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Coupled principal component analysis based face recognition in heterogeneous sensor networks

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ABSTRACT

In this paper, we construct heterogeneous sensor networks (HSN) for face recognition and propose a novel approach named coupled principal component analysis (CPCA) that uses a feature-based representation for heterogeneous face images. We first employ local binary patterns (LBP) to capture the local structure of face images, and then propose CPCA to obtain the global face information. The proposed CPCA could incorporate the information between heterogeneous feature spaces, and therefore it reduces the gap between face images captured from heterogeneous sensors in HSN. Finally, the spare representation is utilized for matching heterogeneous face images. The experimental results demonstrate that the proposed approach achieves better performance than the state-of-the-art approaches.

1. Introduction

The proliferation of wireless communications and electronics has created the opportunities for development of heterogeneous sensor networks (HSN) [1,2]. The HSN consists of a variety of sensors, such as video cameras, infrared sensors, thermal sensors, microphones, and RFID tags, which drives the applications of HSN in the fields of surveillance systems, guiding systems, biological detection, agriculture, and health monitoring [3,4]. Surveillance for suspects and matching passport photos are examples of some applications that require the ability to automatically recognize faces in HSN. Face recognition is also an essential issue in signal processing and pattern recognition [5–7]. It mainly contains two stages: feature representation and classifier design.

With regard to classifier design where face recognition is a multi-class classification problem, the nearest neighbors (NN) classifier and its variants, e.g. nearest subspace [8], are most popular methods. Some approaches transform the multi-class classification problem into a two-class classification problem, and therefore two-class classifiers, for example, SVM [9], Adaboost [10], can be employed. Additionally, sparse representation is developed as the classifier for robust face recognition [11]. Each face is flattened into one vector and then represented as a sparse linear combination of training samples. The sparse coefficients corresponding to faces from the same subject are prone to be larger than that of different subjects. Thus, the reconstruction error can be utilized as the classification criterion.

Beside the classifier design, feature representation is another key issue for face recognition. In real application, the face is easily affected by illuminations, expression and occlusions. Therefore, many research focuses on how to extract discriminative features for face recognition. The feature representation usually includes local appearance feature methods and subspace-based feature methods [12]. The local appearance features have some merits due to stability to local variations, such as illumination and expression. Gabor [13] and local binary patterns (LBP) [14] are two representative features. Gabor wavelets capture

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the local structure corresponding to specific spatial frequency, spatial locality, and selective orientation. It has been demonstrated to be discriminative and robust to illumination and expression variances. LBP is also particularly popular due to its attractive properties, such as rotation invariance, low computational complexity and robustness against monotonic illumination. As a result, many LBP variants are proposed in recent literature [15,16]. Tan and Triggs [17] proposed local ternary pattern (LTP) to quantize the difference between a pixel and its neighbors into three levels, and then encoded the ternary pattern into two LBPs. Heikkilä et al. [18] proposed the center symmetric local binary patterns (CS-LBP) descriptor. Specifically, instead of the center pixel, the center symmetric neighbor pixels are compared and encoded. Based on these improvements, center symmetric local ternary patterns (CS-LTP) [19] was proposed to obtain more discriminative feature. Furthermore, combination of Gabor and LBP can further improve the face recognition performance [20].

As opposed to local features, subspace-based features could describe the global information of face. Typical subspace feature methods contain principal component analysis (PCA) [21], linear discriminant analysis (LDA) [22], independent component analysis (ICA) [23], and so on. PCA seeks a linear transformation to change the original feature space to an orthogonal eigenspace such as the dimensionality of feature could be reduced. LDA provides a linear transformation by maximizing the ratio of between-class variance and within-class variance.

Although these above works have been done on this topic, they only utilize one kind of sensor, i.e., visible light (VIS) image sensors, to capture the faces, which fails in extreme case, such as tremendously illumination change and nighttime. An alternative solution is to acquire face images beyond the visible spectrum. Infrared images including near-infrared (NIR) and thermal infrared could measure the presence of electromagnetic radiation just beyond the visible light range (specifically, optical radiation with wavelengths between 0.7 μm and 1.4 μm). Images acquired in the near-infrared spectrum are close enough to the visible light spectrum to still capture the structure of the face, yet far enough removed to not change the facial appearance due to visible light illumination changes. Therefore, capturing the face images both from VIS and infrared is expected to improve the performance of face recognition. Inspired by the recent advances in HSN, we consider to recognize face in HSN which consists of a mount of heterogeneous sensor nodes, such visible light sensors, near-infrared sensors, and thermal infrared sensors as shown in Fig. 1. These heterogeneous sensors are capable of obtaining multi-modal information of faces. The VIS, NIR and thermal infrared face images could be captured by HSN, and these multi-modal information are compensated.

Multi-modal (heterogeneous) face recognition is critical for applications in HSN. Yi et al. [24] utilized canonical correlation analysis to learn the similarity between two heterogeneous images by training on NIR/VIS image pairs of the same subject. Wang et al. [25] first changed one kind of modal face images to anther one, i.e. from NIR to VIS, and then directly matched them. Based on the similar idea, Chen et al. [26] employed local linear embedding [27] with a dictionary of corresponding face pairs to convert NIR images to synthetic VIS images. Liao et al. [28] first employed difference-of-Gaussian (DoG) filtering to obtain a normalized appearance for heterogeneous faces. Then, MB-LBP [29] is applied to represent the face images in the transformed domain, and the features are further selected by using Gentle AdaBoost. Klare et al. [30] proposed a generic framework for heterogeneous face recognition. All the images are represented in terms of nonlinear similarities, and then generate the prototype subjects. The nonlinear prototype representation is further improved by projecting the features into a linear discriminant subspace.

In this paper, we propose a novel algorithm named coupled principal component analysis (CPCA) for face recognition in HSN. Correspondingly, to achieve this goal, we construct HSN including visible light sensors, near-infrared sensors, and thermal infrared sensors. The flowchart of the proposed approach is shown in Fig. 2. We first utilize the histogram of LBP descriptors to characterize the local structure of the face. Then, we employ the proposed CPCA to reduce the gap between features of heterogeneous face images. Concretely, we project the features into a low-dimensional space for all heterogeneous face images, and sample some point between two projected spaces catenating them into one feature vector. Finally, the proposed approach incorporate sparse representation and nearest neighbors classification. The proposed approach is verified

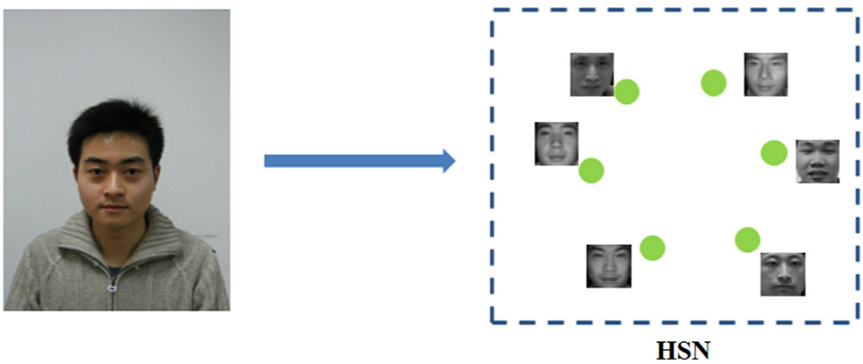

Fig. 1. Face recognition in HSN. With the help of HSN, we can obtain multi-modal face images.