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Optimized face recognition algorithm using radial basis function neural networks and its practical applications

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ABSTRACT

In this study, we propose a hybrid method of face recognition by using face region information extracted from the detected face region. In the preprocessing part, we develop a hybrid approach based on the Active Shape Model (ASM) and the Principal Component Analysis (PCA) algorithm. At this step, we use a CCD (Charge Coupled Device) camera to acquire a facial image by using AdaBoost and then Histogram Equalization (HE) is employed to improve the quality of the image. ASM extracts the face contour and image shape to produce a personal profile. Then we use a PCA method to reduce dimensionality of face images. In the recognition part, we consider the improved Radial Basis Function Neural Networks (RBF NNs) to identify a unique pattern associated with each person. The proposed RBF NN architecture consists of three functional modules realizing the condition phase, the conclusion phase, and the inference phase completed with the help of fuzzy rules coming in the standard 'if-then' format. In the formation of the condition part of the fuzzy rules, the input space is partitioned with the use of Fuzzy C-Means (FCM) clustering. In the conclusion part of the fuzzy rules, the connections (weights) of the RBF NNs are represented by four kinds of polynomials such as constant, linear, quadratic, and reduced quadratic. The values of the coefficients are determined by running a gradient descent method. The output of the RBF NNs model is obtained by running a fuzzy inference method. The essential design parameters of the network (including learning rate, momentum coefficient and fuzzification coefficient used by the FCM) are optimized by means of Differential Evolution (DE). The proposed P-RBF NNs (Polynomial based RBF NNs) are applied to facial recognition and its performance is quantified from the viewpoint of the output performance and recognition rate.

1. Introduction

Biometrics delivers technologies that identify individuals by measuring physical or behavioral characteristics of humans. A password or PIN (Personal Identification Number) type recently used is the means of personal authentication that requires to be memorized. They could be compromised relatively easily. In more advanced biometric scenarios, memorization is not required (Chellappa, Wilson, & Sirohey, 1995). The existing face recognition algorithms were studied by using 2D image. Besides the face, local eye or template matching-based methods were used. The issues of overhead of computing time as well as the memory requirements were raised that concerned an acquisition of image data or the ensuing learning. PCA transformation that enables to decrease processing time by reducing the dimensionality of the data has been proposed to solve such a problem. Boehnen and Russ (2005) used facial color present in 2D images while Colombo, Cusano, and Schettini (2005) used curvature, position and shape of the face. Colbry, Stockman, and Jain (2005) and Lu and Jain (2005) generated a statistical model of the eyes, nose and mouth and eyes. Recently, the more effective applications were supported by the use of ASM (Cootes, Cooper, Taylor, & Graham, 1995).

Most 2D feature-based biometrics algorithms typically require high quality images in order to achieve high performance (Mohammed, Minhas, Jonathan Wu, & Sid-Ahmed, 2011). Therefore in order to properly extract the feature candidates of face image, all unnecessary information existing in the face image must be

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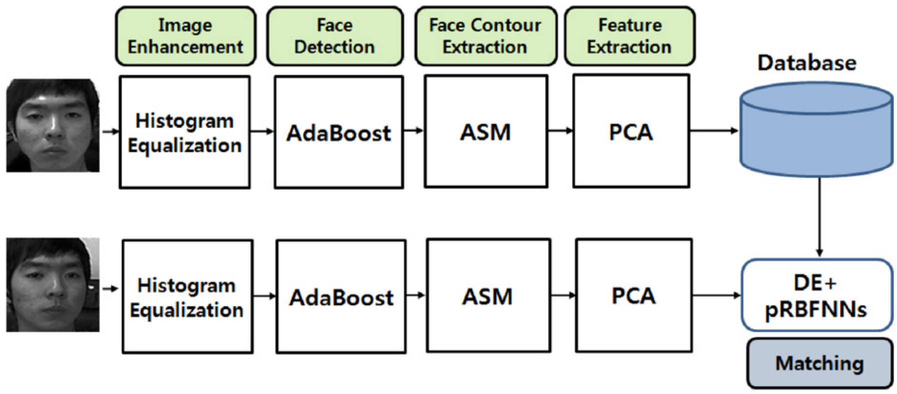

Fig. 1. An overall architecture of the face recognition system.

removed. The facial feature image can be thus obtained after removing the unnecessary features by augmenting the "conventional" recognition system by the ASM process. That is, facial features are extracted by removing the background and obstacles from input images by using the ASM.

In the sequel, face extraction and recognition are carried out by running a series of algorithms such as ASM, PCA, and DE-based P-RBF NNs. The main objective of this study is to improve the face recognition rate by handling the image of enhanced facial features through the multi-dimensional data preprocessing technologies (PCA combined with ASM) and DE-based P-RBF NNs. We realize this objective within the context of a practical recognition environment. Along with this new design approach we provide a thorough comparative analysis contrasting the performance of the recognition scheme proposed here with the performance of other approaches existing in the literature.

This paper is organized as follows: in Section 2, we introduce the proposed overall face recognition system and the design method. Section 3, Histogram equalization, AdaBoost, ASM, and PCA forming the preprocessing part of face recognition. Optimization techniques and a design method of a pattern classifier for face recognition are covered in Section 4. In Section 5, we analyze the performance of the proposed system by using input images data coming from a CCD camera. Finally, the conclusions are covered in Section 6.

2. Structure of face recognition system

In this section, an overall structure of proposed face recognition system and design method is described. Face recognition system is constructed to data preprocessing and RBF NNs pattern classifier applying optimization techniques. Histogram equalization, AdaBoost, ASM, and PCA realized a phase of data preprocessing. Histogram equalization compensates for illumination-distortion of images. The face area is detected by using AdaBoost. By using the ASM, face information is extracted and eventual obstacles are removed. The features of face images are extracted with the use of the PCA method. The RBF NN pattern classifier is constructed. The classifier comprises three functional modules. These modules realize the condition, conclusion and aggregation phase. The input space of the condition phase is represented by fuzzy sets formed by running the FCM clustering algorithm (Tsekourasa, Sarimveisb, Kavaklia, & Bafasb, 2005). The conclusion phase involves a certain polynomial. The output of the network is determined by running fuzzy inference. The proposed RBF NNs come with the fuzzy inference mechanism constructed with the use of the fuzzy rule-based network. In the construction of the classifier, Differential Evolution (DE) is used to optimize the momentum coefficient, learning rate, and the fuzzification coefficient used in the FCM algorithm. Fig. 1 portrays an overall architecture of the system.

3. Data reprocessing for facial feature extraction

In this section, we briefly elaborate on the histogram equalization, AdaBoost algorithm, ASM and PCA as they are being used at the phase of data preprocessing.

3.1. Histogram equalization

Histogram equalization (HE) is a commonly used technique for enhancing image contrast (Gonzalez & Woods, 2002).

Consider a facial image W with N pixels, and a total number of k gray levels, e.g., 256 gray levels in the dynamic range of $[0, L-1]$. The generic idea is to map the gray levels based on the probability distribution of the image input gray levels. For a given image W, the probability density function (PDF) of $PDF(W_k)$ is defined as

$$PDF(W_k) = n_k/n. \tag{1}$$

For $k = 0, 1, \ldots, L-1$, where n_k represents the number of times that the level, W_k appears in the input image W, and n is the total number of samples in the input image. Note that $PDF(W_k)$ is associated with the histogram of the input image which represents the number of pixels that have a specific input intensity X_k. A plot of n_k versus W_k is known as the histogram of image $W(I, J)$. Based on the PDF, the cumulative density function (CDF) is defined as

$$CDF(w) = \sum_{j=0}^{k} PDF(W_j) \tag{2}$$

where $W_k = w$, for $k = 0, 1, \ldots, L-1$. By definition, $PDF(W_{L-1}) = 1$. Through histogram equalization we map the input image into the entire dynamic range (W_0, W_{L-1}).

Fig. 2(a) and (b) show a face image along with its equivalent histogram. The output image produced after histogram equalization is given in Fig. 2(c) and (d). This result demonstrates the performance of the histogram equalization method in enhancing the contrast of an image through dynamic range expansion.

3.2. AdaBoost-based face detection

The purpose of face detection is to locate faces present in still images. This has long been a focus of computer vision research and has achieved a great deal of success (Gao, Pan, Ji, & Yang, 2012; Lopez-Molina, Baets, Bustince, Sanz, & Barrenechea, 2013; Rowley, Baluja, & Kanade, 1998; Sung & Poggio, 1998; Viola & Jones, 2004). Comprehensive reviews are given by Yang, Kriegman, and Ahuja (2002), and Zhao, Chellappa, and Phillips (2003). Among face detection algorithms, the AdaBoost (Freund & Schapire, 1995) based method proposed by Viola and Jones (2001) has gained great popularity due to a high detection rate, low complexity,