Thermal Infrared Face Recognition Using Linear Discriminant Analysis Approach

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Abstract. Despite the variety of approaches, face recognition is not accurate or robust enough to be deployed in uncontrolled environments. Illumination variation is one of the most significant factors affecting the performance of face recognition. Infrared images offer the main advantage over visible image of being invariant to illumination changes for face recognition. In this paper, the application of Linear Discriminant Analysis (LDA) to the recognition of infrared face images offered by OTCBVS workshop is investigated. Experimental results show that the LDA leads to better classification performance than classical Principal Component Analysis (PCA) approach.

Keywords: Infrared face recognition, Linear Discriminant Analysis, Principal Component Analysis

1. Introduction

Face recognition is a hot study topic. It has great potential applications in public security, law enforcement and surveillance, access control, information security, and others. In the past, most such research studies have been conducted using visible images, and a great variety of results are reported. Now in controlled conditions, automatic face recognition systems perform very well, but when it comes to uncontrolled environments, such as the variant illumination, pose and expression condition, the performance of systems need to be improved. As we know, variant illumination is the worst factor of face recognition, and we have proposed some methods to deal with this condition [1]. But the methods we used in [1] cannot solve this problem fundamentally. Then, we focus on thermal infrared imagery face recognition. The thermal IR imagery offers a promising alternative to the visible imagery for handling variations in face appearance due to illumination changes.

Among many approaches to the problem of IR-based face recognition, subspace analysis gives the most promising results, and becomes one of the most popular methods[2][3].In this paper, the application of Linear Discriminant Analysis is investigated over a small thermal IR database with 20 adults collected under uncontrolled condition and offered by OTCBVS workshop[4]. Results show that the LDA leads to better classification performance than classical PCA approach.

2. Data Description

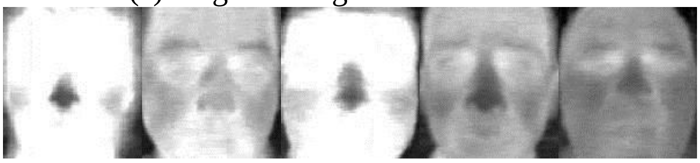
2.1 .The characteristics of IR data

While visual cameras measure the electromagnetic energy in the visible spectrum range ($0.4-0.7\mu m$), sensors in the IR camera respond to thermal radiation in the infrared spectrum range at $0.7-14.0\mu m$ [5].The thermal IR band ($2.4-14.0\mu m$) is associated with thermal radiation emitted by the objects. The amount of emitted radiation depends upon both the temperature and the emissivity of the material. Thermal IR cameras can sense temperature variations in the face at a distance, and produce thermo grams in the form of 2D images [5]. The anatomical information which is imaged by thermal IR camera involves subsurface features believed to be unique to each person [6]. For example, thermal emissions from skin are an intrinsic property, independent of illumination. The main advantage of thermal IR imagery is independence to visible light source. Besides, infrared images have a lot of advantages such as strong anti-interference, defending from camouflage and defending against cheat etc., to a large extent, which makes infrared imagery face recognition make up the shortage of the visible imagery face recognition.

2.2 .OTCBVS IR database description

The data used in this study are previously collected by Roland [4]. A long wave, Focal Plane Array camera without a thermo-electric cooler is used. All face images include full frontal, left and right profile images. Some face images include glasses, head cover, or both. All images have the resolution of 320×240 pixels. The main goal in this study is to investigate the performance of linear subspace analysis approaches and to find out which one can provide the best performance for IR face recognition application, so most of experiment data are frontal images. Before recognition experiment, the IR images need to be pre-processed to be the cropped images of dimensions 120×130 pixels by zooming in and zooming out. A few original images in the database and their corresponding cropped images are shown in Fig. 1.

(a) original images in the database



(b) Cropped images

Fig. 1 Samples of IR images.

3. Review of Linear Discriminant Analysis Approach

Linear Discriminant Analysis (LDA) is an example of the most discrimination subspaces .And it is adopted to seek a set of features best separating face classes [7].Compared with the PCA approach, which is oriented towards representing the data in their entirety, without paying any attention for the underlying structure, LDA finds the vectors in the underlying space that best discriminate among classes. LDA method tries to maximize the between-class differences and minimize the within-class ones.

The difference of between- and within-class is represented by the corresponding scatter matrices S_b and S_w.Considering X_c, $c=1,....N_c$ as subsets of X containing N_i images of the same subject:

$$S_w=\sum_{i=1}^{c}\sum_{x_k\in X_c}(x_k-m_i)(x_k-m_i)^T,\ S_b=\sum_{i=1}^{c}N_i(m_i-m)(m_i-m)^T, \tag{1}$$

Where $m_i=\frac{1}{N_i}\sum_{k=1}^{N_i}x_k$ is the mean vector of samples belonging to class i and m is the mean of all images .If S_w is not singular, the goal is to find a projection $W_{opt}=(w_1,w_2,...,w_l)$ that satisfies the Fisher criterion

$$W_{opt}=\arg\max w\frac{\left|W^TS_bW\right|}{\left|W^TS_wW\right|}\ , \tag{2}$$

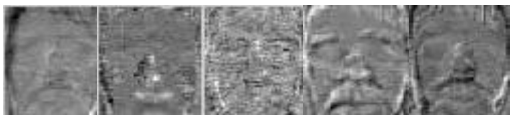
Where $w_1,w_2,...,w_l$ are the eigenvectors of $S_w^{-1}S_b$ corresponding to $l\ (\le c-1)$ largest eigenvalues? So LDA is also known as Fisher linear discriminant. Using this algorithm, it must be paid attention that the precondition of this algorithm is that S_w is not singular. In practice, S_w is usually singular, that is the small sample size problem of LDA. And the inverse of S_w does not exist. So a method which makes use of PCA to project the image set to a lower dimensional space is adopted (Fisherface), so that the new within-class scatter matrix $\widehat{S}_w$ is nonsingular, and then applies the standard LDA[8]. Specifically,

$\widehat{S}_w = W_{pca}^T S_w W_{pca}$, $\widehat{S}_b = W_{pca}^T S_b W_{pca}$,

$$W_{fld} = \arg\max w \frac{\left|W^T \widehat{S}_b W\right|}{\left|W^T \widehat{S}_w W\right|} \quad W_{opt}^T = W_{fld}^T W_{pca}^T \tag{3}$$

In addition, if there is no small sample size problem, PCA also can be used for dimension reduction in Fisher face to reduce the computational complexity [9].

Here some middle results are also shown. Fig. 2 gives the pictorial examples of S_w and S_b projected onto PCA space.



(a) images of S_w projected onto PCA space

(b) images of S_b projected onto PCA space

Fig. 2 Images of S_w and S_b projected onto PCA space

4. Experimental Results

The recognition algorithm is executed by the nearest algorithm. The cosine similarity measures are used, which are previous found to be effective for face recognition [10]. For two vectors, the distance measures for x and y are defined as:

$$d_{COS(x,y)} = 1 - \frac{x^T \cdot y}{\|x\| \cdot \|y\|}, \tag{4}$$

In the IR database, there are 24508 images with c=20 classes (different persons).Each class contains a different number of persons. Several groups are used in the experiment. Train sets are 2 images per person, 5 images per person, 10 images per person and 15 images per person respectively. 800 images are used to test. The experimental results can be seen in Table 1.

Table 1.Recognition performance based on OTCBVS IR database

train numbers / Algorithms	40	100	200	300
LDA	79.37%	87.62%	91.13%	93.5%
PCA	81.75%	85.5%	89.25%	90.5%

According to the result, we can see that recognition rate is gradually improving when the train samples is more. The LDA approach is better than traditional PCA. But when train samples are not enough, the LDA doesn’t work well. Generally, classical PCA method is the most typical subspace method, which has the best representation ability but not the best classification ability. It’s a non-surveillance method. LDA method is a surveillance method. It is good at discriminating different classes. When the train samples number is enough, LDA approach leads to the best classification performance with the improvement of nearly 3% compared with PCA approach.

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