摘　要

面部特征点定位是指在输入人脸图像上自动检测面部关键特征（如眼睛中心点，眼角点，嘴角点等）的技术，可以用于对齐待匹配的人脸图像，因而是全自动人脸识别中的关键步骤之一。此外，精确的面部特征点定位也是实现人脸合成、人脸驱动卡通、人脸跟踪、人脸姿态分析以及人脸表情分析等众多视觉任务的重要步骤。

本文调研面部特征点定位的国内外的研究现状，尤其详细介绍了基于点分布模型（PDM）的主动形状模型（ASM）方法，并对 ASM 的模型建立以及迭代搜索调整进行了深入的分析和讨论。发现面部特征点定位的难点主要在于人脸变化的多样性以及图像采集环境的复杂性。具体在 ASM 中，前者主要表现为主成分分析（PCA）模型不足以描述姿态、表情导致的面部形状显著变化，而后者则主要表现为光照、噪声和部分遮挡等导致的低层图像信息的不确定性问题。针对前者，本文分别首先采用了混合概率主成分分析（MPPCA）方法替换传统 PCA 模型的方法，并进一步提出了基于约束回归的方法。针对后者，本文采用了前端搜索时生成多候选点的方法。另外，为了尽量避免 ASM 迭代优化调整陷入局部极小，我们采用了更加精确的形状初始化方法和预先进行眼嘴状态估计的方案。

具体的，本文的主要研究成果如下：

（1）针对 ASM 定位结果严重依赖初始形状的问题，提出了利用少量关键点（如眼睛中心、鼻尖、嘴角等）设置更精确初始形状的方法。本文介绍了利用少数关键点和主成分分析（PCA）模型计算相似变换系数以及 PCA 投影参数的方法，并以此设置初始形状，实验证明了该方法的有效性。同时，针对表情变化问题，本文设计了一种利用眼嘴状态估计增强 ASM 的方法。该方法通过支持向量分类法（SVC）预测眼睛状态；而通过支持向量回归（SVR）来估计嘴巴的张开程度。由此得到的眼睛和嘴巴的状态，不仅可用于更优的初始形状设置，还可以用于指导、修正前端的局部纹理搜索，以提升定位效果。

（2）研究并实现了基于混合概率主成分分析（MPPCA）改进 ASM 的面部特征点定位方法，以更好地处理表情、遮挡以及复杂背景变化。该方法的鲁棒性得益于一个形状正则化模型（Shape Regularization Model），该模型整合了非线性形状先验即 MPPCA、相似几何变换以及多个候选特征点的似然，是一个基于贝叶斯原理的三层产生式模型。该方法利用期望最大化算法（EM）迭代的检验最优候选位置并更新形状与姿态参数，从而达到鲁棒精确定位特征点的目的。由于混合高斯可以建模非线性形变，我们将其应用于多姿态面部特征点定位，并进行了一系列的评估实验。

（3）提出了利用约束回归方法代替PCA的ASM改进方法。主成分分析作为传统ASM方法的核心，它能很好揭示事物的本质，但同时也有很多缺点：模型难解释，载荷因子均为非零；严格的模型假设，数据只有在符合高斯假设的情况下才具有最优性能；全局线性，不能描述非线性变化；子空间的投影变换容易丢失细节信息等。为此，本文提出采用回归策略代替PCA，并考察了施加不同的约束对定位性能的影响，实验结果表明，回归策略比PCA具有更优的性能。

关键词：面部特征点定位 主动形状模型 主成分分析 混合概率主成分分析 套索回归 岭回归 最近邻回归 支持向量机 支持向量回归

The Research and Implementation of Facial Feature Localization Based on statistic

Face Feature Localization is an automatic localization technology to the face feature(such as the centers of eyes, the corner of eyes, the corners of mouth, etc) which can be used as the alignment of the facial images, so it is a critical step in fully automatic face recognition system. In addition, the accurate facial feture localization is also an important step of the following visual tasks, e.g. face synthesis, face-driven avatar, face tracking, face pose analysis and face expression analysis.

This article describes the current research status at home and abroad，especially introduces the PDM(Point Distributed Model) based ASM(Active shape Model) method, and takes further analysis and discussion to the model training and the model fitting of ASM. We find that the difficulties of Face Alignment primarily are the variation of face shape and the complexity of the background environment, and the former can be summarized as the problem that the PCA model can’t be enough to describe the shape variation, for example the pose and expression; the latter is mainly the ambiguty of the low-level image, such as the noise, clutting and illumination. For the first problem, we use the the tactic of changing the PCA model based method to MPPCA(Mixtures of Probabilistic Principal Component Analysers) based method or constrained regression based method as the solutions; for the second, we allow multiple candidate positions to be generated for each facial landmark to overcome the ambiguity of the low-level image. In addition, in order to avoid the process of iterative search and adjustment falling into the local minimum, we adopted the schemes of setting a more precise initial shape and estimating the eye and mouth state in advance.

The main scientific achievements of this paper are as follows:

(1) To solve the problem of the heavily reliance of the localization result on the initial shape, we proposed the method of using few key points, such as the centers of eyes, nasal tip, and corners of mouth, to set more accurate initial shape. This paper describes a method of using a few key points and principal component analysis shape model to calculate the similarity transformation coefficients and PCA projection parameters which can be used to set initial shape, the experiments proved the validity of this method. Because the facial expressions are mainly embodied in the changes of

eyes and mouth, this paper introduces a kind of eye and mouth state estimation method to solve the problem of localization on the faces with exaggerated expressions. We use SVM(Support Vector Machine) classification and SVR(Support Vector Regression) regression to predict the state of eyes and mouth. After getting the state of eyes and mouth, we can get more accurate localization result through adding more prior knowledge on the phases of shape initialization and local searching.

(2) We took reaserch and implementation of a MPPCA(Mixtures of Probabilistic Principal Component Analysers) based method which can better deal with the localization problem of the facial images with expressions, clutter or complex background. The robustness comes from a shape regularization model, which incorporates constrained nonlinear shape prior, geometric transformation, and likelihood of multiple candidate landmarks in a three-layered generative model. The EM inference method iteratively examines the best candidate positions and updates face shape and pose for the purpose of accurate locating landmarks. Because the mixtures of Gaussian can model nonlinear shape deformation, we put forward a solution for facial feature localization of multi-pose faces based on the above method, and then conducted a series of experiments.

(3) We proposed a facial feature localization method based on the constrained regression. As the core of the traditional ASM method, PCA(Principal Component Analysis) can good reveal the essence of things, but it also has many shortcomings: the inexplicability of model, the value of load factors are non-zero; strict model hypothesis, PCA has the optimal performance only on the data conforming on the Gaussian hypothesis; the nature of global linear; easy to lose the detail information of shape owe to the subspace projection transformation. Therefore, we proposed a strategy of instead of PCA by constrained regression, and investigated the influences to the localization performance of various constraints. The experimental results show that the constrained regression based method have better performance than PCA based method.

Keywords: Facial feature localization, Active Shape Model(ASM), Principal Component Analysis(PCA), Mixtures of Probabilistic Principal Component Analysers(MPPCA), Lasso regression, Ridge regression, KNN regression, Support Vector Machine(SVM), Support Vector Regression (SVR)