

摘要

人脸识别是计算机视觉和模式识别研究中的热点问题,近年来受到越来越多研究者的关注。同时,作为一种生物特征识别技术,人脸识别在公共安全和日常生活的众多领域有着广阔的应用前景。目前,最好的人脸识别系统在理想情况下已经能够取得令人满意的识别性能。但大量测试和实践的经验表明:非理想条件下的人脸识别技术还远未成熟。要开发出真正鲁棒、实用的自动人脸识别系统还需要解决大量的关键问题,尤其需要研究高效的人脸描述特征以及相应的快速、精确的核心识别算法。

本文主要针对人脸识别中的特征提取问题,采取全局和局部特征层级集成的方法,以提高人脸识别系统的正确率和速度。此外,在对Fisher线性判别分析中存在的问题进行深入分析的基础上,设计了一种全新的线性判别特征提取框架。概括而言,本文的主要研究工作包括:

(1) 提出了一种新的基于Gabor特征的人脸识别方法。近年来,Gabor特征被认为是最有效的人脸表示方法之一,但Gabor特征较高的维数不利于后端分类器的实现。针对此问题,本文提出了一种基于Gabor特征分组及其集成的人脸表示和识别方法,其基本思想是将Gabor特征按照一定的规则进行分组并对每组特征单独设计分类器,最后把多个分类器进行集成。该方法的优点在于将高维的Gabor特征“分而治之”,从而既保证可以利用较多的判别信息,又使得每个分类器需要处理的特征维数相对较低。此外,多分类器组合的策略也保证了该方法具有较强的推广能力。实验结果表明,该方法对光照、表情、遮挡、年龄等变化具有较好的鲁棒性,与目前主流的人脸识别方法相比也具有明显的优势。

(2) 提出了一种基于全局和局部特征层级集成的人脸识别方法。心理学和生理学的研究成果表明,人类视觉感知系统在识别人脸时同时采用了全局和局部特征,但二者所起到的作用不同。受此启发,本文提出将全局的Fourier特征与局部的Gabor特征进行层级集成:第一级分类器采用全局特征,进行粗略的分类;而第二级分类器同时采用全局和局部特征,进行更为精确的分类。实验结果表明,全局和局部特征的层级集成不仅可以提高人脸识别系统的正确率,也能够使系统速度得到较大提升。

(3) 提出了一种新的线性判别特征提取框架。提取具有判别能力的特征是解决任何模式识别问题的关键步骤,但是如何设计有效的特征提取算法仍然是一个具有挑战性的问题。在众多的线性判别特征提取算法中, Fisher线性判别分析 (FLDA) 是最常用的一种。但无论是在理论还是在实践中,该方法都存在一些问题。在对这些问题进行深入分析的基础上,本文提出了一种全新的线性判别特征提取框架,称为最优判别投影寻踪 (ODPP)。该框架包含两个主要的步骤:一个是生成候选投影 (特征),另一个是选择最具有判别能力的投影。在合成数据和真实数据上的实验结果均表明: ODPP的性能优于FLDA及其主要的一些改进算法。

通过上述工作,本文对人脸识别中的特征提取问题进行了深入研究,结果表明:人脸图像的全局和局部特征中包含不同的分类信息,对二者进行高效的判别特征提取后再进行层级集成,可以取得优异的识别性能。

关键词 人脸识别; Gabor特征; Fourier变换; 集成学习; 线性判别分析; 投影寻踪

Abstract

Face recognition has been one of the most active research topics in computer vision and pattern recognition. It has held more and more researchers' interest in recent years. Meanwhile, as a biometric technique, face recognition has wide range of potential applications in both public security and private life. Currently, the state-of-art face recognition system achieves satisfied results under the well-controlled environment. However, many evaluations and practices demonstrate that the performances of face recognition systems decrease tremendously under the uncontrolled imaging environment. Furthermore, in order to develop robust and practical face recognition system, many key problems needed to solved, especially the design of effective feature extractor and efficient classifier.

Centering about the problem of facial feature extraction, this dissertation proposes to combine global and local features by a hierarchical manner, by which both the accuracy and the speed of face recognition system can be greatly improved. On the whole, the contributions of this dissertation are summarized as follows:

(1) Propose a novel Gabor-based face recognition method. In recent years, Gabor feature has been recognized as one of the most effective face representation methods. However, the high dimensionality of Gabor features makes the following classifier design very difficult. Aiming at this problem, this dissertation proposes to group Gabor features into several feature vectors, then design a classifier for each feature vector. Finally, these classifiers are combined together to get the final classification result. The merit of this method lies in the "divide and conquer" strategy by which more discriminatory information is reserved and meanwhile the dimensionality of features fed into each classifier is greatly reduced. Experimental results show that this method is robust the variations of lighting, expression, partial occlusion and aging. Besides, compared with some popular face recognition methods, this method gives much better performance.

(2) Propose a face recognition method by hierarchically combining global and local features. In the literature of psychology and neurophysiology, many studies have shown that, in human visual system, both global and local features are adopted for face recognition but they play different roles. Inspired by this phenomenon, this dissertation proposes to hierarchically combine global Fourier features and local Gabor features. Specifically, in the first layer, the global classifier is used for coarse classification. In the second layer, the global and local classifiers are combined together for more accurate classification. Experimental results show that the hierarchical combination of global and local features greatly enhances both accuracy and speed of face recognition system.

(3) Propose a novel framework of linear feature extraction. Extracting

discriminatory features is crucial for pattern classification tasks, but how to develop algorithms for effective feature extraction remains a challenging problem. Among numerous linear feature extraction methods, Fisher's Linear Discriminant Analysis (FLDA) is probably one of the most widely used approaches. However, FLDA has some inherent problems in both theory and practice. Based on the in-depth analysis on these problems, this dissertation proposes a novel framework for extracting linear discriminatory features, i.e., Optimal Discriminatory Projection Pursuit (ODPP). This framework consists of two steps: one is the generation of candidate projections (features); the other is the pursuit of optimal discriminatory projections. Experiments on both synthetic and real data sets show that the performance of ODPP is better than FLDA and its variants.

In conclusion, through above-mentioned work, this dissertation makes an intensive study on the facial feature extraction. The experimental results show that: global and local features contain different discriminatory information for face recognition. By further extracting discriminatory features and hierarchically combining them, excellent system performance can be achieved.

Keywords Face recognition; Gabor feature; Fourier transform; ensemble learning; linear discriminant analysis; projection pursuit