

Fitting a Morphable Model to 3D Scans of Faces

Idea

- Fit a Morphable Model simultaneously to
- **shape** $z(u, v)$ (= depth map)
 - **texture** $r(u, v), g(u, v), b(u, v)$ (= image) of a 3D scan.
 - **u, v** horizontal, vertical coordinates.

Analysis-by-Synthesis

- Simulate the scanning process, reproduce
- shape and texture
 - rigid transformation
 - perspective projection
 - illumination

Morphable Model

- Vector Space of shapes **S** and textures **T**

$$\mathbf{S} = (x_1, y_1, z_1, \dots, x_n, y_n, z_n)^T$$

$$\mathbf{T} = (r_1, g_1, b_1, \dots, r_n, g_n, b_n)^T$$

- Learned from 200 3D scans (Blanz and Vetter, '99)
- Correspondence based on Optical Flow

$$\alpha_1 \cdot \text{[face]} + \alpha_2 \cdot \text{[face]} + \alpha_3 \cdot \text{[face]} + \alpha_4 \cdot \text{[face]} + \dots$$

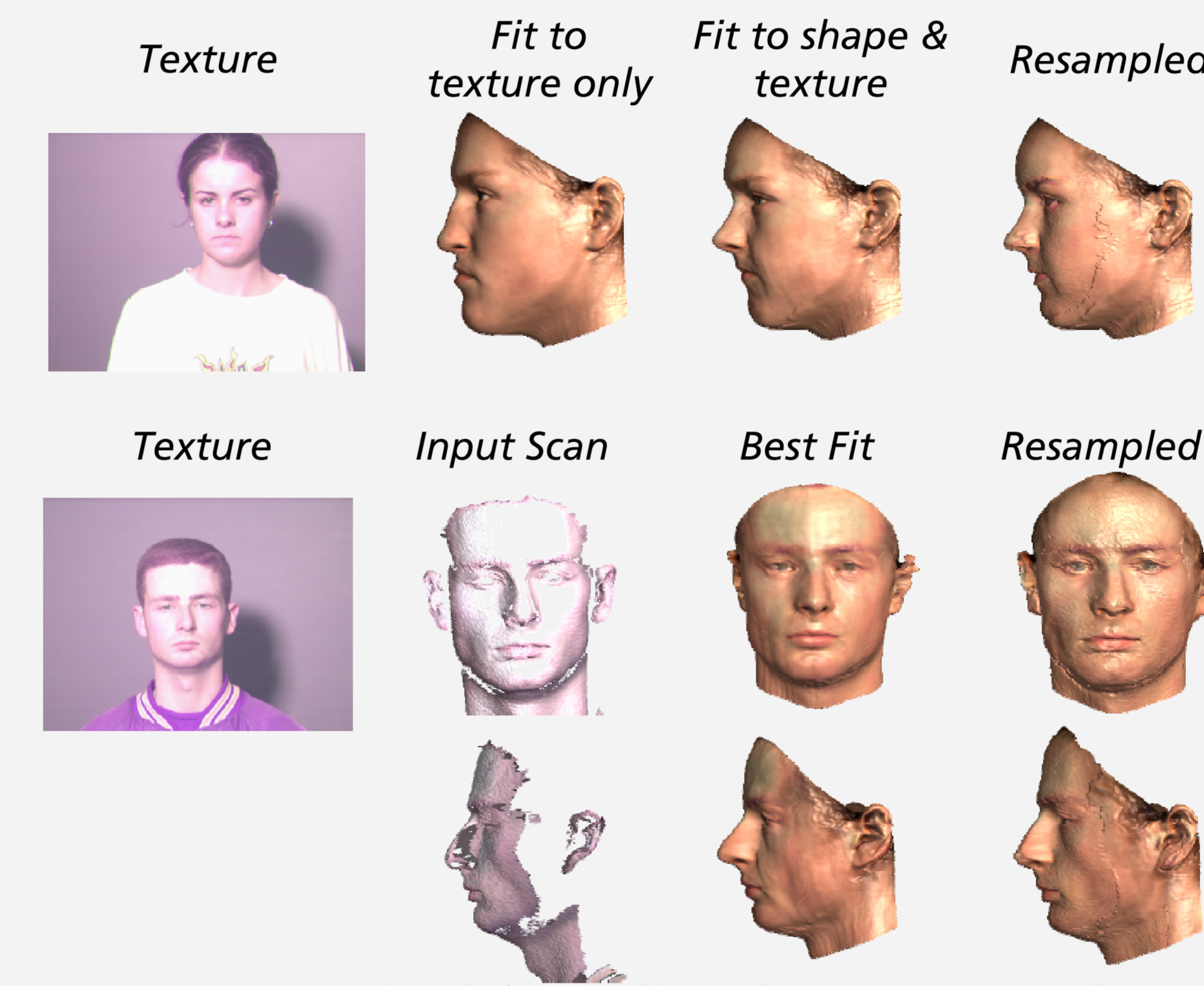
$$\beta_1 \cdot \text{[face]} + \beta_2 \cdot \text{[face]} + \beta_3 \cdot \text{[face]} + \beta_4 \cdot \text{[face]} + \dots$$

Fitting Algorithm

- In each Iteration, select 40 random vertices
- Compute rigid transformation, perspective projection, surface normal, illumination
- Minimize squared difference of $r(u, v), g(u, v), b(u, v), z(u, v)$
 - between model and scan
 - **Regularization** in PCA space: Penalize Mahalanobis distance from average face.
 - **Optimize:** a_i, b_i rigid parameters, illumination.
 - Intrinsic camera parameters are estimated from raw scan: Implicit in 3D versus image coordinates.
 - **Initialize:** click on ~7 feature points.

Shape and Texture Sampling

- After fitting, we know for each vertex (x_k, y_k, z_k) the position u_k, v_k in the scan
- Replace x_k, y_k, z_k by $x(u_k, v_k), y(u_k, v_k), z(u_k, v_k)$
- Perfect reproduction of shape
- Invert illumination effect to replace, r_k, g_k, b_k
- **Results:**



Face Recognition

- **150 individuals** from the FRGC database
- 2 scans each (A and B) from different days
- Compensate for within-person variation using an **intra-object PCA** on different scans
- Simulate 2D recognition by fitting to texture only
- Combined shape+texture superior to texture only
- Cross-modal recognition comparable to intra-modal

Advantages

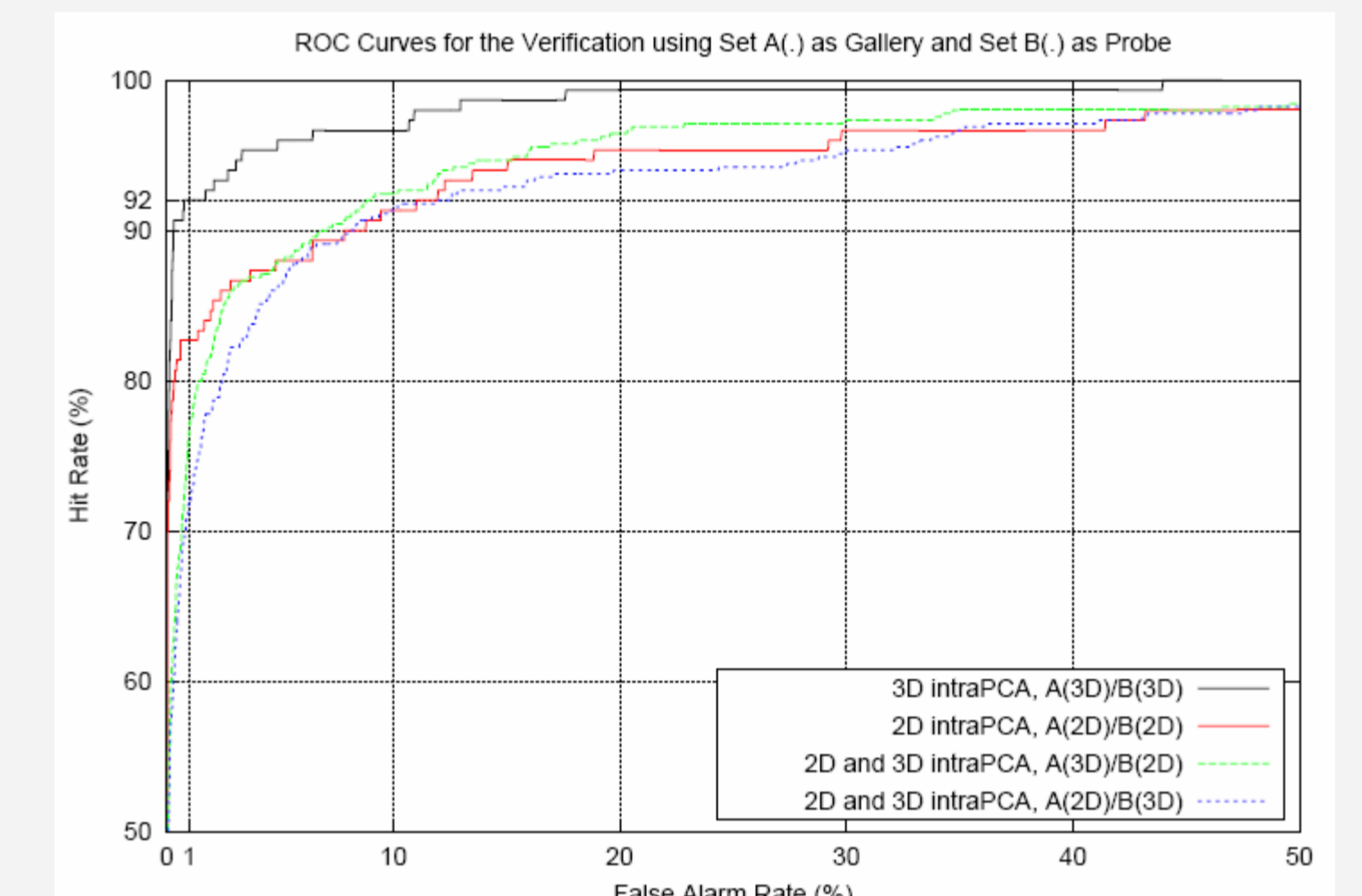
- Very **robust** due to model-based approach and regularization (MAP-estimate)
- Holes do not affect face recognition
- Illumination is compensated
- Combination with fitting to images: Cross-modal recognition

Applications

- **Face Recognition** from 3D Scans
- Preprocessing scans
 - hole-filling, model-based surface completion
- Establish dense point-to-point correspondence
- Model-based surface editing



Scan textures 3D MM Textures



ROC curve for verification

Gallery	Probe	Correct Ident.	intraPCA
A(3D)	B(3D)	96.0	3D
B(3D)	A(3D)	92.0	3D
A(2D)	B(2D)	84.7	2D
B(2D)	A(2D)	79.3	2D
A(3D)	B(2D)	71.3	2D and 3D
B(3D)	A(2D)	66.0	2D and 3D
A(2D)	B(3D)	66.7	2D and 3D
B(2D)	A(3D)	70.0	2D and 3D

Identification Rate (%) measured on pairs of scans (A and B) of 150 faces. 2D denotes fitting to texture only, 3D denotes shape and texture.