Apathy is the Root of all Expressions

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HOSVD-based Face Models

1. 3D face scan database with sparse correpondences [15]
2. Compute full correspondences [16]
3. Arrange into tensor and subtract mean shape
$$\mathcal{T} = \mathcal{T}_{\text{orig}} - \mathcal{T}_0 \in \mathbb{R}^{3N \times P \times E}$$
4. Compute HOSVD
$$\mathcal{T} \approx \widehat{\mathcal{T}} = \mathcal{S} \times_1 \mathbf{U}^{(1)} \times_2 \mathbf{U}^{(2)} \times_3 \mathbf{U}^{(3)}$$
5. 3D shape represented as sum of mean $\mathbf{m}$ and mean-free shape
$$\widehat{\mathbf{s}}^{3D} = \mathbf{m} + \widehat{\mathbf{v}} \in \mathbb{R}^{3N}$$

Mean-free shape $\widehat{\mathbf{v}}$ can be described using different models.

1. Model: Baseline Model

$$\widehat{\mathbf{v}}\,(\mathbf{u}_2, \mathbf{u}_3) = \mathcal{S} \times_1 \mathbf{U}^{(1)} \times_2 \mathbf{u}_2^{\mathrm{T}} \times_3 \mathbf{u}_3^{\mathrm{T}}, \quad \mathbf{u}_2 \in \mathbb{R}^{L_2},\ \mathbf{u}_3 \in \mathbb{R}^{L_3}$$

2. Model: Substructure-aware Model (proposed-1)

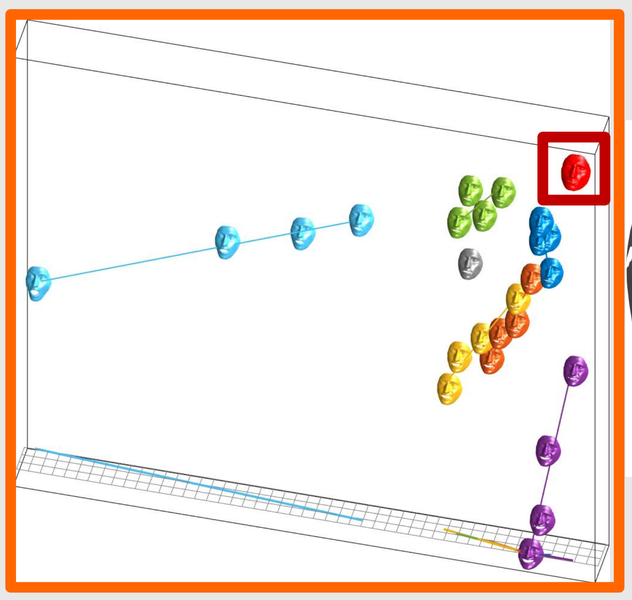
$$\widehat{\mathbf{v}}\,(\mathbf{p}_2, \mathbf{p}_3) = \mathcal{S} \times_1 \mathbf{U}^{(1)} \times_2 \mathbf{p}_2^{\mathrm{T}}\mathbf{U}^{(2)} \times_3 \mathbf{p}_3^{\mathrm{T}}\mathbf{U}^{(3)}, \quad \mathbf{p}_2 \in \mathbb{R}^{P},\ \mathbf{p}_3 \in \mathbb{R}^{E}$$

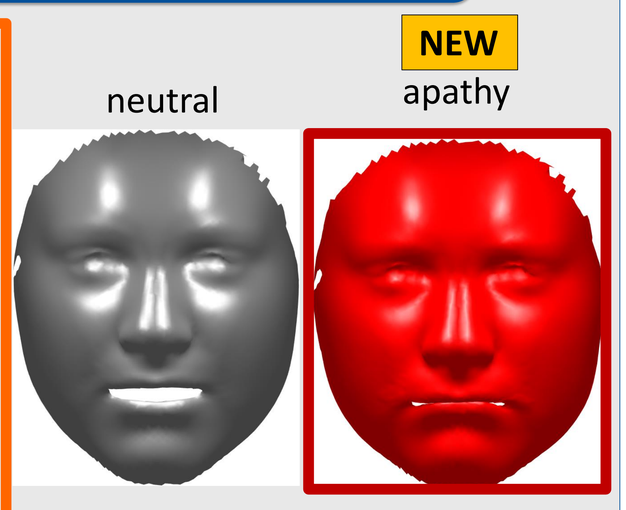
3. Model: ICA-based Model (proposed-2)

$$\widehat{\mathbf{v}}\,(\mathbf{p}_2, \mathbf{b}_3) = \mathcal{S} \times_1 \mathbf{U}^{(1)} \times_2 \mathbf{p}_2^{\mathrm{T}}\mathbf{U}^{(2)} \times_3 \left(\mathbf{b}_3^{\mathrm{T}}\mathbf{B} + \mathbf{a}_0^{T}\right), \quad \mathbf{p}_2 \in \mathbb{R}^{P},\ \mathbf{b}_3 \in \mathbb{R}^{3}$$

	Model 1	Model 2	Model 3
Takes use of person and expression space $\mathbf{U}^{(k)}$	✘	✓	✓
Canonical basis of parameter vectors	✘	✓	✓
Incorporate low-dimensional substructure $\mathbf{U}^{(3)}$	✘	✘	✓
Robust person and expression transfer	✘	✓	✓
Number of expression parameters	$L_3 \leq E$	$E = 25$	3

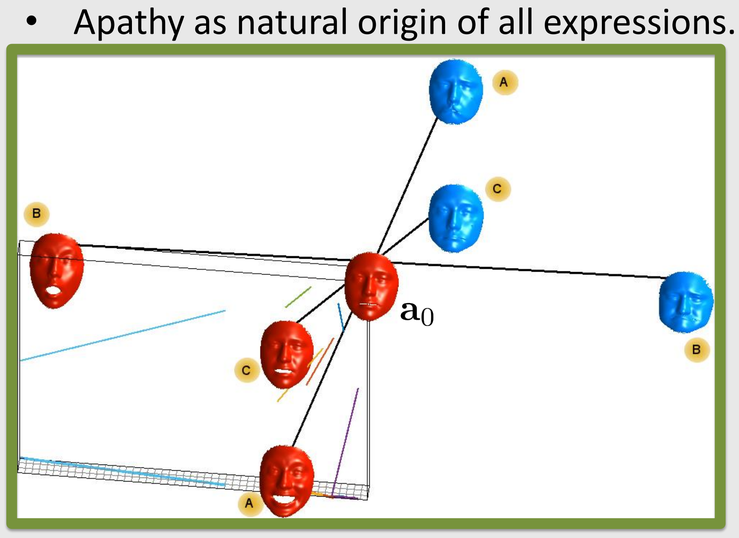
Substructure of Expression Space





First three dimensions of expression space $\mathbf{U}^{(3)}$

- Each emotion displayed in one color approximates one line.
- Expressions form a planar substructure.
- Lines intersect in new *„apathetic“* expression (not part of database).
- Apathy as natural origin of all expressions.



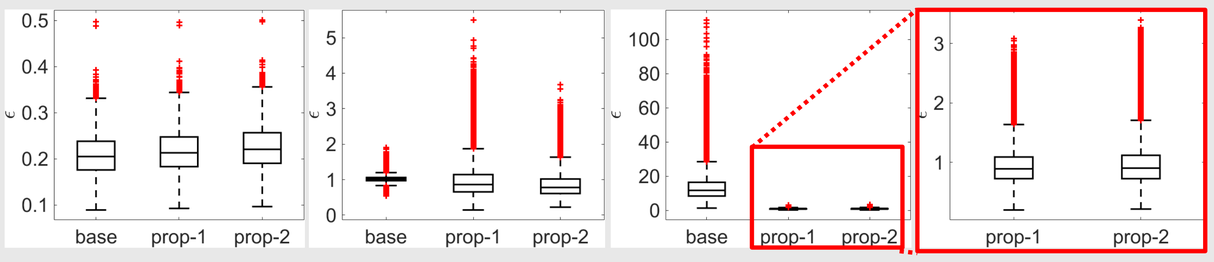
Reduced expression space:
Compute ICA on apathy-centred expression space to receive 3 projection pursuit directions and thereby new basis expressions.
Note that these lie in the plane, but partly outside the training data (blue).

Applications

Person and Expression Transfer

How robust can person and expression transfer be done?

1. Exclude expression (or person) from data tensor
2. Re-estimate model
3. Estimate model parameters for remaining faces for each model
$$\min ||\widehat{\mathbf{v}} - \mathbf{v}||_2^2 + \lambda_1||\mathbf{p}_2||_2^2 + \lambda_2||\mathbf{p}_2^{\mathrm{T}}\mathbf{1} - 1||_2^2 + \lambda_3||\mathbf{p}_3||_2^2 + \lambda_4||\mathbf{p}_3^{\mathrm{T}}\mathbf{1} - 1||_2^2$$
4. Change expression (or person) parameters to known values
5. Compute error
$$\epsilon = \frac{||\widehat{\mathbf{v}} - \mathbf{v}_{\text{true}}||_2}{||\mathbf{v}_{\text{true}}||_2}$$



approximation person transfer expression transfer

Emotion Classification

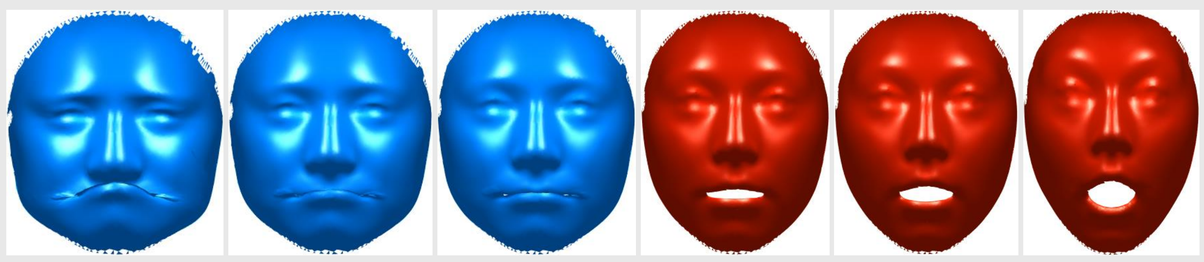
1. Exclude person from data tensor
2. Re-estimate model
3. Estimate parameters for person and expression excluded persons
4. Assign one of the 7 emotions based on *k-nearest-centroid (kNC)* classification

Classification Rate:
Model 1 : 15%
Model 3 : 60%

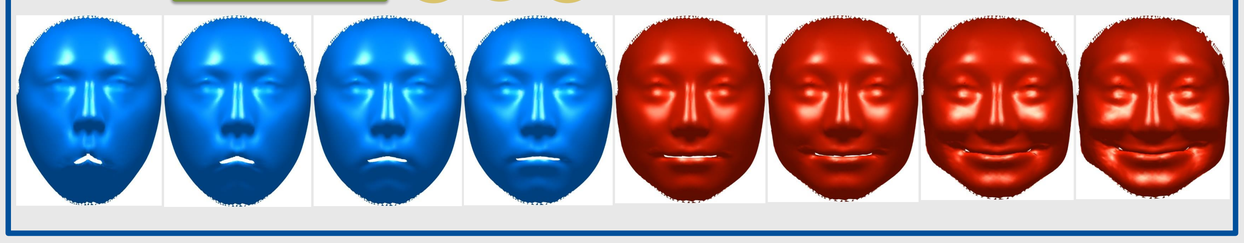
Synthesis of Expression Trajectories

Example expression trajectory based on direction B with weight values

-1 -0.5 -0.25 0.25 0.5 1



Based on basis shapes A B C, synthesize new unseen expressions:



3D Reconstruction from Sparse Landmarks

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