Pattern Recognition 47 (2014) 1573–1585

Contents lists available at ScienceDirect

Pattern Recognition

journal homepage: www.elsevier.com/locate/pr

Face detection based on skin color likelihood

Yuseok Ban [a], Sang-Ki Kim [b], Sooyeon Kim [a], Kar-Ann Toh [a], Sangyoun Lee [a,*]

[a] School of Electrical & Electronic Engineering, Yonsei University, Seoul 120-749, Republic of Korea
[b] LG electronics Umyeon R&D campus, 16, Umyeon-dong, Seocho-gu, 137-900 Seoul, Republic of Korea

ARTICLE INFO

Article history:
Received 10 December 2012
Received in revised form
31 October 2013
Accepted 6 November 2013
Available online 25 November 2013

Keywords:
Face detection
Skin color emphasis
Likelihood
Boosting
Face pose variation
Complex background

ABSTRACT

We propose a face detection method based on skin color likelihood via a boosting algorithm which emphasizes skin color information while deemphasizing non-skin color information. A stochastic model is adapted to compute the similarity between a color region and the skin color. Both Haar-like features and Local Binary Pattern (LBP) features are utilized to build a cascaded classifier. The boosted classifier is implemented based on skin color emphasis to localize the face region from a color image. Based on our experiments, the proposed method shows good tolerance to face pose variation and complex background with significant improvements over classical boosting-based classifiers in terms of total error rate performance.

1. Introduction

Human face detection is among the most important topics in biometric research since it has a broad range of applications. Detection of face is often performed prior to recognition and tracking in biometric and surveillance systems. A variety of techniques have been proposed for face detection in the literature where they can be generally classified into the following categories [1]: knowledge-based methods, invariant feature methods, template matching methods and appearance-based methods.

Knowledge-based methods are rule-based methods which encode human knowledge of what constitutes a typical face. Usually, some rules are designed to capture the relationships among the facial components. Invariant feature methods adopt features such as facial components, texture, skin color and a multiple of these features for face detection. These methods aim to find common structural features which exist among faces under different ambient conditions. Template matching methods store several standard patterns of a face to describe the face either as a whole or as separate facial components. Appearance-based methods learn a model or a group of features from a set of training images to capture the representative variability of facial appearance.

Most of the face detection techniques incur a large number of false rejections due to severe face pose variation and false acceptances due to complex background. To address these issues, we propose a face detection method based on skin color emphasis and iterative boosting to selectively highlight the skin color information and deemphasize background information. Unlike other boosting-based methods using skin color, our method uses neither parametric curve fitting nor morphological operators. Skin color is used for skin color emphasis rather than skin color segmentation.

Our main contributions of this work include the tolerance of proposed system to face rotation and complex background. The boosted classifier reacts less sensitively to face pose variation as it concentrates on probabilistic distribution of facial skin color rather than the details of facial components in gray-level brightness. Also, non-skin color information including background is significantly reduced, so that skin color likelihood can be discriminatively learned.

The organization of this paper is as follows. Section 2 provides a review on related works in face detection using skin color information. Section 3 describes our proposed method in detail. Section 4 presents the experimental results of our method on several face databases. Finally, our conclusion is given in Section 5.

2. Related works

Many face detection methods based on a face model have been proposed to cope with varying conditions including face rotation and complex background. Wang and Yuan [2] proposed a human face detection from color images under complex conditions including arbitrary image background. They used an evolutionary computation technique to cluster skin-like color pixels and segment each face-like region. After the face-like regions are located,

* Corresponding author. Tel.: +82 2 2123 5768; fax: +82 2 313 2879.
E-mail addresses: van@yonsei.ac.kr (Y. Ban), boxboxsk@gmail.com (S.-K. Kim), sykim1221@yonsei.ac.kr (S. Kim), katoh@yonsei.ac.kr (K.-A. Toh), syleee@yonsei.ac.kr (S. Lee).

0031-3203/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.patcog.2013.11.005

the wavelet decomposition is applied to each face-like region to detect the possible facial components and to check if there is an eye in the region. Regions in which an eye is detected or the facial components are distributed like a predefined face model are recognized as human faces. Yao and Gao [3] established a type of coordinate transformation which is able to improve chrominance of skin and lips. With the coordinates, they suggested a face detection method based on skin chrominance and lip chrominance transformations to deal with the varying pose of object and the complex background. Hsu et al. [4] presented a face detection algorithm for color images in the presence of varying lighting conditions and complex background. The algorithm is based on their novel lighting compensation technique and a nonlinear transform to the *YCbCr* color space. They first detected skin regions to generate face candidates that are then verified according to eye, mouth and boundary maps. Aldasouqi and Hassan [5] proposed a fast algorithm for detecting faces using morphology-based techniques in *HSV* color space. Sanjay Kr. Singh et al. [6] have combined *RGB*, *YCbCr* and *HSI* color spaces to get a new skin color based face detection algorithm. As presented above, model-based face detection methods commonly use transformation of color space and are based on single or multiple ranges of threshold and morphological operations in order to segment skin regions [7]. The advantage of explicitly defining the boundary of skin cluster is the simple skin detection rules which allow very rapid classification. However, to achieve a high recognition accuracy using this method, we need to find a specifically adequate threshold levels and appropriate decision rules in an empirical way [8].

Many face detection methods based on boosting algorithm have been also suggested. Viola and Jones [9] proposed the boosting-based face detection from learning a sequence of Haar-like features. The differences in average intensities between two rectangular regions are encoded by Haar-like features. The cascade structure of classifiers is built using boosting algorithm which chooses distinctive features [9]. Lienhart et al. [10] extended the work of Viola and Jones using an extended set of Haar features for different views of faces. Despite of the usefulness of Haar-like features, the complete set of the features has to include a mass of redundant information, and the use of pixel brightness shows limitation against varying conditions such as face rotation and complex background. Zhang et al. [11] used AdaBoost learning to select a set of local regions and their weights with respect to Local Binary Pattern (LBP) features for face detection. Many face detection techniques have difficulty in finding face under conditions of large variation in face pose and complex background, and so does AdaBoost using LBP features. Yan-Wen Wu et al. [12] used AdaBoost algorithm combined with skin color segmentation, and the segmentation is obtained by single Gaussian model fitting and morphological operations on binary image. Furthermore, Gaussian mixture models have been suggested for modeling the skin color distribution [13]. Kai-Biao Ge et al. [14] suggested an AdaBoost algorithm combined with skin segmentation and LBP based face description. Although parametric curve fitting such as Gaussian fitting or elliptical fitting enables incomplete training data to be generalized and interpolated, the result highly depends on the shape of the curve [8]. Additionally, either general facial shape information or specific facial component information can be lost via skin color segmentation.

In this paper, we propose a boosting-based face detection method using skin color information without any parametric fitting or morphological operation. Skin color information is used not for skin color segmentation but for skin color emphasis. A cascaded classifier based on AdaBoost is combined with skin color emphasis, resulted in achieving improved face detection

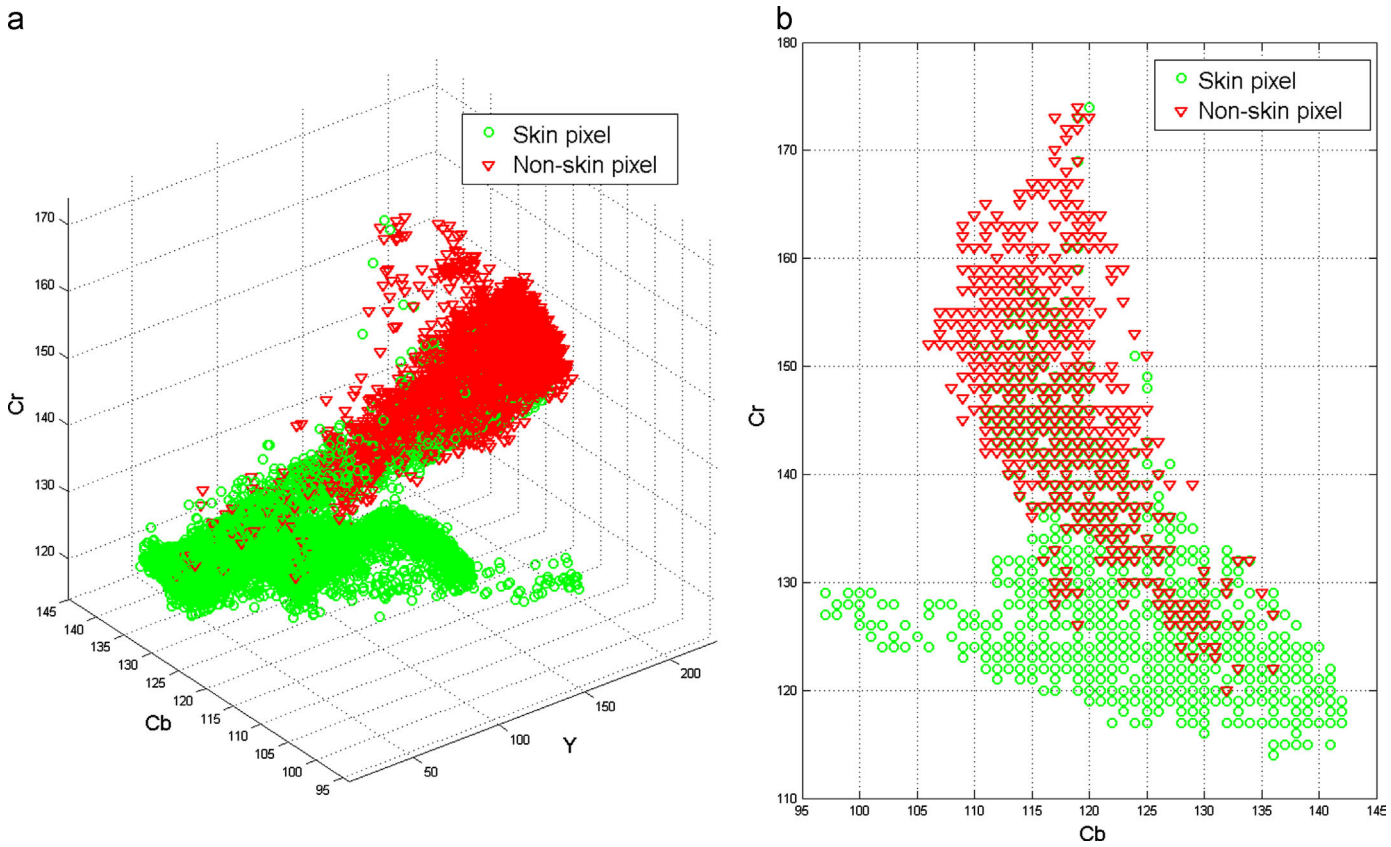

Fig. 1. Examples of skin and non-skin color distributions on (a) *YCbCr* space and (b) *CbCr* space.