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Evaluation of suitable color model for human face detection

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ABSTRACT

Skin color as a technique for face detection is a technology applied in many applications such as pornography filtering, human-computer interaction, and face recognition systems. A human face detection approach is presented in this paper using the skin color segmentation algorithm. Choosing appropriate color model is very important to increase algorithm efficiency. Yet, there is no conclusion about which color space is the best fit for skin color detection. The motivation is to provide a platform to decide which color model is the best to build efficient skin color detector that can improve the overall face detection system. The proposed technique is based on finding the maximum energy of histogram signal for skin which is limited to the ranges for each component of the color space under study. Different parameters such as energy of the histogram of each component of the color space, the limit of skin range in each color space and the maximum energy of the color spaces are used to evaluate the result. The result indicates that YCbCr provide better performance compared to RGB, YUV, HSV and CMYK color model. A detection rate of 97.51% was obtained using PICS database.

1. Introduction

Face detection involves determining the presence and location of the face in a given image. It is a prerequisite for feature extraction and face recognition systems. Application areas such as video conferencing, intelligent human-computer interfaces, passport authentication require face detection. An efficient face detection algorithm should be robust to occlusion, pose, expression, and illumination variations. These variations degrade the performance of face detection algorithms (Mohamad and Sufyanu, 2015; Yusuf et al., 2014). Several algorithms such as Skin color, Neural Network (NN), Linear Discriminant Analysis (LDA) and Principal Component Analysis (PCA) are used to handle those problems which occur during face detection (Aldasouqi and Hassan, 2011).

Skin color segmentation technique has been widely used because (i) it is fast, simple and has low computational cost, (ii) it is invariant to image sizes and orientation (iii) it gives extra dimension compared to grayscale methods and (iv) can classify entire image into face and non-face region (Kumar, 2014).

Face detection using skin color involves representing the facial image into skin and non-skin pixels. This is achieved by choosing appropriate color model. There is different skin color models used for skin color segmentation such as Red Green Blue (RGB), Hue Saturated Intensity (HSI), Chroma: Blue; Chroma: Red (YCbCr), Cyan Yellow Magenta and blacK (CMYK) (Kumar, 2014). But choosing the best model, whose performance is better for efficient face detection, is a difficult task since some of the original colors in an image might not be suitable for analysis. Hence, they need to be adjusted by transforming colors from one color model to another while maintaining the image's natural looks and original details at the same time (Liu, 2012). Additionally, there are no standard databases for the benchmark comparison.

The aim of the study is to select suitable color model and determine its proper range for human face detection. The performance of the technique should be compared with other previous works.

The rest of the paper is arranged as follows; section 2 describes the selection process of the color model used for skin detection. Section 3 states the methods used in the study. Results and discussion are given in section 4 and conclusion is drawn in section 5.

2. Color model selection process

A literature of some research work is presented to identify the best color model for a specific task,

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since no consensus on the suitable color model for image segmentation. For example, a comparative study (Jurio et al., 2010) was carried out between the various color spaces in cluster based image segmentation using two similar clustering algorithms. Their study involved the test of four color models namely, RGB, HSV, CMY, and YUV to identify the best color representation. They obtained good result using HSV color spaces, while CMYK presented the best results in most cases. Busin et al. (2008) proposed a technique that selected a specific color model based on a spectral color analysis. This criterion evaluates the quality of the segmentation in each color model and selects the best approach. The research shows that the choice of the color space depends on the image to be segmented. Ghotkar and Kharate (2012) described a hand segmentation method by using a threshold technique for hand gesture recognition. They made a comparison between HSV, HSL, and HTS color spaces. HTS gave better results than the others.

For the purpose of face recognition, the research conducted by Liu and Shih (2006) shows that color models such as YCbCr and YIQ, are suited to the recognition. Another study of the ten most common color spaces for skin color detection was presented in Chaves-Gonz´alez et al. (2010). They concluded that HSV is the best color space to detect skin in an image. And YCbCr color model is compared against YIQ in Sagheer and Aly (2012), then with RGB, HSV, YIQ, and YUV in Ketenci and Gencturk (2013) and with HSV in Wijaya et al. (2015). The YCbCr emerged as the best color model for skin color detection.

YCbCr color model has been defined in response to increasing demands for digital algorithms for handling video information and has become a widely used model in a digital video. It belongs to the family of television transmission color models. Other members of the family include YUV and YIQ. YCbCr is a digital color system while YUV and YIQ are analog spaces for the respective PAL (Phase Alternating Line) and NTSC (National Television System Committee) systems. These color spaces separate RGB into luminance and chrominance information and are useful in compression applications though, the specification of colors is somewhat unintuitive.

In this study, we adopt YCbCr color space for skin color detection for the following reasons;

i. Its space format removes brightness component from the color components which makes it robust against changing intensity.
ii. Its principle is similar to the procedure of human visual perception.
iii. Space format of YCbCr color is commonly used in TV display area. It is also used in video compression coding such as Motion Picture Expert Group (MPEG) and Joint Photographic Expert Group (JPEG).
iv. Its representation of spatial coordinates and space format's calculation process are easier compare to other color models.
v. Clustering characteristics of skin color is better in YCbCr color room. RGB color space and YCbCr color space can transform from one other. Hence, it is very attractive for skin face detection.

In YCbCr color space, Y component represents the luminance information; Cb component represents the blue chrominance information and Cr component represents the red chrominance information.

In our approach, parameters such as energy of the histogram of each component of the color space, the limit of skin range in each color space and the maximum energy of the color spaces are used to determine the suitable color model for face detection.

3. Methodology

By default images are represented in RGB space color. The problem is that RGB is significantly affected by illumination and pose changes. So, there is need to transform the images from RGB to YCbCr color space to separate the luminance and chrominance information. We used equation 1 for the transformation.

$$\begin{bmatrix} \mathrm{Y} \\ \mathrm{Cb} \\ \mathrm{Cr} \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.500 \\ 0.500 & -0.419 & -0.081 \end{bmatrix} \begin{bmatrix} \mathrm{R} \\ \mathrm{G} \\ \mathrm{B} \end{bmatrix} \quad (1)$$

To determine the appropriate range values of skin color, we choose a set of database under study. And then define the facial parts manually as well as calculating the histogram of color components. Fig. 1 represents samples of faces randomly obtained from Psychological Image Collection at Stirling (PICS) database and the skin areas are manually detected using Photoshop software. Histogram of R, G and B components for skin is wide and difficult to be confined in RGB color model. Therefore, other color spaces are preferable for appropriate color space which may define and detects skin optimally. We found a huge contrast of Cb and Cr values in YCrCb color space comparing to the contrast of R, G, B values in RGB color space. In the case of images with low illumination in the database, we select a set of images and then determine the Cb and Cr range.

Fig. 1: Manually detected faces from PICS database

The proposed technique is based on finding the maximum energy of the histogram signal for skin which is limited to the narrowest possible ranges for each component of the color space under study. Firstly, we need to find the histogram signal of each component of the image after ignoring the black color. Then the histogram is divided by the number of skin pixels to avoid the effect of image size during the comparison and concluding results. And also ignore some anomalous values that may be located on the outskirts of the signal histogram and finally conclude the average energy in this range. The maximum value is calculated by taking the cube root of average component energy (see equation 2).

$$AE'(Cm) = \sqrt[3]{\prod AE(Cm(Cmp_i))} \quad (2)$$

where

$$AE(Cmp) = \frac{Energy'(Cmp)}{\beta_2(cmp) - \beta_1(cmp)} \times 256$$

$$Energy(Cmp) = \sum_{.}^{.} H'(Cmp(i)^2)$$

4. Results and discussion

The experimental result was conducted on 2D face Iranian woman sets, Psychological Image Collection at Stirling (PICS). This database has 369 images; the size is 1200×900, 34 women, mostly with smile and neutral in each of five orientations. The For the experiment purpose Matlab software was used on a personal computer with the following specifications; Intel Celeron 1.0 GHz processor and 2.00 GB DDR3 RAM. Table 1 depicts the results of the comparison of RGB, CMYK, HSV, YUV, and YCbCr color models (Cm). Different parameters such as the components of each color space (Cmp), energy of the histogram of each component of the color space (Energy), β_1 and β_2 are the ranges while ($\Delta\beta$) is the limit of skin range in each color space. The maximum energy of the color spaces (EA') are determined and presented in the Table 1.

Table 1: Evaluation of range skin threshold and proper color model

Cm	Cmp	Energy	β_1	β_2	$\Delta\beta$	Energy '	EA	EA '
RGB	R	0.0112	168	255	87	0.0096	0.0350	1.27e-05
	G	0.0078	112	210	98	0.0074	0.0190	
	B	0.0079	77	176	99	0.0075	0.0191	
YUV	Y	0.0081	127	220	93	0.0077	0.0208	6.79e-04
	U	0.0179	34	77	43	0.0170	0.0985	
	V	0.0328	25	47	22	0.0309	0.3315	
HSV	H	0.0508	10	24	14	0.0483	0.8160	0.0012
	S	0.0121	74	140	66	0.0115	0.0437	
	V	0.0112	186	255	69	0.0096	0.0350	
CMYK	M	0.0211	34	70	36	0.0201	0.1385	3.06 e-04
	Y	0.0132	62	117	55	0.0125	0.0569	
	K	0.0112	186	255	69	0.0107	0.0388	
YCbCr	Y	0.0094	125	205	80	0.0089	0.0281	0.0073
	Cb	0.0360	94	115	21	0.0343	0.4080	
	Cr	0.0444	146	162	16	0.0419	0.6375	

From Table 1, highest maximum histogram energy of 0.0073 was obtained using YCbCr color space indicating that it is the most suitable for detecting the faces. The corresponding skin color range for YCbCr is indicated in the same table and its representation is shown in equation 3 shows the.

$$Face_{candidate} = \begin{cases} 1, & 94 \ll Face_{Cb} \ll 115 \text{ and } 146 \leq Face_{Cr} \ll 162 \\ 0, & otherwise \end{cases} \quad (3)$$

Where

$Face_{Cb}$ is the range of value for Cb component of blue Chrominance information and

$Face_{Cr}$ represents the range of value for Cr component of red chrominance information.

In Fig. 2, we present our proposed algorithm where the images (a), are converted from RGB to YCbCr color using equation 1. Then, skin threshold is applied on the input image (b) to produce image (c), where the white color represents the skin area (see equation 2). Watershed algorithm is employed in two stages. The first stage is to isolate the biggest connected white area and merges small isolated white areas from the background. The second stage is to isolate the background and facial features background as shown by in gray in image (d) while facial feature areas are shown black. It reduces the background noise and fills the missing pixels in the face region resulting in one connected face region. However, lips color usually interferes with skin color which may cause missing lips during detection. The potential lips area can be localized using (Hsu et al., 2002) formula.

$$LipMap = C_r^2 \times (C_r^2 - \eta\ (C_r/C_b)) \quad (4)$$

where

$$\eta = 0.95 \frac{\sum C_r^2}{\sum\left(\frac{C_r}{C_b}\right)}$$

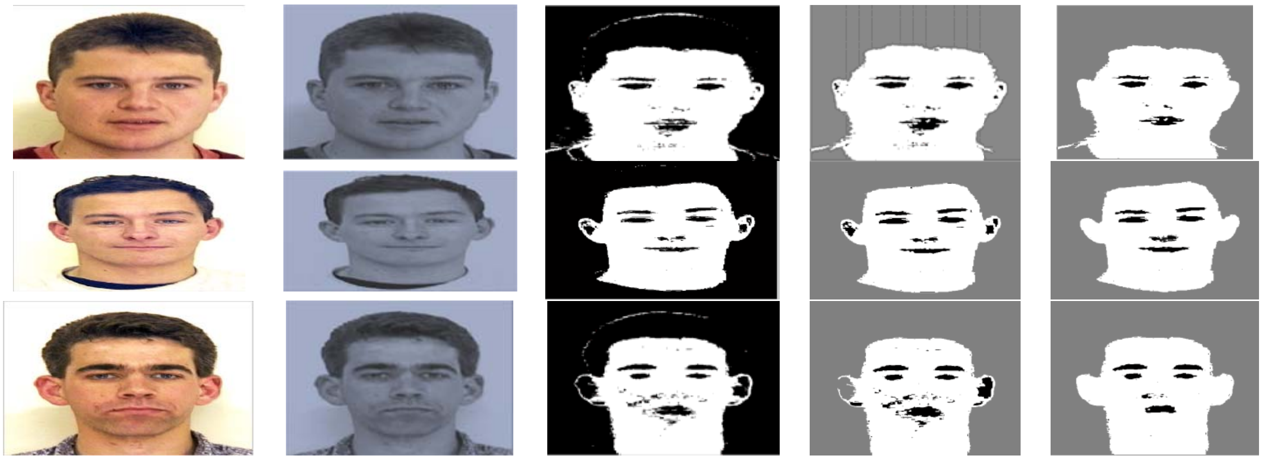
Finally, image (e) is produced by applying equation 3 to detected skin area. The expected result of the face detection is depicted in Fig. 2.

The performance metric; Detection Rate (DR) and False Rejection Rate (FRR) are selected as criteria to evaluate the results of the face detection algorithm as shown in Table 2. Detection Rate is the percentage of the correct skin detection and False Rejection Rate is the percentage of detection instances in which false rejection occurs.

This is a situation where the system fails to recognize an authorized person and rejects that person as an impostor. The DR and FRR are expressed in equation 5 and 6 respectively.

$$\text{DR} = \frac{\text{number of pixels correctly classified}}{\text{total pixels in the database}} \times 100\% \quad (5)$$

$$\mathrm{FRR} = \frac{\text{skin error}}{\text{total pixels in the database}} \times 100\% \quad (6)$$



a b c d e

Fig. 2: Sample of images undergoing the stages of detection process

Table 2: Face detection results of the proposed algorithm using YCbCr

Database	No. of Images	Perfect Detection	False detection	Detection Rate	False Rejection Rate
PICS	361	352	9	97.51 %	2.49 %

Table 2 shows the accuracy of the proposed system, where YCbCr color space has been used. A detection rate and False Rejection Rate of 97.51% and 2.49% was obtained. Table 3 shows the comparison results of the existing methods with the proposed method.

Table 3: Comparison with some current works

Authors	Color model	Database	Detection Rate
(Raghuvanshi and Agrawal, 2012)	YCbCr	--	84.61%
(Al-Mohair et al. 2014)	YCbCr	ECU	92.05 %
Proposed method	YCbCr	PICs	97.51 %

From the table above we can conclude that higher detection rate was obtained using the proposed method applying the same color model.

5. Conclusion

In this research paper, the authors proposed a platform for determining the proper color space for skin color detection and also proposed face detection algorithm using skin color detection. RGB, YUV, HSV and CMYK, and YCbCr color models were selected for the evaluation. And energy of the histogram of each component of the color space, the limit of skin range in each color space, and the maximum energy of the color spaces are the parameters use for the evaluation. The color model with the highest maximum energy of the histogram signal for skin is selected as the best. YCbCr emerges as the suitable color model for the skin color detection. The overall performance of the proposed method is quite satisfactory. The efficiency of the face detection was found to be 97.51% on standard database, which outperform some previous works.

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