Journal of Systems Architecture 64 (2016) 100–109

Contents lists available at ScienceDirect

Journal of Systems Architecture

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

Faces detection method based on skin color modeling

Seokhoon Kang*, Byoungjo Choi, Donghw Jo

Incheon National University, Incheon, Korea

ARTICLE INFO

Article history:
Received 23 July 2015
Revised 13 November 2015
Accepted 17 November 2015
Available online 2 December 2015

Keywords:
Face detection
Skin-color model
Skin-color classifier
Sliding window

ABSTRACT

This study suggests a method to improve the speed of a sliding window type of face detector by way of skin color region detection. The face detection method by way of skin color region detection has been studied in various perspectives: Complicated background images because of the area whose color is similar to the skin color cause high false positive rates. In contrast, the face detection method based on appearance, which adopts a sliding window type, may involve high face detection rates but cause tremendous computational costs in the process of detection scanning as the image size increases, whereas the processing time is also extended accordingly. This study suggests a method to control the subwindow size and detection area of a sliding window by detecting and using the skin color region with the processing time reduced. By means of a face detector with haar wavelet and LBP features, 274 images were collected online in addition to Bao database images, and then an experiment was conducted with them. As a result, the face detection time in utilization of an existing sliding window decreased down to a maximum of 47%.

1. Introduction

In psychology, neurology, and various engineering areas, research works on face and facial expression recognition have been conducted mainly for practical use in life such as identification, security system, human resource data management, and membership management. The very first step to be taken for such face and facial expression recognition researches is face detection to locate a face in an image. If this step fails, face recognition is impossible. Face detection is a technology to determine if a static image includes a face and detects it. A face may be seen differently depending on changes in its size, horizontal or vertical turning, profiles and front faces, facial expressions, light conditions, etc., which causes various challenges in face detection research works. Accordingly, because of the difficulty in and the importance of face detection, this area of research is regarded as an independent sector rather than a preliminary step of face recognition. Recently, the areas of face detection application have continued increasing.

Face detection has been examined in various perspectives. It is categorized into four major methods: knowledge-based method, characteristic-based method, template matching method, and appearance-based method. First, the knowledge-based method is used to locate the eyes, nose, and mouth in a face and measure the distance between them based on the general information of human faces [1–4]. Second, the characteristic-based method includes the color-based method and utilizes structural characteristics, which are useful for face detection regardless of changes under postures and lighting conditions [5]. Structural features include the regional characteristics, textures, shapes, and skin colors of faces. The regional features of faces include two eyes, nose, eyebrows, mouth, etc. The color-based method distinguishes skin color pixels from image pixels and views them as a specific area in determining if a face exists in an area. The skin color region classifier used in this study is one example. Some research works examine the way of face detection in the utilization of skin color pixels, and some the way of improving detection rates by using edges in addition to skin colors [10–12,23–28].

Third, the template matching method is a way of detecting a face based on a certain level of correlation among basic formation elements of a face [6]. When an image is given, the correlation values of the contour, eyes, nose, and mouth are calculated to determine if there is a face in that image. Fourth, the appearance-based method is significantly different from the other three in that it models faces through self-learning. This method continues to learn “faces” from all former face images and “non-faces” from images with no face for future recognition. Eigen value, LDA, neural circuit networks, SVM (Support Vector Machines), and Adaboost (Adaptive Boosting) are some of the examples. The sliding window-based face detector used in this study is a type of appearance-based face detection method [7–9].

Among characteristic-based face detection methods, the skin color-based face detection method has been studied in various perspectives. Hsu detects faces based on colors under various light conditions and complicated backgrounds [12].

This study utilizes a light compensation technique called “white reference” and YCbCr color model in detecting face candidates, which

* Corresponding author. Tel.:/fax: +82 32 835 8760.
E-mail addresses: hana@inu.ac.kr (S. Kang), bjc97r@inu.ac.kr (B. Choi), tacha6613@gmail.com (D. Jo).

http://dx.doi.org/10.1016/j.sysarc.2015.11.009
1383-7621/

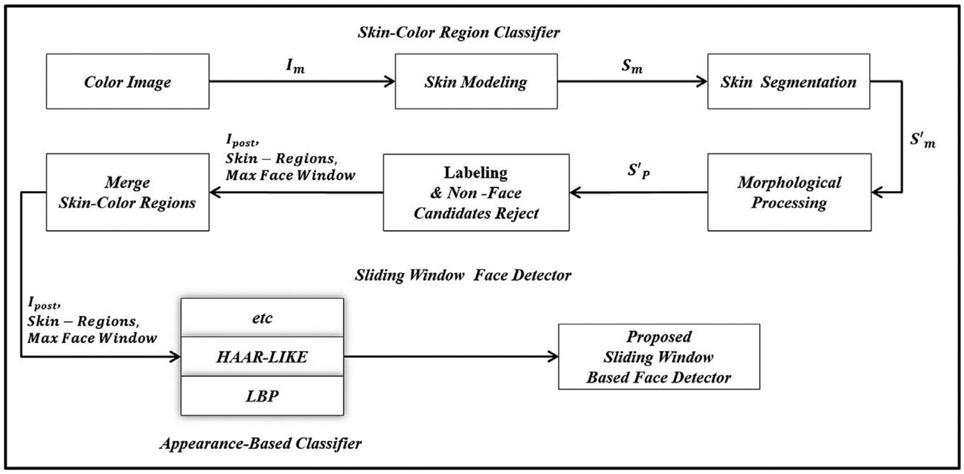

Fig. 1. The proposed face detection flow

is followed by the detection of the eyes and mouth and then the facial contour. Abin suggests a real time multiple face detection and a tracing algorithm based on the skin color, edge, and shape information [13]. However, the false positive rate was quite high—up to 27.6% in Compaq database. Aldasouqi suggests a methodology to detect a face promptly by using a morphology operation in an HSV color model [14]. Sanjay Kr. Singh suggests a new face detection algorithm based on skin colors in combination of HSI, YCbCr, and RGB Color models [15]. Lin has developed an efficient methodology of detecting multiple faces based on color images in complicated environments and different lighting conditions [16].

As for the appearance-based face detection method, the sliding window-based detector is commonly used in object detection [7,17]. A number of systems utilize this in steps of facial detection, tracing, and recognition. In a detector, the classifier detects objects when a certain processing response in the subwindow is returned at each location of an image. One important challenge of these research works is to avoid performance deterioration in real time processing. This study focuses on improving the speed in the step of detection. Viola suggests a cascade type of face detector, which improves speed by removing the background promptly and spending more time in processing candidate areas [18]. Nonetheless, computational costs in a subwindow are quite high, and the number of subwindows is reduced, the size of subwindows is limited, or the movement unit of subwindows is increased in order to improve the speed of a classifier.

Decades, skin color-based face detection algorithms have been developed by means of various color models. As for skin color characteristics, however, false positive rates would increase and detection rates decrease when an image contains a complicated background or many spots whose colors are similar to the skin color. In contrast, as the appearance-based face detection method based mainly on the sliding window means scans the whole image and utilizes learning data, it maintains high face detection rates but the computational costs are also high. Thus, as the size of an image increases, the scanning process involves a lot of computational costs and processing time.

This study suggests a face detector that utilizes the advantages of the skin color-based face detector and the sliding-based face detector. As for the skin color-based face detection method, a certain skin color region is separated from the entire image by using the skin color region classifier, and then the face is detected by using the sliding window-based face detector, which is one of the appearance-based face detection methods. Hence, subwindows detect a face only in skin color regions to reduce the number of subwindows, and the size of them is also limited by using a skin color region. As a result, at the same detection rates of the existing sliding-based face detector, false positive rates are decreased and the detection speed is improved.

This study consists of the following sections: Section 2 presents explanations on the suggested skin color region classifier. Section 3 presents the sliding window-based face detector with the sliding window-based face detector briefly explained. Section 4 shows the performance of the suggested algorithm based on experiments. Section 5 presents the conclusion of this study.

2. Skin color region classifier algorithm

The methodology suggested in this study consists mainly of the skin color region classifier and the sliding window-based face detector as shown in Fig. 1 below, which presents the entire flow diagram of the suggested facial detection method. In Fig. 1, *Im* indicates the color image of (NXM), $S'm$ a binary image in application of the skin color segmentation, S'_p a binary image after the morphological image processing, and I_{post} an image after the labeling and non-face candidate rejection process. The process of combining skin color regions is to reduce overlapping areas with the max size of a subwindow limited. I_{post} is an image delivered to the sliding window face detector. The skin color regions delivered along are face area candidates. The max face window is the largest area among segment sections. With the max size of a subwindow limited, performance enhancement is expected. The following sections explain each block.

2.1. Skin color modeling segmentation

Skin color modeling requires the process of selecting used ones among various color models. Color models include RGB, Normalized RGB, HIS (hue, saturation, and intensity), HSL (hue, saturation, and lightness), TSL (tint, saturation, and luminance), and YCbCr. Among these, a YCbCr color model distinguishes luminance elements from chrominance elements, and a linear conversion of an RGB color model is possible, and thus is widely used for skin color models because of simplicity and minimal operation. This study too utilizes this YCbCr color model.

In this study, skin color regions are classified as the preliminary step to accelerate the appearance-based facial detection. Thus, algorithms that are complicated require high computational costs and speed influence is excluded. The focus is on separating skin color regions as accurately as possible. Accordingly, a certain color scope is decided for classification in designing the skin color detector.

First of all, only a simple linear conversion makes conversion into a color model possible [19]. After conversion into YCbCr, 26,214,989 pixels of Ground-Truth data were analyzed, which were skin color pixels collected to grasp the scope of pixels closest to the skin color.