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Using backpropagation neural network for face recognition with 2D + 3D hybrid information

Te-Hsiu Sun [a], Fang-Chih Tien [b,*]

[a] *Department of Industrial Engineering and Management, Chaoyang University of Technology, 168, Gifeng E. Rd. Wufeng, Taichung County, Taiwan, ROC 413*

[b] *Department of Industrial Engineering and Management, National Taipei University of Technology, 1, Chung-Hsiao E. Rd. Section 3, Taipei 106, Taiwan, ROC*

Abstract

Biometric measurements received an increasing interest for security applications in the last two decades. After the 911 terrorist attacks, face recognition has been an active research in this area. However, very few research group focus on face recognition from both 2D and 3D facial images. Almost all existing recognition systems rely on a single type of face information: 2D intensity (or color) image or 3D range data set [Wang, Y., Chua, C., & Ho, Y. (2002). Facial feature detection and face recognition from 3D and 3D images. *Pattern Recognition Letters*, *23*, 1191–1202]. The objective of this study is to develop an effective face recognition system that extracts and combines 2D and 3D face features to improve the recognition performance. The proposed method derived the information of 3D face (disparity face) using a designed synchronous Hopfield neural network. Then, we retrieved 2D and 3D face features with principle component analysis (PCA) and local autocorrelation coefficient (LAC) respectively. Eventually, the information of features was learned and classified using backpropagation neural networks. An experiment was conducted with 100 subjects, and for each subject thirteen stereo face images were taken with different expressions. Among them, seven faces with expressions were used for training, and the rest of the expressions were used for testing. The experimental results show that the proposed method effectively improved the recognition rate by combining the 2D with 3D face information.

Keywords: Stereovision; Face recognition; Principle component analysis (PCA); Local autocorrelation coefficients (LAC); Disparity face; Backpropagation neural network

1. Introduction

Biometric measurements received an increasing interest for security applications in the last two decades. Owing to the growing number of real world applications, many face recognition techniques were developed. In this area, principle component analysis (PCA) (Turk & Pentland, 1991), linear discriminant analysis (LDA) (Zhao, Chellappa, & Rosenfeld, 2003), Elastic Graph Matching (EGM) (Wiskott, Fellous, Kruger, & von der Malsburg, 1997), Support Vector Machine (SVM) (Wang, Chua, & Ho, 2002) and artificial neural networks (Valentin, Abdi, O'Toole, & Cottrell, 1994; Zhang, Yan, & Lades, 1997) are widely used in the literature as face recognition approaches. Reviews of face recognition techniques can be found easily in literature such as Chellappa, Wilson, and Sirohey (1995), Zhao et al. (2003), Abate, Nappi, Riccio, and Sabatino (2007). In addition, local autocorrelation coefficient (LAC) is a widely used method in character recognition (Hotelling, 1993), time series classification (Keogh & Pazzani, 1998), and face detection and recognition (Goudail, Lange, Iwamoto, Kyuma, & Otsu, 1996; Hotta, Kurita, & Mishima, 1998; Popovici & Thiran, 2002) because of its economics of computation and translation-invariant property. Goudail et al. (1996) applied LAC to recognize a face database with 116 faces and derived a 98% recognition rate. Later, Goudail

* Corresponding author. Tel.: +886 2 27712171x2343; fax: +886 2 27317168.
E-mail address: fctien@ntut.edu.tw (F.-C. Tien).

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et al. (1996) used LAC and linear discriminant analysis (LDA) to improve the performance of recognition. They found that LAC is fast and reliable method for face recognition, but requires high demand of memory. Popovici and Thiran (2002) applied PCA to autocorrelation feature vector to avoid the computation of the autocorrelation coefficients for pattern recognition.

3D face recognition is a new research topic, but few studies exist on 3D or multi-modal 2D + 3D face recognition (Chang, Bowyer, & Flynn, 2003; Chang, Bowyer, & Flynn, 2005; Chang, Rioux, & Domey, 2003). The early applications of 3D face recognition include Cartoux, LaPreste, and Richetin (1989), Lee and Milios (1990), Gordon (1991), Nagamine, Uemura, and Masuda (1992), Achermann, B, Jiang, and Bunke (1997), Chang et al. (2003), and Tanaka, Ikeda, and Chiaki (1998). Recently, techniques have been developed and applied to 3D face recognition. Beumier and Acheroy (2001) constructed a structured lighted 3D face acquisition system for face authentication. Lao, Sumi, Kawade, and Tomita (2000) performed 3D face recognition using a sparse depth map constructed from stereo images using iso-luminance line-based stereo matching, and achieved an 87–96% recognition rate for a dataset containing ten individuals. Wang et al. (2002) combined the information from Gabor filter responses in 2D and "point signatures" in 3D to create a feature vector for multi-modal face recognition. Furthermore, Hesher, Srevastava, and Erlebacher (2003) explored PCA-typed approaches with a different number of eigenvectors and the sizes for the range face images. Medioi and Waupotitsch (2003) used iterative closest point (ICP) matching of the probe faces against gallery faces. Blanz and Vetter (2003) used a laser scanner to determine the face shapes and incorporated them into statistical, morphable models for face recognition. Samani, Winkler, and Niranjan (2006) used stereo vision to derive the disparity map of a face to enhance the performance of a face recognition system. Using stereovision, Sun, Chen, Lo, and Tien (2007) integrated the information of disparity faces (3D) and 2D to improve performance of face recognition. Among them, stereovision is widely applied in numerous fields such as cartography, psychology, neurophysiology, passive visual navigation for autonomous vehicle guidance, industrial automation, and the interpretation of microstereophotographs. The advantages of stereovision include ease of use, non-contact, non-emission, low cost and flexibility, but with less precision and accuracy.

According to Tsalakanidou, Tzovaras, and Strintzis (2003) study, performing recognition using both 2D and 3D faces can overcome their individual shortcomings and boost the recognition rate. Therefore, the objective of this paper is to improve the performance of using merely 2D faces through: (1) increase the resolution of stereo images to improve the quality of 3D faces (disparity faces); (2) obtain 3D face with a designed synchronous Hopfield neural network (SHNN); (2) extract the 2D and 3D face features with principle component analysis (PCA) and local autocorrelation coefficient (LAC); (3) integrate the information of 2D and 3D (disparity) faces; and (4) learn and recognize faces with backpropagation neural networks (BP). The remainder of this paper is organized as follows: Section 2 introduces the process of the proposed method, while Section 3 describes the proposed synchronous Hopfield neural network-based stereo face matching to obtain the disparity faces. Section 4 presents the 2D and 3D face recognition processes, including feature extraction with PCA and LAC and face recognition using BP. The implementation is described in Section 5. Finally, conclusions are drawn in Section 6.

2. The proposed method

This study proposes a hybrid face recognition system that combines the face information of 2D and 3D faces under a stereo vision system. The proposed method is divided into two phases: learning and recalling processes, as shown in Figs. 1 and 2. Two face images (left and right) were digitized in a parallel stereovision system, and a designed synchronous Hopfield neural network (SHNN) was used to match the left and right face to obtain the 3D face, called disparity face. Two methods, local autocorrelation coefficient (LAC) and principle component analysis (PCA), were applied to left and disparity faces to obtain three sets of features, called PCA, LAC, and LAC + PCA.

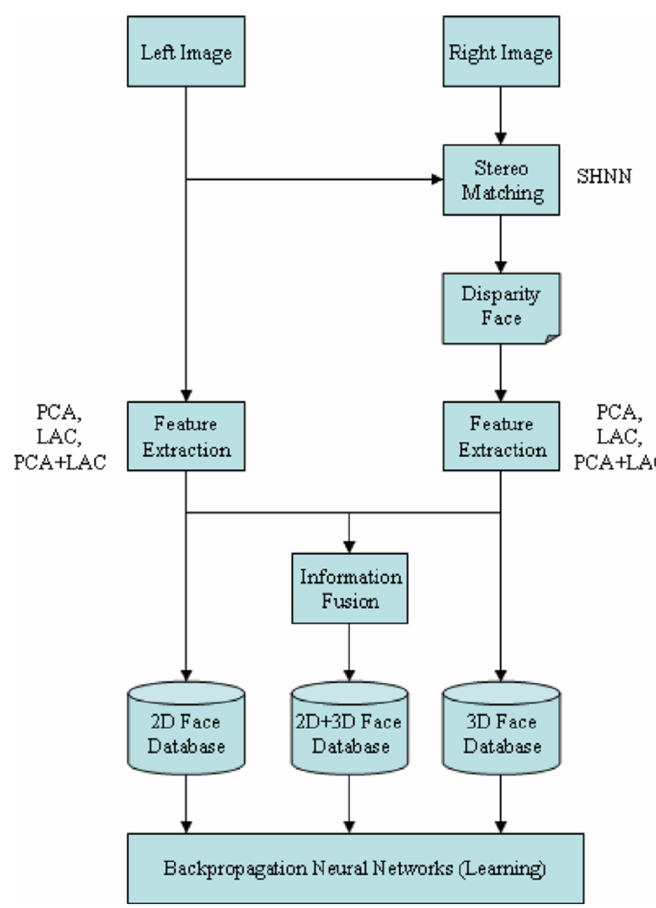

Fig. 1. Proposed learning process.