and leaves perceptual holes. Therefore, any ordinary distance function defined in this space will be unsatisfactory. Also it has the weakness that equal distances in the RGB color space may not correspond to equal distance in color perception.

The RGB skin color detection is based on the following set of conditions [8], [9]: (R, G, B) is classified as skin.

In case of uniform daylight illumination

$$\begin{aligned} &R > 95 \ AND \ G > 40 \ AND \ B > 20 \ AND \\ &\max\{R,G,B\} - \min\{R,G,B\} > 15 \ AND \\ &|R-G| > 15 \ AND \ R > G \ AND \ R > B. \end{aligned} \qquad (1)$$

where R, G and B are the components of RGB color space.

In case of under flashlight or daylight is called lateral illumination

$$\begin{aligned} &R > 220 \ AND \ G > 210 \ AND \ B > 170 \ AND \\ &|R-G| \leq 15 \ AND \ R > G \ AND \ G > B. \end{aligned} \qquad (2)$$

where R, G and B are the components of RGB color space.

(a) (b)

(c) (d)

(e) (f)

Fig.2. (a), (c), (e) Original image
(b), (d), (f) RGB based segmented image

Fig. 2 (b), (d) and (f) images are obtained from the skin conditions of the RGB color space. i.e., Eqs. (1) & (2) were applied to the original images with the logical OR operation.

4.2 YCbCr BASED SEGMENTATION

This is the international standard for digital coding of TV pictures at 525 and 625 line rates. It is independent of the scanning standard and the system primaries, therefore there are no chromaticity co-ordinates, no CIE XYZ matrices and no assumptions about white point or CRT gamma. The skin color can be accurately represented by independent of luminance within a small range of chrominance. In this proposed method we use the YCbCr color image, because the Cr and Cb (Chrominance) components are independent of the skin color. The main advantage of this method is the simplicity of the skin detection rules, which permit a fast classification of pixels. The major drawback is the difficulty in finding both robust color spaces and reliable decision rules for a convenient skin detection. Nevertheless, for any color space, the problem to be solved can be summarized as: finding the optimal bounding limits for robust skin color detection. The range of chrominance for skin gives a rectangular region spanning

$$77 \le Cb \le 127 \ AND \ 122 \le Cr \le 173 \quad (3)$$

where Cb represents the difference between the blue component and a reference value and Cr represents the difference between the red component and a reference value.

(a) (b)

(c) (d)

(e) (f)

Fig.3. (a), (c), (e) Original image
(b), (d), (f) YCbCr based segmented image

In order to obtain the skin region of YCbCr color space, first the input RGB color image is converted into YCbCr color image using Image Processing Toolbox by color space conversion method. Then Eq. (3) is applied to the converted image for detecting the skin region. Fig. 3 (b), (d) and (f) shows the skin region detected by the YCbCr based segmentation.

4.3 CIEL*a*b BASED SEGMENTATION

CIEL*a*b defines colors more closely to the human color perception and the system is often used in the quality control of colored products. This is a uniform chromaticity color space. It is known that Euclidean distance of two colors is proportional to the difference that human visual system perceives in the CIEL*a*b color space. Fig. 4 shows the relation between color difference measure values vs. Euclidean distance in color space.

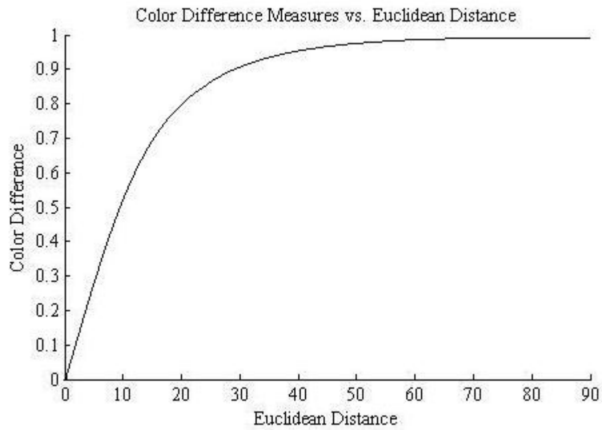


Fig.4. Color Difference vs. Euclidean Distance in Color space

Generally the image is composed of RGB color components. So, convert RGB color components to CIEL*a*b color components, by using the following equations [11].

$$L = \begin{cases} 116(Y/Y_n)^{1/3} - 16 \ ; Y/Y_n > 0.008856 \\ 903.3(Y/Y_n) \ ; otherwise \end{cases} \quad (4)$$

$$a = 500[f(X/X_n) - (Y/Y_n)] \quad (5)$$

$$b = 200[f(Y/Y_n) - (Z/Z_n)] \quad (6)$$

Where

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.412453 & 0.357800 & 0.180423 \\ 0.212671 & 0.715160 & 0.072169 \\ 0.019334 & 0.119193 & 0.950227 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (7)$$

and

$$f(t) = \begin{cases} t^{1/3} & ; t > 0.008856 \\ 7.787t + (16/116) & ; otherwise \end{cases} \quad (8)$$

Here *L* component is the lightness of color, *a* component represents its position between red/magenta and green and *b* component represents its position between yellow and blue. *X*, *Y* and *Z* are the tristimulus values of CIEXYZ Color space and *R*, *G* and *B* are the components of RGB Color space.

The converted CIEL*a*b color image is segmented by HillClimbing segmentation with K-Means clustering. The object based identification is very important in skin color detection. In general, HillClimbing algorithms work by starting at a random point in an N-Dimensional search space and moving in the direction of the maximum gradient until it converges to an optimal point. It tries to move an object to another cluster. Hence it is used in the proposed method.

Here, HillClimbing segmentation is used to create each of the three channels in the 3D color histogram of CIEL*a*b color space and its number of histogram bins in each dimension was set to 10. The outputs of the HillClimbing algorithm were the number of local peaks of the image. These peaks can be used as the number of clusters in the K-Means clustering. K-Means is a popular unsupervised learning algorithm for finding clusters and cluster centers in a set of unlabeled data. K-Means uses the following steps:

Step 1: Define k centers, one for each cluster.

Step 2: Each point is assigned to the cluster with the smallest distance.

Step 3: Once all points are assigned, recalculate the cluster centers.

Step 4: Repeat steps 1 to 3 until no more changes are done. In other words centers do not move any more.

Finally, K-Means clustering algorithm produces the labelled image. The sample segmented images obtained from K-Means clustering method is also shown in Fig. 5(b), (d) and (f).

Fig.5. (a), (c), (e) Original image
(b), (d), (f) CIEL*a*b based segmented labeled image

These labels are more close to human color perception. The label of the skin region identified and the proposed method applied on the labelled image.

5. HYBRID METHOD

An overview of the proposed method can be illustrated in Fig. 6, the steps in which will be further explained.

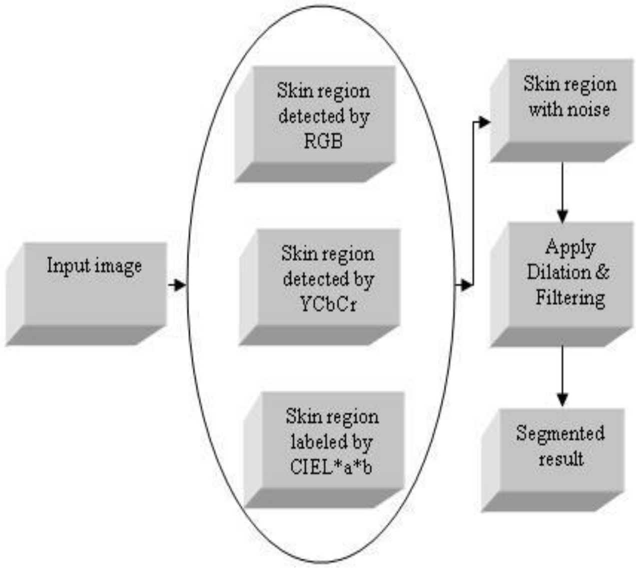


Fig.6. Overview of the proposed method

In the above discussed methods, they fail to locate the skin region from the input color image for different reasons. Therefore, the proposed method is to combine the three color space segmentation methods in a systematic way to overcome the weaknesses of the individual methods and result in a method that is more accurate than each of the individual methods.

The first two methods were segmented with the skin color conditions. The first method is sufficient to detect skin patches. However, image presented in Fig. 2 (b), (d) and (f) is generating the holes in skin patches. Also the detected skin region of the image includes some non-skin region too, like the background region, hair region and eye region of the image. Hence RGB based segmentation has not clearly detected the skin region of the image alone. The second method, YCbCr color space based segmentation (Fig. 3 (b), (d) and (f)), which produces more skin region compared with RGB based segmentation. But it also includes more non-skin regions too, like RGB based segmentation.

The third segmentation method is based on CIEL*a*b color space. The image objects were identified by applying HillClimbing segmentation with K-Means clustering algorithm. The different labels of the segmented image illustrates the objects of an image (Fig. 5 (b), (d) and (f)).

The hybrid of RGB, YCbCr skin colored region and CIEL*a*b labelled skin region produces more skinned region of the image. To enhance the skin region boundaries, dilation of arbitrary shape can be applied. The resulting image would be more informative than any of the input images. Actually digital images are prone to a various types of noise and different methods are better for different kinds of noise. The methods are Linear, Median and Adaptive Filtering. Linear filter is useful for removing grain noise from a photograph. Adaptive filtering is based on local image variance. Whereas Median filtering is set to an average of the pixel values in the neighbourhood of the corresponding input pixel. The value of an output pixel is determined by the median of the neighbourhood pixels, rather than the mean. Also it is better able to remove the outliers without reducing the sharpness of the image. Hence the proposed method detected is only more skinned region of the image. Example images are illustrated in Fig. 7.

The algorithm of the proposed method is as follows,

Algorithm

Input: RGB color image

Output: Segmented skin region of the input image

Begin

Step 1: Input RGB color image of size N x M.

Step 2: Apply the Eqs. (1) & (2) to the input image with logical OR operation and the resulted image as skin region segmented image.

Convert the input image into YCbCr and CIEL*a*b color space by applying color space conversion function and the equations discussed in section 4.3 respectively.

Step 3: Apply the Eq. (3) into YCbCr color image and the resulted image as skin region segmented image.

Step 4: HillClimbing segmentation with K-Means clustering algorithm is applied to the CIEL*a*b color image and the skin region label is identified.

Step 5: Hybrid method is applied to the segmented and labelled image, obtained from the above steps.

Step 6: Finally, Dilation and Median filter can be applied to the hybridized image for enhancement and denoise respectively.

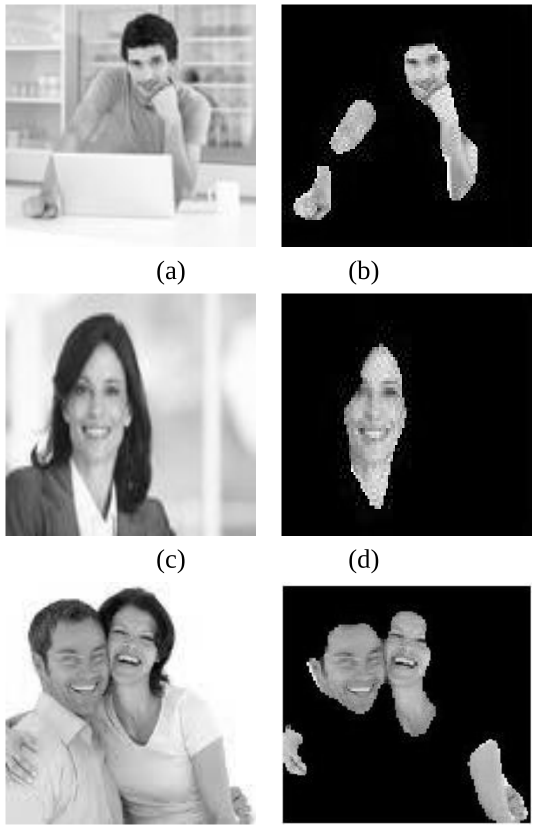
End

6. EXPERIMENTAL RESULTS AND DISCUSSION

This section presents some experimental results obtained by our human skin detector and was implemented with Matlab 7.0 on a 2.4 GHz Pentium IV machine running on 256MB RAM using the image processing toolbox and clustering algorithm.

The proposed Hybridized segmentation method has been experimented with 170 different images and the results are reported in this section. The test images are of size (N x M), where N, M values is taken as less than or equal to 512. One such image is shown in Fig 2 (e). This image is segmented with the threshold (logical OR operation of the Eqs. (1) & (2)) values of the skin region of the RGB image and the segmented image is shown in Fig. 2 (f), which includes non-skin regions and noise. Then the original image is applied to the color space conversion into YCbCr and CIEL*a*b color spaces. When the segmentation on YCbCr image with the threshold (Eq. (3)) values of the skin region is performed, this segmented image contains the non-skin regions of the image, but produces higher skin region than RGB based segmentation. The segmented image is shown in Fig.3 (f). In order to improve the detection of human skin region of the image, CIEL*a*b based segmentation is performed by HillClimbing segmentation with K-Means clustering algorithm. The objects on the image are identified with different label values and the labelled image is shown in Fig. 5 (f).

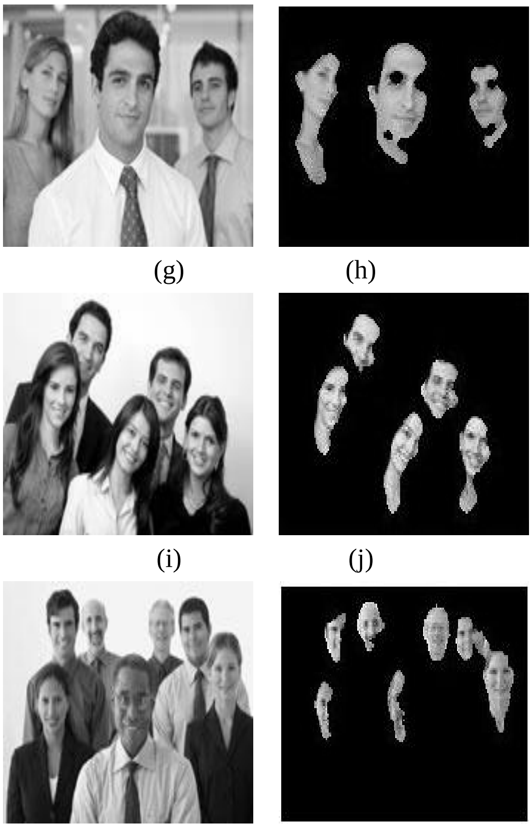
Hybridization is performed on the RGB, YCbCr based segmented images and CIEL*a*b based skin labelled image. The output image is more informative than any of the input images. At last, Dilation of arbitrary shape and Median filter is applied on the hybridized image. The resultant image produces more skinned region. The same experiment is repeated for different images and some of the results obtained by our proposed method are shown in Fig.7. However, the proposed method is somewhat not to detect the teeth segment and reduce the segment of skin region. For example, Fig. 7 (d), (f) resultant image includes the teeth segment, due to its brightness and Fig. 7 (l) resultant image skin region has been reduced, due to high intensity variation in the skin segment and the small skin patch.



(a) (b)

(c) (d)

(e) (f)



(g) (h)

(i) (j)

(k) (l)

Fig.7. Proposed method results
(a), (c), (e), (g), (i), (k) Original image
(b), (d), (f), (h), (j), (l) Hybridized skin region segmented image

Hybridized segment images are more refined than the one that is obtained from RGB, YCbCr and CIEL*a*b based segmentation discussed in the fourth section. The individual segmentation method produced non-skin regions like hair, eyes, background, etc. and the images also have noise. Therefore the output of the individual segmentation method is not upto the expected results. From the experimental results it is evident that the proposed hybridized segmentation method provides more accurate skin region than the skin detector designed in [10], [12].

Table.1 shows the efficiency (in seconds) of the proposed method by the sample images in terms of duration of execution taken to form the clusters by HillClimbing segmentation and to detect the skin regions by the hybrid method. This table also includes the frame buffer consumed (in bytes).

Table.1. Efficiency of the proposed method

Images / Measures	Fig. 2(a)	Fig.2(c)	Fig.2(e)
Size	110x101	100x67	170x120
Number of Clusters formed	4	7	7
Cluster formation duration	1.203	1.062	1.328
Total elapsed duration	1.484	1.421	1.875
Memory space consumed by resultant matrix	33330	24090	42090

Table.2 shows the region detection performance based on the above discussed methods and the performance measured is based on the detection of the different regions in an image.

Table.2. Region detection performance

Region	RGB	YCbCr	CIEL*a*b	Proposed
Hair	ND	ND	PD	D
Eye	ND	ND	PD	D
Wood	PD	ND	ND	D
Background	PD	PD	D	D
Skin	PD	PD	PD	D

In the above table, D represents Detected, ND represents Not Detected and PD represents Partially Detected.

7. CONCLUSION AND FUTURE WORK

This paper presented a new method to detect the human skin region from the real color images using hybrid method. This method combined the results obtained from three different color spaces. Here K-Means clustering algorithm, Hybrid method, Dilation and Median filtering made the process robust. Results of the skin region detection have shown that the proposed method offers high accuracy and speed in a large variety of images, since it consumed less memory space for frame buffer. In future work, the skin region detection makes use of spatial and texture information. Then the results will be integrated into pixel features for clustering and the segmented images will be used for hybrid.

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