COMPARISON OF THREE COLOUR SPACES IN SKIN DETECTION

Chelsia Amy Doukim, Jamal Ahmed Dargham & Ali Chekima

School of Engineering & Information Technology,
Universiti Malaysia Sabah, 88999 Kota Kinabalu, Sabah, Malaysia

ABSTRACT. *Skin detection is used as the first step for subsequent feature extraction in image processing techniques. In this work, the performance of skin detection in three colour spaces; Normalised RGB, Modified Normalised RGB and YC_bC_r is investigated. The most famous and large database namely Compaq database is used to construct the histogram model and to test the skin detection algorithm. It was found that the chrominance component from the Modified Normalised RGB colour space gave the highest correct detection rate compared to the other two colour spaces.*

KEYWORDS. Skin detection, Colour space, Histogram thresholding

INTRODUCTION

Skin detection is an important preliminary process for subsequent feature extraction in image processing techniques. It has been proved that skin-colour information can be used for detecting human skin in various computer vision applications. An appropriate colour space is required in modelling the skin colour distribution. Many colour spaces have been selectively used for modelling the skin colour distribution, such as RGB, Normalised RGB, HSV/HSI/HSL, YC_bC_r, YES, YUV and YIQ, etc. (Chai and Bouzerdoum, 2000; Yang *et al.*, 1998; Vezhnevets *et al.*, 2003).

Phung *et al.* (2000) demonstrated the distribution of human skin colours in the YC_bC_r colour space by modelling it into three Gaussian clusters for the human face detection. A study on the effect of colour space choice on skin detection performance was done and a comparison of five colour spaces is provided by Zarit *et al.* (1999). Chai and Bouzerdoum (2000) proposed an image classification technique that uses the Bayesian approach to classify pixels into skin colour and non-skin colour in YC_bC_r colour space. Terrillon *et al.* (2000) presented the results of using colour spaces with separated luminance and chrominance components which are more appropriate for human face detection. Gomez *et al.* (2002) evaluated each component of several colour models by using the attribute selection approach which is well-known in the machine learning community to select the suitable colour space for skin detection. Albiol *et al.* (2001) proved that if an optimum skin detector system is designed for every colour space, then the performance of all these skin detectors systems is the same.

There are several skin detection algorithms utilizing the histogram based-approach to skin pixels segmentation. These approaches are fast in training and practical and are theoretically independent from the shape of skin distribution (Vezhnevets *et al.*, 2003). Zarit *et al.* (1999) used the colour histogram-based approach for segmenting the skin pixels that is projected to work with a wide variety of individuals, lighting conditions and skin tones. Sigal *et al.* (2000) applied an adaptive colour histogram technique for real-time skin segmentation in video sequences. Soriano *et al.*, 2000 employed the histogram backprojection technique where the skin colour model is updated by pixels in the search region that falls in the skin locus. Fang and Qiu (2003) proposed a colour histogram-based approach to detect human face and make use of the principal component analysis (PCA) for robust detection rate.

In this paper, the performance of skin detection for the three colour spaces: Normalised RGB, Modified Normalised RGB and YC_bC_r on Compaq database are discussed. The distributions of skin and non-skin regions are modelled using the histogram-based approach where the global thresholds for each chrominance components in the three colour spaces are determined. These thresholds values are then used to classify whether a pixel belongs to skin or non-skin. The paper is organized as follows. Section 2 and Section 3 briefly describe the Modified Normalised RGB colour space and the YC_bC_r colour space respectively. In Section 4, the database used in this work is described. Section 5 explains the methodology of this work. Section 6 gives the experiment results and Section 7 concludes the paper.

MODIFIED NORMALISED RGB COLOUR SPACE

The Modified Normalised RGB colour space is used in this work. For an image with M x N pixels, the rgb components for pixel (x,y) are given by Equation 1:

$$\left.\begin{aligned} r(x,y) &= \frac{R(x,y)}{R(x,y)+G(x,y)+B(x,y)} \\ g(x,y) &= \frac{G(x,y)}{R(x,y)+G(x,y)+B(x,y)} \\ b(x,y) &= \frac{B(x,y)}{R(x,y)+G(x,y)+B(x,y)} \end{aligned}\right\} \quad (1)$$

where *R(x,y)*, *G(x,y)* and *B(x,y)* represent the three chromaticities of the red, green and blue additive primary colours respectively.

This equation performs pixel-by-pixel normalisation of the RGB components of the RGB colour system. Equation 1 is modified so that the RGB components are normalised by the maximum value of (R + G + B) over the entire image and is given by Equation 2 (Dargham and Chekima, 2006).

$$\left.\begin{aligned} r(x,y) &= \frac{R(x,y)}{Max(R+G+B)} \\ g(x,y) &= \frac{G(x,y)}{Max(R+G+B)} \\ b(x,y) &= \frac{B(x,y)}{Max(R+G+B)} \end{aligned}\right\} \quad (2)$$

YC_bC_r COLOUR SPACE

YC_bC_r is the orthogonal colour space that reduces the redundancy present in the RGB colour channels and represents the colour with statistically independent components (Kakumanu *et al.*, 2007). In this format, the luminance information is stored as a single component (Y), and the chrominance information is stored as two colour-difference components; C_b and C_r. C_b represents the blue component and a reference value, while the C_r component represents the difference between the red component and a reference value. This colour space is considered as a favourable choice for skin detection due to the transformation simplicity and unambiguous separation of luminance and chrominance components.

THE DATABASE

The database used in this work is the famous training and test database for skin detection namely Compaq database (Jones and Rehg, 1999). This database comprises 13,640 images with its corresponding masked images. There are two sets of data preparation, the first one is the data set used to build the histogram models and the second one is the test data set used to evaluate the performance of the skin detection algorithm. The first data set consists of 100 images randomly picked from the database. For the testing evaluation, 100 images were also randomly picked from the database.

METHODOLOGY

Performance Metrics

The performance metrics are used in order to determine which chrominance component yields the best skin detection results. Three different metrics are used to evaluate the results of the skin detection algorithms. The **%C** is the percentage of the correct skin detection and is given in Equation 3. The **FAR** (False Acceptance Rate) is the percentage of identification instances in which false acceptance occurs. For example, an unauthorized person is identified as an authorized one. The **FRR** (False Rejection Rate) is the percentage of identification instances in which false rejection occurs. This is the case when the system fails to recognize an authorized person and rejects that person as an impostor. The FAR and FRR are expressed in Equation (4) and (5) respectively. The best chrominance in both colour spaces are then combined and the effectiveness of the combination is investigated.

$$\%\mathbf{C} = \frac{\text{number of pixels correctly classified}}{\text{total pixels in the database}} \times 100\% \tag{3}$$

$$FAR = \frac{\text{non - skin error}}{\text{total pixels in the database}} \times 100\% \tag{4}$$

$$FRR = \frac{\text{skin error}}{\text{total pixels in the database}} \times 100\% \tag{5}$$

Skin Detection

The histogram-based segmentation approach is an effective methodology to skin pixel segmentation because it is fast in training and is theoretically independent of the shape of skin distribution (Vezhnevets *et al.*, 2003). The skin and non-skin histogram models for the three colour spaces; Normalised RGB, Modified Normalised RGB and YC_bC_r were constructed using 100 images randomly picked from the famous Compaq image database respectively. The corresponding masked images were used as the reference and as well as the ground truth when evaluating the performance of the skin detection method. The histograms of skin and non-skin pixels from the chosen images were drawn using a number of chrominance components: r, g, b, r.g, r.b, r-g and r-b for the Normalised RGB and Modified Normalised RGB, and C_b, C_r, C_b/C_r, $C_b.C_r$ and C_b-C_r for the YC_bC_r.

The chrominance components that gave the lowest overlap between the skin and non-skin distributions were selected for skin detection on their respective colour space. Figure 1 shows an example of histograms with low overlap and high overlap. For each chrominance component, a global threshold is selected that minimizes the skin detection error.

The performance of the skin detection model was measured over a test data set comprising 100 images randomly picked from the Compaq database with corresponding masked images. To perform the skin detection, an image is first transformed into the colour space. The colour values will indicate the value for each pixel in the image, and if the value falls between the low threshold and the high threshold, then the pixel is classified as skin. Otherwise, the pixel is identified as non-skin.

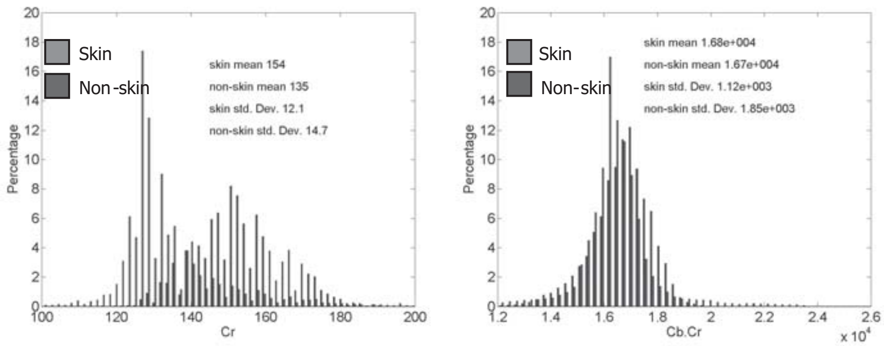

Figure 1. Example of histogram with low overlap (left) and high overlap (right) between the skin and non-skin distributions.

RESULTS AND DISCUSSION

Figure 2 provides the results obtained for the Normalised RGB colour space. From the results, the highest correct detection is given by the r.g chrominance. The skin detection result for the Modified Normalised RGB is provided in Figure 3. For this colour space, the r-g chrominance yields the highest correct detection rate with an improvement of more than 0.1% compared to the r.g chrominance from the Normalised RGB colour space. Figure 4 shows the results for the YC_bC_r colour space. The highest correct detection rate is obtained from the C_r chrominance although it is slightly lower than the performance given by the r-g chrominance from the Modified Normalised RGB.

Table 1 lists the chrominance that gave the highest correct detection rate for each colour space. The r-g chrominance from the Modified Normalised RGB colour space ranked as the highest with 81.45% of correct detection.

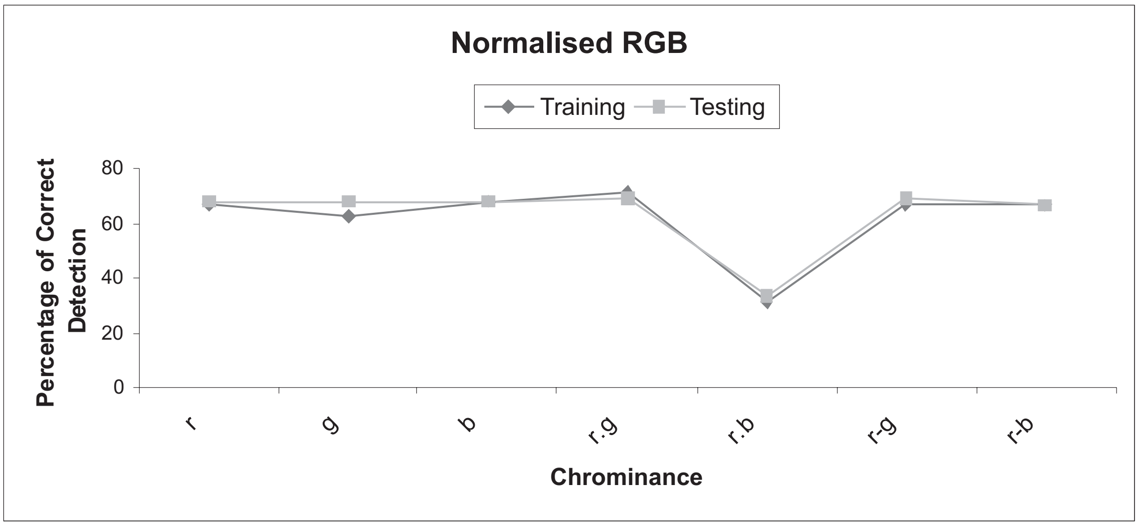

Figure 2. Percentage correct detection for several chrominance of the Normalised RGB colour space on the training and testing images.

Table 1. The chrominance that gave the highest correct detection rate from each colour space.

Colour Space	Chrominance	Correct Detection Rate
Normalised RGB	r.g	69.09%
Modified Normalised RGB	r-g	81.45%
YC_bC_r	C_r	81.31%

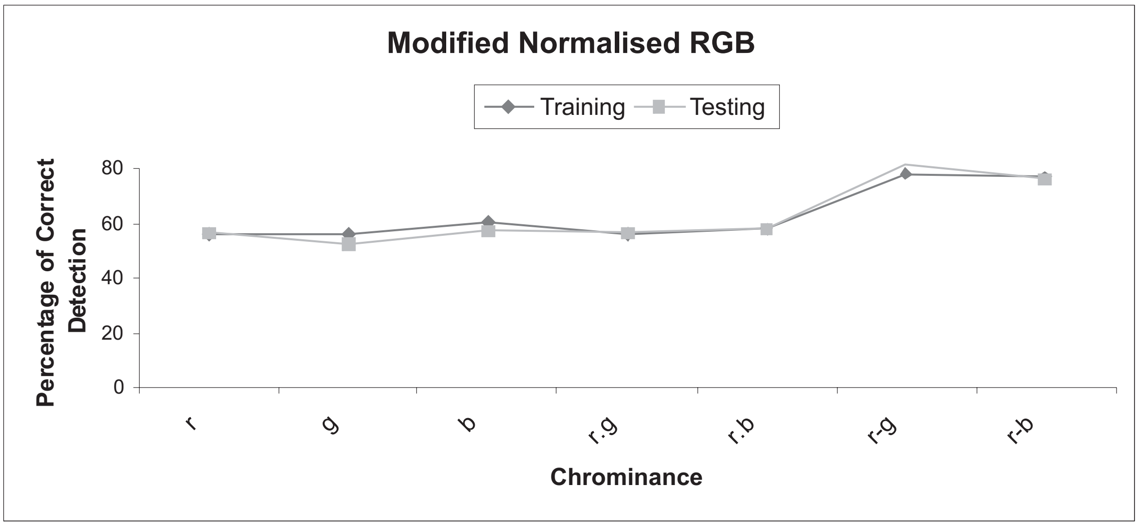

Figure 3. Percentage correct detection for several chrominance of the Modified Normalised RGB colour space on the training and testing images.

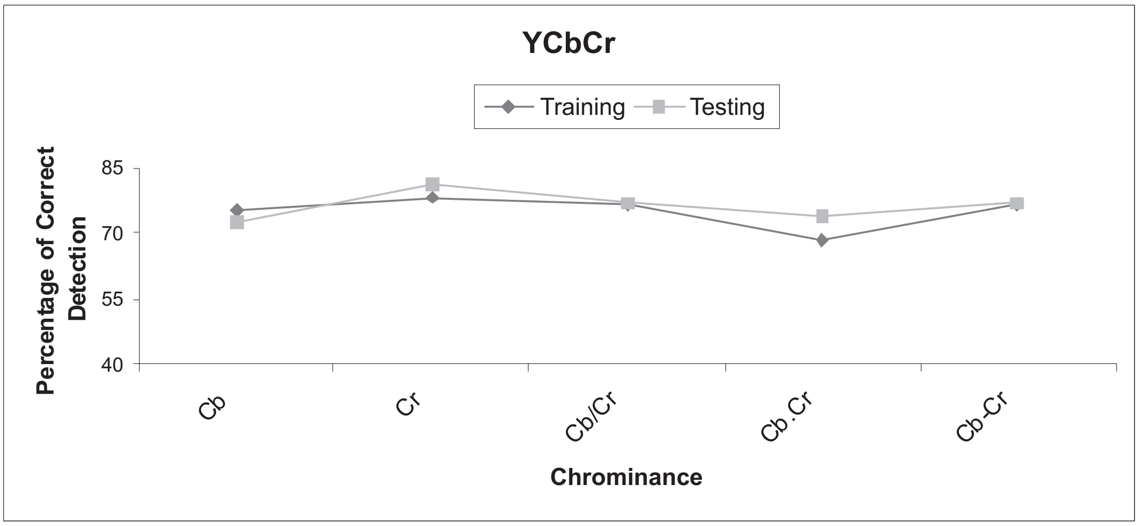

Figure 4. Percentage correct detection for several chrominance of the YC_bC_r colour space on the training and testing images.

CONCLUSIONS

In this work, the performance of skin detection in the Normalised RGB, the Modified Normalised RGB and the YC_bC_r colour spaces was investigated. Histogram-based approach is used where the global threshold value for each chrominance component was determined. The r-g chrominance from the Modified Normalised RGB colour space yields the highest correct detection rate of 81.45%, followed by the C_r chrominance from the Normalised RGB colour space and finally the r.g chrominance from the Normalised RGB. The result obtained is considered to be slightly superior compared to the detection rate of 80% obtained by Jones and Rehg (1999).

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