Discriminating Features for Characterization of Human Skin

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Abstract— *Skin colour is often being used as a cue for face detection, recognition, tracking in videos and other skin-based biometrics. Over the years, there has been a lot of works done and is still on in skin detection for face detection and other video analytical purposes. Thus, there is a call for availability of relevant information on discrimination features for human skin characterization; especially the black skin. Black people skin is very clumsy to detect because black peoples' skin has so many colours, ranging from total black, red, yellow, orange and brown, unlike white peoples' skin that is clustered around the white region. Thus, this paper aims at investigating two possibilities and presents some findings on the characterization of human skin and attempts to discriminate between gender and race based on skin tone. This is carried out using the histogram based explicit rules in the CrCb colour space models. The result shows that skin tone is not sufficient to discriminate between gender but is sufficient to discriminate between the black and white human race.*

Keywords— Human-Skin, Characterization, Gender, Race, Colour-Space

I. Introduction

Skin regions have been used as clues for face detection and tracking over the past decades. Many types of research have been carried out on skin detection and segmentation-based face detection. Among feature-based face detection methods, ones using skin colour as a detection cue, have gained strong popularity [1]. Skin detection is the process of finding in an image or video, pixels or regions that are skin coloured. Normally, a skin detector transforms each pixel in an image to a suitable colour space and classifies it to skin or non-skin region by a classifier. The margin for the classification is obtained based on a training database of skin coloured pixels

It is recognized that colour allows fast processing and is robust to geometric variations of the face pattern [1, 2]. When building a system, that uses skin colour as a feature for face detection, the researcher usually faces three main problems. First, what colour space to choose, second, how exactly the skin colour distribution should be modelled, and finally, what will be the way of processing of colour segmentation results for face detection [1]. Skin pixels have a distinctive range of colours which corresponds to a region(s) in Red, Green and Blue (RGB) colour space.

The colour space utilised has a significant role in skin-based face detection, so the colour space should be selected carefully. For instance, how the colour space separate chrominance and luminance data is of importance because these can define the amount of overlapping that could happen between skin and non-skin distribution in the colour space. Skin pixels have a distinctive range of colour which corresponds to regions in different colour spaces. The classifier classifies each pixel in the image as either skin or non-skin, different colour spaces can be used such as normalised RGB, YCrCb, Hue, Saturation, Value(HSV), Luminance, In-phase Quadrant (YIQ) and so on. The RGB colour space consists of a combination of chrominance and luminance data so it is required to be transformed into a 2-dimensional chrominance space to attain the robustness of the illumination condition. This makes the condition of the two-chrominance component suitable for skin representation. The YCrCb colour space has some advantages which make it suitable for modelling skin colour. These includes similarity to how humans perceive sight, wide use in video compression code and television display, clustering characteristics of skin colour being better than that of the RGB colour space [3]. it is also a suitable colour space for real-time applications [4].

In probabilistic models, the skin regions are extracted and then used to train a skin classifier. The skin classifier determines if a pixel X = (R, G, B) is a skin colour or not. To find the skin regions, the skin/non-skin pixels are manually labelled in one or more "training

images", and then the training data is plotted in RGB space. Given a pixel X = (R, G, B), a skin can be determined using the data modelling algorithm. Let X be a random variable, then P(X) is the probability that X achieves a certain value to be treated as skin.
The probability function satisfies:

$$0 \le P(X) \le 1 \tag{1}$$

and for continuous X

$$\int_{-\infty}^{\infty} P(X)\,dX = 1 \tag{2}$$

and for discrete X

$$\sum P(X) = 1 \tag{3}$$

Skin region can also be modelled by using explicit-rules in different colour-spaces.

This paper reports some facts found in previous works and is also a fact-finding experiment aimed at making ground truths available in the characterization of human skin; experimenting on criteria that can be used in skin-based human discrimination.

II. RELATED WORKS

In [5], a probabilistic model for the human skin detection was proposed for automatic human face recognition in video scenes using colour intensity values and mixture of Gaussians models. The skin colour was modelled in the chromatic subspace using multivariate statistics which is by default illumination normalized. Skin samples from both white and black people were collected and used to estimate a parametric statistical model of a mixture of Gaussian probability density functions (pdfs). The colour model used was the normalized RGB, in which the r and b chromaticity colour were used to build the model using a set of 140,000 skin pixels sampled from 40 people. The system performs well in recognition but had a high false detection rate. Static skin colour models have been used for real-time skin regions segmentation in face images. The model is popular because it is simple to implement and very fast in operation [1].

It was demonstrated by [6] that Explicit rule as given in Equation 4 was capable of effectively detecting human skin with an accuracy of 93%.

$$pixel = \begin{cases} skin, & if\ 77 < Cb < 127\ and\ \ 133 < cr < 173 \\ non-skin, & otherwise \end{cases} \tag{4}$$

The CbCr adopted has been used in skin segmentation. It has also been proven that similarly to the normalised rgb space, skin colours derived from people of various ethnicities are very tightly clustered within the CbCr space [7], meaning that individual models can successfully be applied to people of any skin tone. The limitation of the model is that it is subjected to illumination changes. An explicit rule was proposed for skin detection in the YCrCb colour space by [8]. This was used for skin detection in gaussian modelled skin detection system using equation 5 and obtained a 96% detection rate.

$$85<Cb<135, 135<Cr<180, Y>80 \tag{5}$$

A research to characterize the Indian sub-continental skin was also carried out by [9] using the HSV Colour model and reported a 91.1% true positive detection rate. Black skin was segmented in a face detection algorithm using the fast skin detection algorithm by [10]; which is an explicit rule based on the Dark face databased [11] in the CrCb colour space, skin pixels were classified based on the explicit rule stated in equation 6

$$pixel = \begin{Bmatrix} 1, 10 \le Cr < 45 \\ 0, \quad\quad otherwise \end{Bmatrix} \tag{6}$$

and obtained a 66.18% detection rate.

A research was carried out by [12] utilizing a hybrid of the Gaussian and explicit rule that characterised black skin models in a face detection and recognition system on video streams. This paper extends [12] and presents further investigations and discoveries on features that characterize human skin by investigating two hypotheses.

III. MEYHODOLOGY

Images were converted from RGB and YCrCb colour space and then modelled by a single Gaussian probability density function which classifies the pixels of the image to skin and non-skin regions by a thresh-holding method. This is classified as Skin A

Another algorithm used to build a skin classifier is to define explicitly (through a number of rules) the Explicit-rule skin segmentation algorithm is also used to obtain the skin region.

The algorithm for the Explicit-rule is given in equation 7.

$$SkinB = \begin{cases} 1, & (Cb_{lowert\,hrshold} \le Pixel \le Cb_{uppert\,hreshold})\ AND\ (Cr_{lowert\,hreshold} \le Pixel \le Cr_{uppert\,hreshold}) \\ 0, & otherwise \end{cases} \tag{7}$$

The output of the two algorithms (Gaussian skin probability model and Explicit-rule) were fused using pixel-based logic rule combination, by the logical OR or AND to get the actual skin region.

$$Finalskin = (SkinA)\ AND\ (SkinB) \tag{8}$$

Based on equation (7) two hypothesis were tested on human skin characterization.

Formulation of Hypothesis

Hypothesis 1:

'Male and female can be discriminated based on skin tone'. The first hypothesis investigates the probability of discriminating between the male and female gender based on skin tone.

This is investigated observing the Cr and Cb histogram plots of male and female black skinned people. This experiment was carried out by training the histogram with 300 samples of male skin and 300 samples of female skin from the Black eye blink and Face Corpora [11], separately.

Hypothesis 2:

'The black and white race can be discriminated based on skin tone'. The second hypothesis investigates the probability of discriminating between the white and the black race based on skin tone.

This was investigated by observing the Cr and Cb histogram plots of black and white skinned people. White skin samples were also cropped from the AT&T (American Telephone and Telegraph) database. This was used to train the white skin Cr and Cb histograms. The Female black skin Cr and Cb histogram were used to represent the black skin.

IV. Discussions and Findings

In the skin detection sections, the Single Gaussian skin probability model was utilised. The system was trained using light and dark coloured black skin. It was discovered that the model was able to detect most of the black skins well. When the different tones of black skin were not well represented in the training database, some skin tones were difficult to detect.

To improve on this, the Explicit-rule model was introduced which used histogram plotting of the Cr and Cb colour models of the skin training database, which were plotted, and the histogram valley technique was used to get suitable threshold intervals for each to segment skin area. This also worked well for the different black skin tones. The Explicit rule model has more false positives compared to the Gaussian model [11]. This is an indication that the Gaussian PDF model works better for black skin detection than the Explicit-rule model with same training data [11].

The Explicit-rule model was combined with the Gaussian skin map and it improved the output for the skins that were detected. Some worked better with the pixel-based fussioning .AND. operator and some with the .OR. operator. So the best for each picture was utilised for most total detection accuracy. The AND gave a better percentage of good detection than the OR. The performance measures are shown in Table 1.

Table 1: Performance Measures of Hybrid Fussioning Operators

Fussioning Operator	Detection Rate	False Positive Rate	False Negative Rate
. AND.	89%	19%	11%
.OR.	42%	37%	5%

Detection rate is the percentage of correctly detected pixels. False Positives (FP) are non-skin pixels incorrectly classified as skin pixels, True Positives (TP) are the number of skin pixels correctly identified as skin, True Negative (TN) is the number of non-skin pixels correctly identified as non-skin and the False Negative (FN) are the skin pixels incorrectly identified as non-skin. The False Positive Rate (FPR) and False Negative Rate (FNR) are adopted as the quantitative performance in the skin detection algorithm.

$$\text{Detection Rate} = TP/(TP+FP) \quad (9)$$

$$FPR = FN/(FN + TP) \quad (10)$$

$$FNR = FP/(FP + TN) \quad (11)$$

Two hypotheses were investigated. Hypothesis one was to answer the question; can we discriminate between a male and a female based on skin colour? The Cr and Cb histograms were obtained and explicit rules were formulated using the valley thresholding formula. The following thresholds were obtained. The female skin Cr histogram had a lower limit threshold of 85 and an upper limit of 200 that is ($85<Cr<200$) as shown in figure 1 and the male histogram had a lower limit threshold of 80 and an upper limit threshold of 190 that is ($80<Cr<190$) as shown in figure 2.

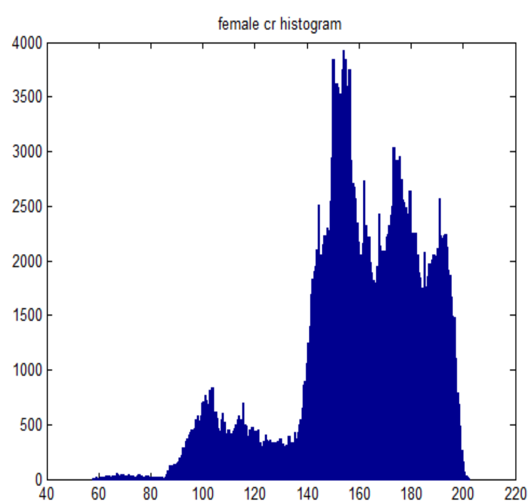

Figure 1: Female skin Cr Histogram

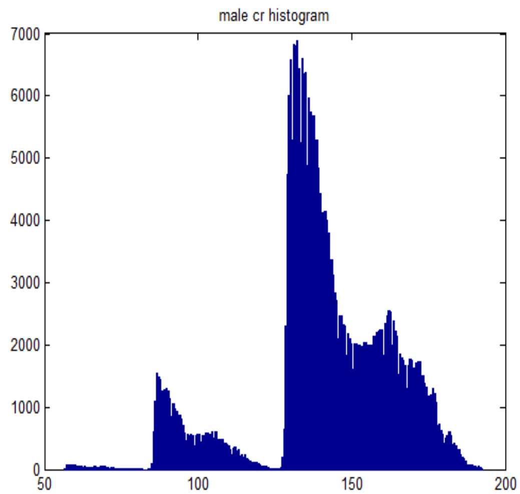

Figure 2: Male skin Cr Histogram

From the Cb histograms, it is deduced that the female lower limit threshold was 60 while the upper limit threshold was 130 that is (60<Cb<130) as shown in figure 3 and for the male 65 to 142 that is (65<Cb<142) as shown in figure 4. From the results, it was deduced that there is a lot of interleaving between the data, and it was concluded that the skin tone is not enough to discriminate between the male and female gender. Thus, proving Hypothesis one wrong.

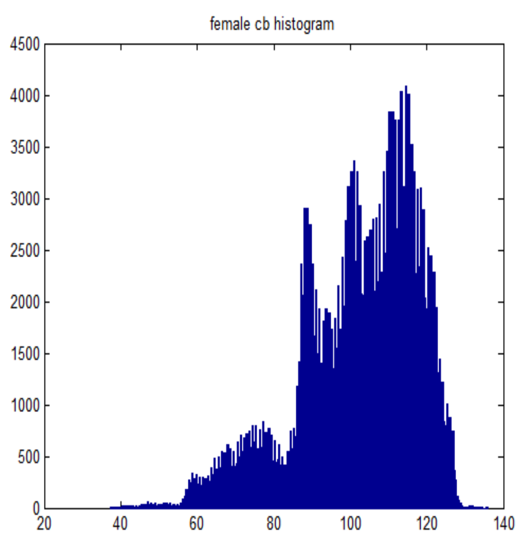

Figure 3: Female skin Cb Histogram

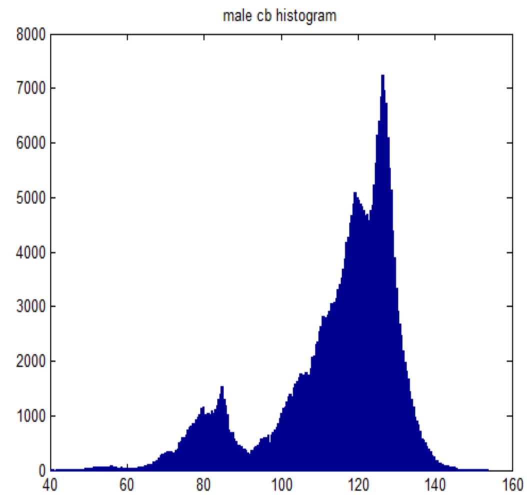

Figure 4: Male skin Cb Histogram

Further in this study, the female skin histogram was chosen to typify the black skin. This is because combining the male skin histogram with the female skin histogram produced larger amounts of false positive detections.

Hypothesis two was to answer the question; Can we discriminate between the black and white people based on skin colour? The lower limit Cr threshold for the white skin obtained was 125 with an upper limit threshold of 140 that is (125<Cr<140) as shown in figure 5. This contrasts with that of the black skin which is (80<Cr<190) from the Cb histogram of the white skin a lower limit threshold of 125 was obtained and an upper limit of the threshold of 160 that is (125<Cb<160) as shown in figure 6. This contrasts with that of the black skin which is (65<Cb<142). From this observation, it was deduced that the Cr of the white skin falls in a bracket within the Cr of the black skin and the lower limit of the Cb of the white skin is far higher than that of the black skin and the upper limit surpassed that of the black skin. This is enough room to discriminate between the white skin and the black skin based on skin colour. Thus, proving hypothesis two correct.

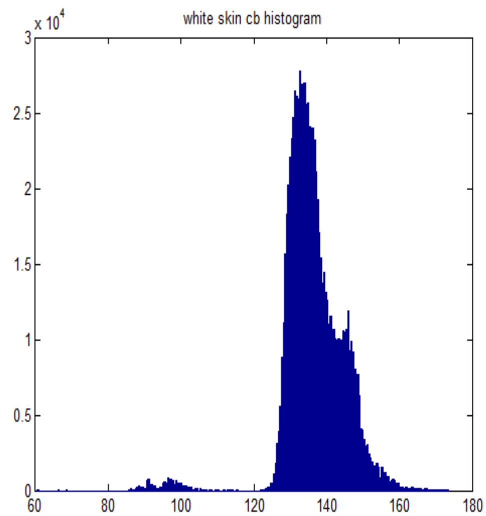

Figure 5: White skin Cb Histogram

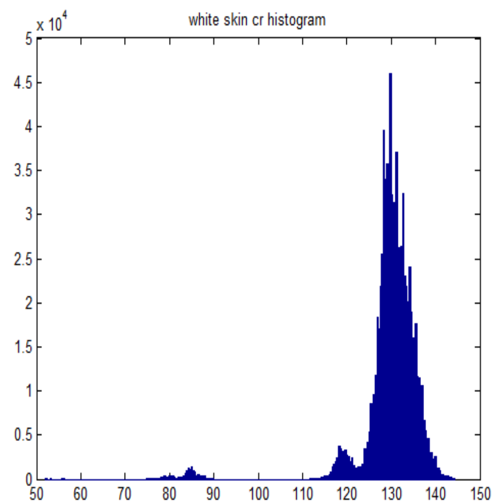

Figure 6: White skin Cr Histogram

V. CONLUSION

Different skin-based experiments were presented in this paper, the superiority of the Gaussian skin modelling algorithm over the explicit rule for black skin was revealed. It was also highlighted that in the hybrid of the Gaussian and black skin explicit rule the .AND. operator gave a higher percentage of good skin detection.

From the testing of the two hypotheses in this study it has been deduced that skin tone is not a sufficient criterion to discriminate the human gender and that skin tone can be used to differentiate between human races.

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