3-D Facial Expression Representation using Statistical Shape Models

Wei Quan, Bogdan J. Matuszewski, Lik-Kwan Shark, Djamel Ait-Boudaoud
Applied Digital Signal and Image Processing Research Centre
University of Central Lancashire

Abstract

This poster describes a methodology for facial expressions representation, using 3-D/4-D data, based on the statistical shape modelling technology. The proposed method uses a shape space vector to model surface deformations, and a modified iterative closest point (ICP) method to calculate the point correspondence between each surface. The shape space vector is constructed using principal component analysis (PCA) computed for typical surfaces represented in a training data set. It is shown that the calculated shape space vector can be used as a significant feature for subsequent facial expression classification. Comprehensive 3-D/4-D face data sets have been used for building the deformation models and for testing, which include 3-D synthetic data generated from FaceGen Modeller® software, 3-D facial expression data caputed by a static 3-D scanner in the BU-3DFE database and 3-D video sequences captured at the ADSIP research centre using a 3dMD® dynamic 3-D scanner.

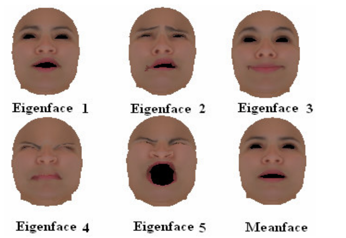
1. Statisitcal shape model

A statistical shape model also known as a point distribution model (PDM) describes shape variations based on statistics of the position of the corresponding points in a training data set. The first step of building a 3-D statistical shape model is to establish point-to-point correspondence between each face in the training data set. For the 3-D synthetic data generated from the FaceGen Modeller®, the correspondence information is already provided. For others, the point correspondence is calculated using a modified iterative closest point (ICP) method[2,3]. Subsequently after the principal component analysis (PCA), the faces in the training data set can be approximately represented in a low dimensional shape vector space instead of the original high dimensional data vector space:

$$\hat{Y} = Pb + \overline{Y}$$

Where: P denotes a so called "Shape Matrix", $\overline{Y}$ is a mean face, and b stands for the shape space vector which controls contribution of each mode of variation in the model.

Provided that the faces in the training data set are a fair sample from the population of faces to be represented by the model the statistical shape model can be used to represent faces not present in the training data set.



2. Model fitting

Model fitting algorithm iterates between the pose estimation using ICP and the model refinement using projection onto the shape space

Correspondence search (ICP)

$$\left\{\hat{R},\hat{T},\hat{S}\right\} = \arg\min_{\{R,T,S\}}\left(\sum_i \left\| \hat{y}_i^{(k-1)} - SRx_i^{(k-1)} - T \right\|^2\right)$$

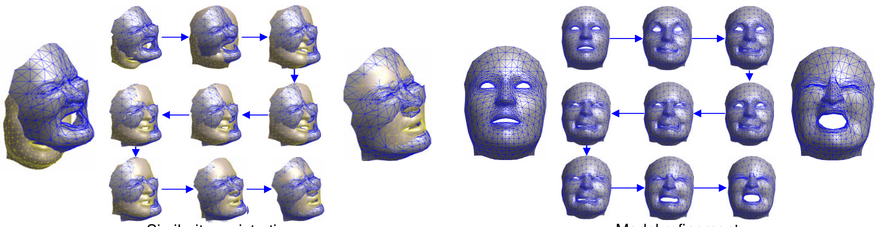
$$x_i^{(k)} = \hat{S}\hat{R}x_i^{(k-1)} + \hat{T}$$

$$x_i^{(k)} \rightarrow x_{j(i)}^{(k)}$$

Projection onto shape space

$$b^{(k)} = P^T\left(X^{(k)} - \overline{Y}\right)$$

$$\hat{Y}^{(k)} = Pb^{(k)} + \overline{Y}$$

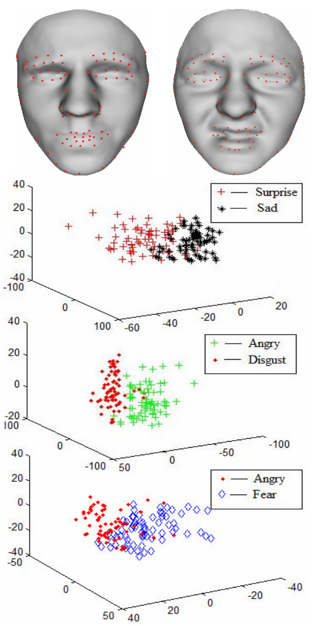


Similarity registration

Model refinement

3. Facial landmarks

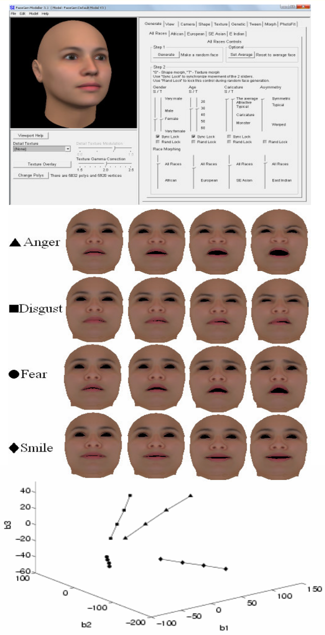
The proposed method assumes that the shape space vector can be used as a significant feature for representing facial expressions. This had been validated in the past using facial landmarks. Here the BU-3DFE database[3] was used to repeat that experiment. 83 landmarks were manually selected on the specified areas of the face such as eyebrow and lips. The experimental results show that low dimensional shape space vector build from this landmarks exhibit an ability to distinguish between the facial expressions.



First free elements of the shape space vector

4. Synthetic faces

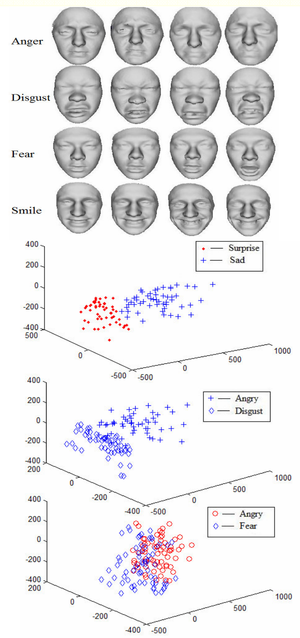
After the validation that the shape space can be used as a feature space for facial expression classification, the next question which needs to be answered is if the shape space can be effectively build from all available 3-D face vertices instead of the selected landmarks. In this stage, the 3-D synthetic faces generated from FaceGen Modeller® are being used. Since the correspondence information is provided in the synthetic data, the statistical shape model can be built directly without correspondence search.



First free elements of the shape space vector

5. Faces from BU-3DFE database

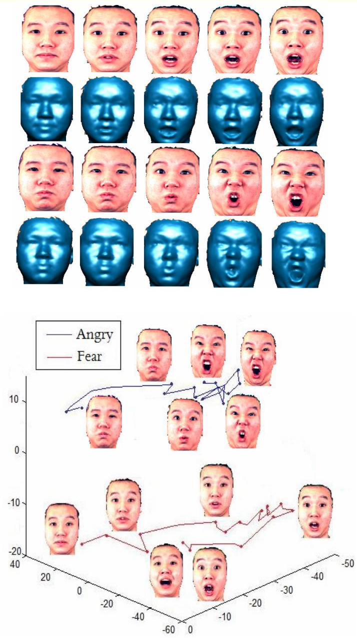
In this stage, the data used is extended from the synthetic data to the real 3-D faces from the BU-3DFE database[3]. To establish a dense correspondence between faces in the database the modified ICP method is used to perform the correspondence search[1,2]. The results show that the proposed method in general is working well on the BU-3DFE 3-D faces. A few expressions are sometimes difficult to distinguish between with angry and fear being the most difficult.



First free elements of the shape space vector

6. Dynamic 3-D face sequence

In the last experiment, the dynamic 3-D face sequences are used instead of the static 3-D faces. The dynamic 3-D face sequences are captured by a dynamic 3-D scanner from 3dMD®. Using the face sequences, the trajectory of each specified facial expression can be recorded and displayed in the 3D feature space. It is postulated that analysis of these trajectories can improve classification for those facial expressions which are difficult to interpret from the static data e.g. angry and fear.



First free elements of the shape space vector

7. Summary

In this work, a methods for a compact representation of 3-D facial expressions based on statistical shape models have been presented. The effectiveness of the proposed method has been demonstrated by tests carried out on four types of 3-D data, and the experimental results show that the statistical shape modelling methodology can offer an efficient and effective 3-D faces representation which can handle large face variations and some subtle expression differences.

Further details:

[1] Quan, W., Matuszewski, B. J., Shark, L.-K. & Ait-Boudaoud, D, (2007), Low Dimensional Surface Parameterisation with Applications in Biometrics, in Proceedings of International Conference on Medical Information Visualisation – BioMedical Visualisation 2007, pp. 15-22.

[2] Quan, W., Matuszewski, B. J., Shark, L.-K. & Ait-Boudaoud, D, (2007), 3-D Facial Expression Representation using B-spline Statistical Shape Model, in Vision, Video and Graphics Workshop, University of Warwick.

BU-3DFE database has been obtained from Binghamton University USA:

[3] Lijn Yin, Xiaozhou Wei, Yi Sun, Jun Wang, Matthew J. Rosato, A 3D Facial Expression Database For Facial Behavior Research, IEEE 7th International Conference on Automatic Face and Gesture Recognition (FGR06), Southampton, UK, 10-12 April 2006. p211-216

This work has been, in part, supported from the MEGURATH project (EPSRC project No. EP/D077540/1)