UNIVERSITI PUTRA MALAYSIA

SKIN COLOUR DETECTION BASED ON AN ADAPTIVE MULTI-THRESHOLDING TECHNIQUE

Ahmed M. Mharib

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

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Dedication

TO MY PARENTS, MY BROTHERS, MY SISTER AND MY HOME IRAQ

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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September 2007

Chairman : Mohammad Hamiruce b. Marhaban, PhD

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Today, human region detection in complex scenes has received a great attention due to the wide use of websites and the considerable progress of the still and video images processing tasks. Skin detection or segmentation is a very popular and useful technique for detecting and tracking of human body parts, especially faces and hands. It is employed in tasks like face or hand detection and tracking, filtering of objectionable web images, people retrieval in databases and the Internet.

This thesis aims to build a skin detection system that will discriminate between the skin and non-skin pixels in still coloured images. This is done by introducing a metric, which measures the distances of the pixel colour to skin tone. The need for a compact skin model representation stimulates the development of parametric skin distribution models which is used in this research.

An adaptive skin colour detection model has been proposed in this thesis. The model is based on the bivariate normal distribution of the skin chromatic subspace. The model uses the 2D Single Gaussian model (SGM), and the 2D Gaussian mixture model (GMM) to represent the skin colour distribution. The model also based on the image segmentation using an automatic and adaptive multi-thresholding technique.

This thesis shows that the Gaussian mixture model alone or the Gaussian single model does not improve the performance of the skin detection model due to the number of false detections for high correct classification. For this reason, a combination of SGM and GMM in the same model is proposed in this research. The results show that when processing images of different people taken in different imaging conditions, the use of only one single threshold value is not adapted, and since the proposed method is capable of adaptively adjusting its threshold values and effectively separating skin colour regions from non skin ones, it is applicable to images with various conditions. The experiment shows that the suggested algorithm achieves a noticeable performance improvement and offers a robust solution for skin detection under varying illumination. The results show that the average of the correct rate “True Positive” rate for the test images is equal to 94.064% while the False Positive average is equal to 13.166%.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENGESANAN WARNA KULIT BERDASARKAN ADAPTASI TEKNIK PEMERINGKATAN PELBAGAI

Oleh

AHMED M. MHARIB

September 2007

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Pada masa kini, pengesanan anggota badan manusia di dalam pemandangan yang komplek semakin mendapat perhatian disebabkan penggunaan laman web yang meluas dan kemajuan yang pesat di dalam kerja pemprosesan imej kulit gambar kaku dan video. Pengesanan atau segmentasi kulit merupakan satu teknik yang terkenal dan sangat berguna di dalam pengesanan dan penjejakan bahagian-bahagian badan, terutamanya muka dan tangan. Teknik ini digunakan di dalam kerja-kerja seperti pengesanan dan penjejakan wajah atau tangan, penurasan imej web terlarang dan pencarian individu di dalam pengkalan data dan internet.

Penyelidikan ini bertujuan untuk membina satu sistem pengesanan kulit yang dapat membezakan pixel kulit dan bukan kulit di dalam imej-imej berwarna. Ini dibuat dengan memperkenalkan satu metrik yang mengukur jarak di antara pixel-pixel warna terhadap tona kulit. Keperluan untuk membuat satu perwakilan model kulit

padat, merangsang pembangunan model taburan kulit parametrik yang telah digunakan dalam penyelidikan ini.

Satu model pengesanan warna kulit suai telah dicadangkan di dalam penyelidikan ini berdasarkan taburan normal dwi-variate. Model ini menggunakan 2D Model Gaussian Tunggal (GSM) dan 2D Model Gaussian Campuran (GMM) untuk mewakilkan taburan warna kulit. Model tersebut juga berdasarkan segmentasi imej menggunakan teknik automatik dan pelbagai takat suai.

Penyelidikan ini menunjukkan bahawa model campuran Gaussian sahaja ataupun model Gaussian tunggal tidak boleh meningkatkan keupayaan model pengesanan kulit disebabkan oleh jumlah kadar kesalahan di dalam pengelasan yang tinggi berbanding yang betul. Disebabkan masalah ini, kombinasi SGM dan GMM di dalam model yang sama telah digunakan. Keputusan menunjukkan bila imej orang berlainan diproses di lakukan dalam keadaan penggambaran berbeza, penggunaan nilai tunggal tidak disuai, dan disebabkan kaedah yang dicadangkan berkebolehan untuk menyuai ubah nilai takatnya dan secara berkesan membezakan kawasan warna kulit daripada kawasan bukan kulit, ia boleh diaplikasikan kepada imej pelbagai keadaan. Ujikaji menunjukkan bahawa algorithma yang dicadangkan berjaya mencapai peningkatan prestasi yang boleh dilihat dan menawarkan penyelesaian yang tegap untuk pengesanan kulit di dalam kesan cahaya yang berubah-ubah. Keputusan tersebut menunjukkan bahawa purata kadar positif benar yang tepat untuk imej ujian adalah bersamaan dengan 94.064%, manakala purata positif salah adalah bersamaan dengan 13.166%.

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I certify that an Examination Committee has met on 20 September 2007 to conduct the final examination of Ahmed M. Mharib on his Master thesis entitled "SKIN COLOUR DETECTION BASED ON AN ADAPTIVE MULTI-THRESHOLDING TECHNIQUE" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 22 January 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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AHMED M. MHARIB

Date: 30 November 2007

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LIST OF ABBREVIATIONS

SGM	Single Gaussian Model
GMM	Gaussian Mixture Model
TSL	Tint, saturation and lightness
JPEG	Joint Photographic Experts Group
HVS	human visual system
URL	Uniform Resource Locator
TIFF	Tagged Image File Format
CRT	cathode-ray tube
RGB	Red-Green-Blue
HSI	hue, saturation and intensity
LUT	lookup table
EM	Expectation-Maximization
PDF	probability distribution function
ROC	receiver operating characteristic
LPF	low-pass filter
SDM	skin detection model
TP	true positive
FP	false positive

CHAPTER 1

INTRODUCTION

1.1 Background

Skin detection has gained popularity and importance in the computer vision community. It is an essential step for important vision tasks such as the detection, tracking and recognition of face, segmentation of hand for gesture analysis, person identification, as well as video surveillance and filtering of objectionable web images. All these applications are based on the assumption that the regions of the human skin are already located.

Skin segmentation is a computer vision process that aims to locate the skin regions in an unconstrained input image. In the pixel-based skin detection methods, the task can be considered as a standard two-class classification problem; taking each pixel of the input image (individually and independently from its neighbours); and producing binary output image that represents both the skin pixel and non-skin pixel.

Using skin colour as a detection cue, have gained strong popularity. Colour allows fast processing. Also, the experience suggests that human skin has a characteristic colour, which is easily recognized by humans (Vezhnevets *et al*, 2003). Researchers usually

face three main problems in designing skin detection systems. 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.

In this thesis, a skin colour detection model has been proposed. This model is based on the bivariate normal distribution of the skin chromatic in the single Gaussian and the mixture of Gaussians with two components. In addition, the model is also based on a method to estimate an adaptive threshold values. Tint, saturation and lightness (TSL) colour space is chosen since it is superior to the other colour spaces when a parametric model was used (Terrillon *et al* 2000). Seven different database of bitmap with JPEG file format are used to build the model and test the performance.

1.2 Motivation

Skin detection is an essential step for many important vision applications such as face detection and recognition, human tracking, hand segmentation for gesture analysis, filtering of objectionable images and others. The robustness and reliability of the skin detection step is crucial for the success of such systems. The efficiency of these systems depends significantly on the accuracy of the performance of the skin detection model. An improved human skin detector with a higher correct detection ratio helps to enhance the performance of the computer vision applications based on the skin detection operation.

1.3 Statement of the Problem

Skin colour classification is regarded as a difficult problem due to many reasons (Zhang *et al* 2004). Skin colour is affected by among others, an ambient light which is unknown in many situations, different cameras produce different colours, and even from the same person, under the same illumination conditions and the skin colours change from one person to another. All of these active factors may work together to reduce the efficiency of any human skin detection model.

Due to variations of lighting conditions and camera hardware settings and the existence of many ethnic people with a wide range of skin colours, the adaptive thresholding technique afforded improved performance comparing to the one based on fixed threshold values (Huynh-Thu *et al* 2002). While most of the previous segmentation techniques adopt a fixed threshold scheme, few researchers proposed methods to automatically compute an adaptive threshold values.

Cho et al (2001) presented a skin-colour filter that was capable of adaptively adjusting its threshold value and separating skin-colour regions from similar back ground colour regions. Huynh-Thu *et al* (2002) proposed a method to find the optimal threshold automatically for each sub-model in the GMM. Phung *et al* (2003) proposed an adaptive skin segmentation technique which employed the texture characteristics of the human skin by using appropriate homogeneity measures for skin regions. All these methods involve iterative processes, thus increase the computational cost.

Wimmer and Radig (2005) presented an explicitly defined skin color classifier that can be adapted to the conditions of each image by evaluating some previously know skin color pixels which are acquired by applying a face detector. The limitation of this work represented by the used method to estimate the bounds of the adaptive skin color classifier, normally, skin detection is pre-processed operation of the face detection task. and also, the main difficulty in achieving high correct rates with this method is the need to find adequate decision rules empirically. Almohair *et al* (2007) reported an experimental investigation, which aims at using different threshold values to classify the human skin. The chromatic skin color model was used to model skin color in the normalized Red and Green (*r*-*g*) chromaticity space, the proposed method here didn't consider the covariance between *r* and *g* in the design of the model, which has a passive impact on the resulted correct rates, and also this method used the False Negative and the True Positive measurements to estimate the threshold values which make this method inapplicable.

The proposed skin colour detection model based on adaptive thresholds tries to achieve high correction detection rates by solving the following problems:

- The robustness of skin colour detection under varying lighting conditions.
- The effect of the input image hardware settings on the skin colour values.
- The variety of the skin tones from one person to another with respect to the ethnic group.

This is achieved by designing a sophisticated skin colour distribution model, and by using an automatic and adaptive multi-thresholding technique which is non- iterative process, and by using this technique heavy computational cost can be saved.

1.4 The Aims and Objectives of the Research

In this research, a human skin colour detection model is suggested, this model is used for segmenting a coloured still image file into a skin and non-skin regions, whereas the skin detection operation is person independent and work in complex dynamic backgrounds and under variable lighting. The objectives of this work are as follows:

- Contributing a new technique for estimating adaptive threshold values for the suggested skin detection model to achieve a high True Positive rate.
- Building a skin detection model that is more general for different lighting conditions and camera hardware settings.

These objectives can be achieved by comparing and evaluating different skin colour models in order to estimate the properties of the human skin colours, and by proposing an adaptive skin colour detection model based on statistical models that used both the SGM and GMM.

1.5 Scope of the Research

This thesis suggests a skin detection model based on the bivariate statistical models. The proposed method uses the single Gaussian model (SGM) and the Gaussian mixture model (GMM) to represent the skin colour distribution in the chromatic subspace, so that any pixel detected as skin by any one of these models will be considered as skin pixels. The suggested method is based on the segmentation of images using an automatic and adaptive new multi-thresholding technique.

The strategy of this work consists of two main steps. First, the SGM and GMM of the skin-colour distribution are built based on 1000 skin samples (64X64 pixel) taken from a wide variety of people and in different lighting conditions. Second, the skin-colour segmentation is performed based on the SGM and GMM of the skin-colour distribution, where an automatic adaptive thresholding technique is used to segment the image into the skin and non-skin regions.

Based on the observation, it is found that the images with pixels having high probability to be a skin need a big threshold value, whereas the images with pixels having a low probability to be a skin need a rather small value. This study suggests a new segmentation technique to evaluate the threshold values so that a high degree of separation between the skin and non-skin pixels can be achieved.

There are no limitations in relation to the different colour of the skin such as fair and dark complexions as once the skin samples from those who are having these different

skin colours are collected, these samples are then used to estimate a parametric statistical model of the SGM and GMM. The GMM parametric estimation is performed by a learning process based on the Expectation-Maximization (EM) algorithm. The scheme of this work has been designed by using the MATLAB version 6.0, where any bitmap still colour image file with 24-bit/pixel (8 bit for each channel) can be used with the proposed model.

1.6 Thesis Organization

This thesis is organized in five chapters. In Chapter Two, the theoretical background for this thesis introduces and reviews related work in this particular field including the concepts of colour and the colour space representations and transformations, giving a general description of the human skin colour characterization. Graphics file formats are introduced briefly; and colour-based skin modelling and detection methods are also reviewed. Chapter Three presents the methodology of this thesis, including the stages in developing the proposed skin detection model. The results derived from the experimental work are discussed in Chapter Four. These results are useful in giving a topical evaluation for the performance of the suggested model. The final chapter draws the conclusions and suggests further perspectives.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter introduces the theoretical background of the skin detection task and reviews the colour-based skin detection and modelling techniques. It presents a comprehensive study of the two important issues of the colour pixel classification approach to skin segmentation, the colour representation and the classification algorithms. This chapter consists of five sections; the first section introduces the concepts of colour and a description of the human skin colour characterization. After that, an introduction to the skin detection task and its applications are introduced. In the third section, graphics file formats and some colour space representations and transformations are reviewed. Then, the colour-based skin modelling and detection methods for computer vision are defined focusing on the published work in this field with details. Finally, summary and conclusions are given.

2.2 Concepts of Colour

Colour is a perceptual representation of the surface reflectance of an object, as a result of the human eye sensitivity to electromagnetic radiation wavelengths in the range