Isometric Deformation Modeling using Singular Value Decomposition for 3D Expression-Invariant Face Recognition

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Abstract
Currently, the recognition of faces under varying expressions is one of the main challenges in the face recognition community. In this paper a method is presented dealing with those expression variations by using an isometric deformation model. The method is built upon the geodesic distance matrix as a representation of the 3D face. We will show that the set of largest singular values is an excellent expression-invariant shape descriptor. Face comparison is performed by comparison of their shape descriptors using the mean normalized Manhattan distance as dissimilarity measure. The presented method is validated on a subset of 900 faces of the BU-3DFE face database resulting in an equal error rate of 13.37% for the verification scenario. This result is comparable with the equal error rates of other 3D expression-invariant face recognition methods using an isometric deformation model on the same database.

Method
Preprocessing
- Noise tip detection → z-coordinate
- Geodesic cropping: geodesic distance, i.e., distance along the surface, calculation and holding closest points: \[ V^T_i = 1 \]
- Downsampling

Face representation:
Geodesic distance matrix:
- invariant for isometric transformations (expression variations)
- determined up to permutations of rows and columns

Singular values / eigenvalues
- invariant for row and column permutations
Condition: corresponding point exists
Proof: \[ G = PGP^T = PUSV^T \]

Dissimilarity measures
- Examined in [1], mean normalized Manhattan distance as dissimilarity measure:
\[ D = \sum_{i \neq j} \frac{1}{2} | S^T_i - S^T_j | \]

Results
Data
- BU-3DFE database
- 100 subjects
- 900 face scans, 11% neutrals
- 4 levels of expression strength

Experiment
Verification experiment
- one-to-one matching in order to verify if a person is truly the pretended subject
- performance measure: ROC (FRR vs FAR), characteristic: EER

Method parameters
- geodesic distance threshold: 80 mm
- no. of points: 2000
- dissimilarity measure: mean normalized Manhattan distance
- no. of eigenvalues (Fig. 1)
- geodesic distance matrix (Tab. 1)

Comparison with literature
on BU-3DFE. 1600 face scans [1]
- Mpperis et al.: EER of 9.4%
- Bronstein et al.: EER of 15.4%

Discussion
Strengths
- no need for correspondences
- no need for training (vs. statistical methods)
- use of whole face (vs. region-based methods)

Weaknesses
- isometric deformation assumption is an approximation (±15% relative change)
- cannot handle occlusions or open mouth

Conclusions
A simple 3D expression-invariant face recognition method without need for correspondences is presented. It is based on the isometric deformation assumption for expression variations and therefore it uses the geodesic distance matrix as representation. The singular value decomposition makes the representation invariant for row and column permutations (and therefore the sampling order).

References