Face Detection Using Sketch Operators and Vertical Symmetry

Hyun Joo So[1], Mi Hye Kim[1], Yun Su Chung[2], and Nam Chul Kim[1]

[1] Laboratory for Visual Communications, School of Electrical Engineering and Computer Science,
Kyungpook National University, Daegu, 702-701 Korea
{ufo24, rlaalgp77}@vcl.knu.ac.kr, nckim@ee.knu.ac.kr
http://vcl.knu.ac.kr

[2] Biometric Chipset Technology Research Team, Electronics and Telecommunications Research Institute, Daejeon, 305-700, Korea
yoonsu@etri.re.kr

Abstract. In this paper, we propose an algorithm for detecting a face in a target image using sketch operators and vertical facial symmetry (VFS). The former are operators which effectively reflect perceptual characteristics of human visual system to compute sketchiness of pixels and the latter means the bilateral symmetry which a face shows about its central longitudinal axis. In the proposed algorithm, horizontal and vertical sketch images are first obtained from a target image by using a directional BDIP (block difference inverse probabilities) operator which is modified from the BDIP operator. The pair of sketch images is next transformed into a generalized symmetry magnitude (GSM) image by the generalized symmetry transform (GST). From the GSM image, face candidates are then extracted which are quadrangular regions enclosing the triangles that satisfy eyes-mouth triangle (EMT) conditions and VFS. The sketch image for each candidate is obtained by the BDIP operator and classified into a face or nonface by the Bayesian classifier. Among the face candidates classified into faces, one with the largest VFS becomes the output where the EMT gives the location of two eyes and a mouth of a target face. If the procedure detects no face, then it is executed again after illumination compensation on the target image. Experimental results for 1,000 320x240 target images of various backgrounds and circumstances show that the proposed method yields about 97% detection rate and takes a time less than 0.25 second per target image.

1 Introduction

Face detection is to automatically search out the locations of human faces in target images, which precedes image processing such as face retrieval, facial coding, face tracking, and face recognition. It is generally composed of face candidate detection and face-nonface classification [1]. The former may contain low-level analysis and face-like constellation analysis, and the latter feature enhancement, dimension reduction, and face-nonface discrimination. In low-level analysis, pixels which are closely related to significant information such as edge, generalized

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symmetry (GS) [2], skin color, and motion are more emphasized or extracted from a target image. In face-like constellation analysis, using the output image by low-level analysis, face candidates are located which satisfy geometric relations of a face and its components such as eyes and a mouth, for example, eyes-mouth triangle (EMT) conditions [3]. As an input feature, each candidate may then enter a face-nonface discriminator directly, or through feature enhancement or even through dimension reduction using techniques such as principle component analysis (PCA) [4]. In conventional feature enhancement tools, there are horizontal and vertical Sobel operators [5], horizontal and $\pm\pi/4$ directional gradient operators [6], wavelet filters [7], and the combination of Harr wavelet, horizontal projection, and vertical projection [4]. In face-nonface discrimination, each raw or enhanced face candidate is decided to be a face or a nonface by a classifier such as Bayesian discriminator [4], support vector machine [8], Fisher linear discrimination [9], and neural network approach [10].

One can find many face detection algorithms which use gradient operators for lowlevel analysis or feature enhancement [2], [4]-[7]. However, most of gradient operators are oriented to edge extraction and sensitive to local change of illumination. On the other hand, the BDIP (block difference inverse probabilities) operator [11], which is recently known to yield excellent performance in content-based image retrieval, extracts not only edges but also valleys well that are perceptually more important features and is robust to local change of illumination. It also emphasizes more dark features than bright ones so as to output sketch-like images, which is consistent with the characteristics of human visual system. Since human eyes must be one of the best face detection systems, the BDIP operator is thus expected to be so helpful for face detection. In addition, it is a well-known common sense that a face is bilaterally symmetric about its central longitudinal axis, which has been used in many works such as facial component extraction from a face image [12], face authentication with 3D face images [13], and pose compensation for 3D face recognition [14]. Along with EMT conditions, the use of such VFS in face detection is expected to promote the detection performance greatly.

We propose a face detection algorithm using BDIP operators and VFS. In lowlevel analysis, a target image is converted into horizontal and vertical sketch images by a directional BDIP operator, which is modified from the BDIP operator, and then the pair of the sketch images produces a generalized symmetry magnitude (GSM) image by using the generalized symmetry transform (GST) [2]. In face-like constellation analysis, EMTs which satisfy EMT conditions and VFS are constructed from the GSM image and the quadrangular region enclosing the EMTs become face candidates. In face-nonface classification, the candidates which pass through the BDIP operator for feature enhancement and PCA for dimension reduction are decided to be faces or nonfaces by the Bayesian classifier. Among face candidates decided as faces, one with the largest VFS results in a detected face. If the detection procedure declares no face, it is executed again after illumination compensation on the target image.