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A Hybrid Skin Color Model for Face Detection

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ABSTRACT – For a human vision system performing the process of face detection is an easy task compared to an intelligent machine. This paper contains a system for human Face detection by combining various skin color models. It's an amalgamation of three diverse skin color models specifically the RGB, YCbCr and HSV. A hybrid Skin color model has been proposed for varying illumination conditions. The main objective for using is to overcome the problem of illumination conditions availability in an arbitrary image. Skin detection can be defined as the process of finding skin-colored pixels and regions in a given image. Skin detectors classically transform a given pixel into an appropriate color space and the classification is used to label whether it is a skin or non-skin pixel. The extraction of skin region is carried out using a set of bounding rules based on skin color distribution. Later the segmented face regions are classified using combination of morphological operations. Experimental results on the benchmark face databases such as FERET and the acquired images showed that the proposed model is able to achieve an accurate detection for near-frontal face orientation and skin color.

Keywords: Face detection, skin color models, skin likelihood, skin segmentation, extraction of skin region, morphological operations, face regions.

1. Introduction

In today's era of fast growing biometric systems several approaches of face detection have been proposed. Face detection is one of the elementary techniques enabled by human-computer interaction (HCI), whereas still the process for best system is under hunt as it has become a challenging problem in the field of pattern recognition and holds a very important position in computer vision research. Face detection is essentially a step of processing system to check for presence of object (human face) and subsequently the position of object in an image. Given an arbitrary image the face detection system should be able to analyze the image and determine the various features, region of face.

There are several challenges in a face detection system as human face has varying posture, orientations, expressions and skin color. There also exist some exterior factors such as compound backgrounds, occlusion, and quality of image and differing illuminating conditions. These all factors contribute extensively to the overall problem.

According to the literature survey [1] and [2] lot of approaches of face detection are based on knowledge, invariant feature approach, statistical and template matching etc. Some methods which are used earlier namely the Gaussian model [7], Gaussian mixture density model [8] and histogram based model [9]. Detecting of faces in color images has become important for a face detection system. As the color being one of the timely and most useful components to extract skin regions. Numerous color spaces have their luminance component and chromatic component separated, and they hold a higher dissimilarity between skin pixels and non-skin pixels over differing illuminating conditions. Skin color models that employ only on chrominance subspaces [3] likely Cb-Cr and H-S found to be efficient in characterising varying human skin colors.

In this paper we have proposed a hybrid skin color model that is a combination of RGB, YCbCr and HSV for a face detection system. Face detection is based on extracting skin color information of skin regions in a given image. Skin-color is an important and relatively steady feature for face, and it can be detached from most of the environment objects. The skin-color of human appears very differently in various conditions.
In this hybrid model a two phase process is carried out. In the initial phase skin information is extracted in skin regions of a given image, which yields a result of separate skin and non-skin regions (a skin likelihood image). Later skin-segmentation process is deployed which generates a binary image of resultant image from first phase.
This model utilises the additional hue and chrominance information of the image on top of standard RGB properties to improve the dissimilarity between skin pixels and non-skin pixels. In our approach, skin regions are classified using the RGB boundary rules introduced by Peer et al. [4] and also additional new rules for the H and CbCr subspaces.

The rules are constructed based on the skin color distribution obtained from the training images. The cataloguing of the extracted regions is further refined using a parallel blend of morphological operations. The rest of the paper is organised as follows: Brief description of the various steps: Section 2: A System Overview, Section 3: The Hybrid Skin Color Model, Section 4: Morphological Operations. Section 5: Experimental Results and comparative study. Finally, Section 6: Conclusion of the paper.

2. A System Overview

Face detection is a field which integrates the system such as: Computer vision, Computer graphics, Physiology, Evaluation.

An overview on a face detection system is explained as given in the Figure 1.

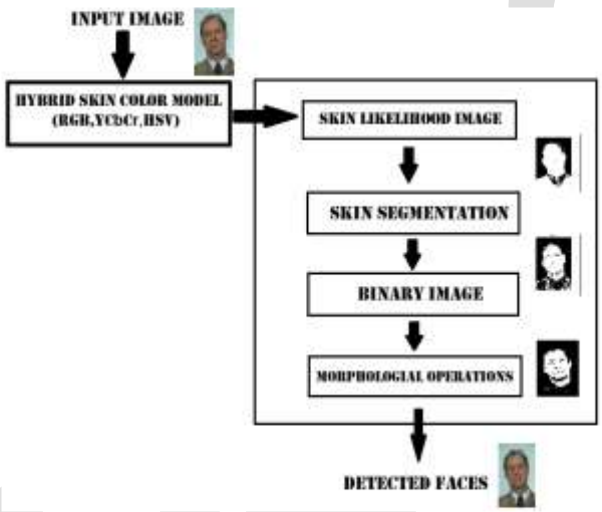

Figure 1: Face Detection system overview

The proposed face detection system consists of two image processing steps to detect the human face in a given arbitrary image. Initially the set of input images are taken as first step of face detection. Colors play a significant role for object detection. In our proposed hybrid skin color model (color based approach), a combination of RGB, YCbCr and HSV are used to construct the bounding rules for skin color distribution. The unique features of the image are extracted and skin likelihood image is obtained. The bounding rules are used to segment the skin regions from the resultant images (binary image).

In the second step a combination of morphological operations is carried out to extract the skin regions to remove non-skin regions. Adding or removing the pixel from an object is fully based on the size or shape of the structuring element, which defines the neighbourhood pixel. Hence morphing process is completed by filling all the holes present in skin regions with proper shape of face region. Lastly the box is drawn around retained face regions which detect faces.

3. The hybrid skin color model

3.1 Color Segmentation

Color being one of the prominent components, human facial skin component is subspace of the total color space. It would be precise to use face color correlations by deploying appropriate color model. A hybrid model is a combination of RGB, YCbCr and HSV skin color model. RGB is one of the device dependent color space where the resultant color always depends on the set up deployed.

An overview of RGB, YCbCr and HSV skin color model is explained.

RGB: A different way to a device dependency is to imagine an RGB cube within a color space representing all possible colors. We define a color by its values on the three axes, however the exact color will depend on the position of the cube within the perceptual color space, i.e. move the cube (by changing the set-up) and the color will change. They are known as device calibrated color spaces [12].

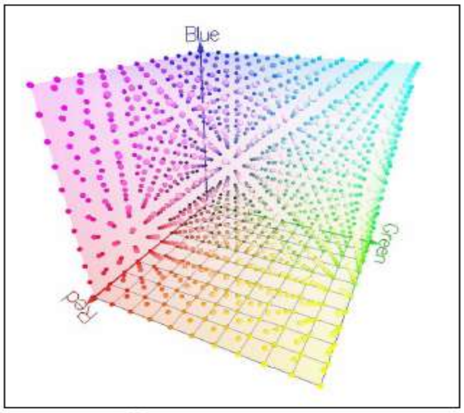

Figure 2: RGB color space

RGB space may be displayed as a cube based on the three axis corresponding to red, green and blue, [CST 2004] where the value of (R,G,B) is classified as skin

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

YCbCr: The YCbCr color space is commonly used in image processing as it separates the luminance, in Y component, form the chrominance described through Cb and Cr components. Several definitions of this transformation exist as [6]: two color difference in Cb and Cr values is formed by subtracting luma from RGB red and blue values

$$Y=0.299R+0.587G+0.114B$$

$$Cb=B-Y$$

$$Cr=R-Y$$

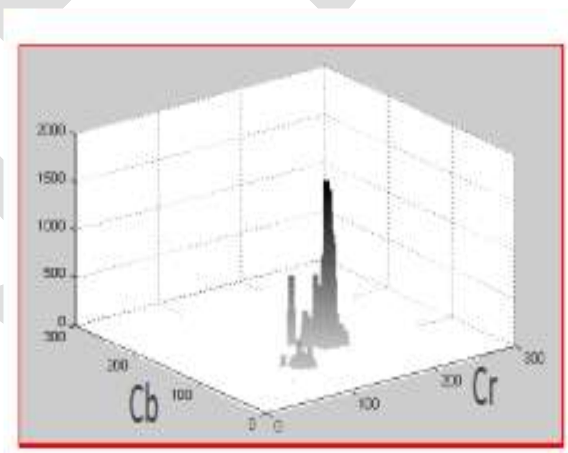

Figure 3: Skin color distribution in CbCr color space.

The Cb and Cr components are used to characterize the skin color information. It is shown that skin color is localized in a small cluster in this color space [10].

HSV: In situations where color description plays an integral role, the HSV color model is often preferred over the RGB model. HSV color model is the cylindrical representation of RGB color model. HSV stands for hue, saturation and value. In each cylinder, the

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angle around the central vertical axis corresponds to "hue" or it form the basic pure color of the image, the distance from the axis corresponds to "saturation" or when white color and black color is mixed with pure color it forms the two different form "tint" and "shade" respectively. The HSV model describes colors similarly to how the human eye tends to perceive color.

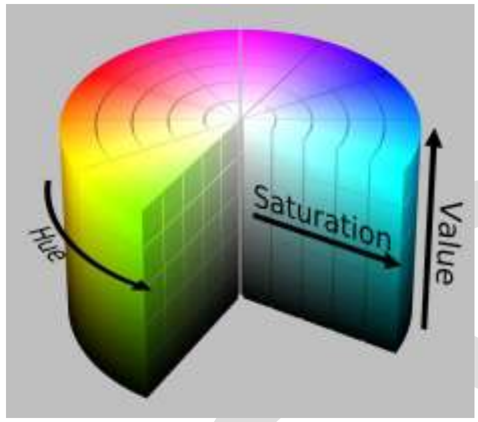

Figure 4: HSV color space

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RGB defines color in terms of a combination of primary colors, whereas, HSV describes color using more familiar comparisons such as color, vibrancy and brightness.

Hence by considering all the features of RGB, YCbCr and HSV skin color models, a hybrid model is proposed. To build a color model, set of images were analyzed and the properties of skin color in various spaces. The images containing skin color regions were either exposed to uniform illumination or flashlight illumination.

A. Illuminant bounding rules

Illumination in Computer vision can be defined as the methods for acquiring, processing, analyzing, and understanding images. The illumination of the subject is a key element in creating an object (image), and the interchange of light and shadow is also important. The position of the light sources can make a considerable difference in the type of object that is being presented. In divergence, a single light source, such as daylight, can serve to highlight any texture or interesting features. Illumination is an important concept in computer graphics.

Images were analyzed in hybrid color spaces (i.e., RGB, YCbCr and HSV). In RGB color space all the 3 channels are not distinguished, so a simple histogram will show the uniformity across spectrum values. In RGB space the skin rules introduced by Peer et al. [4], [11] are:

1. Uniform daylight illumination rule can be defined as

$(R > 95)$ AND $(G > 40)$ AND $(B > 20)$ AND $(\max\{R, G, B\} - \min\{R, G, B\} > 15)$ AND $(|R - G| > 15)$ AND $(R > G)$ AND $(R > B)$

2. The skin color under flashlight or lateral illumination rule is given by

$(R > 220)$ AND $(G > 210)$ AND $(B > 170)$ AND $(|R - G| \leq 15)$ AND $(R > B)$ AND $(G > B)$

Considering both the illuminations conditions i.e., uniform daylight and lateral illumination, A logical OR is used to combine both the illuminating conditions and a bounding rule is obtained.
But the CbCr subspace is a strong discriminates of skin color,

C_B>=60 && C_R>=130
C_B >=130 && C_R>=165

And in HSV model hue shows the significant discrimination of skin color regions

H>=0 && H<=50
S>=0.1 && S<=0.9

B. Skin segmentation

The hybrid model a combination of the bounding rules from all the 3 skin color models. The segmentation process is a precise and accurate. Segmentation technique uses all 3 color space to boost up face detection rate.
Skin color detection may avoid extensive search of face regions in a given entire image. Initially the process of rejecting non-skin regions, so that only the skin like areas of given image i.e. the skin color segmented image for further processing.

From all 3 color models, the RGB color model is lighting sensitive, in YCbCr color model the distribution of skin areas is consistent in Cb and Cr components across different races and lastly the HSV color model hue is not reliable when saturation is low. Hence combination of these color models overcomes the illumination conditions and yields better result than individual color model.
But still there exists some common issues in resulting segmented skin color regions:

a. The fragmented regions often consist of holes and gaps.
b. The extracted skin color regions may not be face regions; there are possibilities that certain skin regions (arms & legs) are exposed limbs.
c. Even the similarity of skin color may exist in foreground and back ground objects.

4. Morphological operations

The face detection system involves subsequently the usage of morphological operations to refine the skin regions extracted from the segmentation phase.
Initially the simple hole filling operation to fill any individual holes or gaps, and the process of simple dilation is applied on the regions, the dilate function maintains the size of individual blobs of skin detected. Then flood fill operation is used to close gaps and holes within each region.

Later the determination of the skin likelihood region is evaluated for properties. The height and width ratio of the region bounding box has range of values lies between 1.6 and 0.8. The ratio above 1.6 would not suggest a human face, as the orientation is vertically longer height than width. Ratios below 0.8 are misclassified as arms, legs and other elongated objects. After the height and width ratio is applied it results in face detection.

5. Results:

Our proposed face detection method was implemented with MATLAB. Testing was carried out with benchmark face database set such as FERET and acquired images. The images are near-frontal faces and also of various indoor, outdoor scenes with varying lighting conditions.

Two performance metrics are defined to estimate the success of face detection system. They are FDR and SDR.(refer original paper)

False Detection Rate (FDR) is defined as the number of false detections over the total number of detections.

$$FDR = \frac{\text{false detections}}{\text{number of detections}} X100\%$$

Success Detection Rate (SDR) is defined as the number of correctly detected faces over the actual number of faces in the image, where the number of detected faces is equal to the number of faces minus the number of false dismissals.

$$SDR = \frac{\text{correct detected faces}}{\text{number of faces}} X100\%$$

By considering set of parameters the performance of hybrid model was evaluated. The parameters are face detected, time to execute using combination of skin color model, false positive and accuracy.

Table 1: Results of face detected on RGB, YCbCr and HSV Color spaces

No. of Images (20)	FDR (%)	SDR (%)	Time to execute	Face detection
RGB	41.01	67.00	4.6623	16
YCbCr	35.16	76.15	4.6463	17
HSV	32.62	78.14	6.3046	17

Table 2: Results of face detected on combination of two color spaces

No. of Images (20)	FDR (%)	SDR (%)	Time to execute	Face detection
RGB + YCbCr	40.10	68.02	5.6236	15
YCbCr + HSV	33.01	77.12	6.4053	17
RGB + HSV	39.13	67.32	5.9743	16

Table 3: Results of face detected on hybrid model (RGB, YCbCr, HSV color spaces).

No. of Images (20)	FDR (%)	SDR (%)	Time to execute	Face detection
RGB + YCbCr + HSV	31.26	79.14	4.5243	18

Comparative study:

The 3 color sub spaces RGB, YCbCr and HSV are compared for the varying illuminating conditions with set of images. Now through the analysis process the obtained results are as follows, for the daylight illumination YCbCr color spaces gives better results compare to other two color model. In lateral illumination HSV color space is better compared to RGB and YCbCr.

Illumination conditions	No of images	RGB (%)	YCbCr (%)	HSV (%)	Analysis
Daylight illumination	10	64	69	65	YCbCr is better color space.
Lateral illumination	10	53	54	57	HSV is better color space

Set of face detected result set images:

FERET DATABASE:




BENCHMARK IMAGES:








Aquired images:




6. Conclusion:

A hybrid skin color mode was used to detect human faces. A combination of RGB, YCbCr and HSV are used to construct the bounding rules for skin color distribution. The unique features of the image are extracted and skin likelihood image is obtained. The bounding rules are used to segment the skin regions from the resultant images (binary image). Thus it is two phase of IP steps separating skin and non-skin pixels and performing morphological operations by considering the illuminations conditions. The skin segmentation was combination of RGB, YCbCr and HSV subspaces which verified discrimination between skin and non-skin regions. The experimental results showed the system is a simple implementation and should be feasible in real time. In our future work we intend use soft computing techniques such as fuzzy inference rules to detect faces which may yield better results.

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