# Automatic Reconstruction of Personalized Avatars from 3D Face Scans


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COMPUTER GRAPHICS • ERLANGEN


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# Motivation

- “Virtual Worlds” are becoming increasingly realistic


e.g. games, 3D chat rooms ...

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- A users wants his virtual character to look like himself

(unless he wants to fake handsomeness)


# How to create a "virtual clone"?

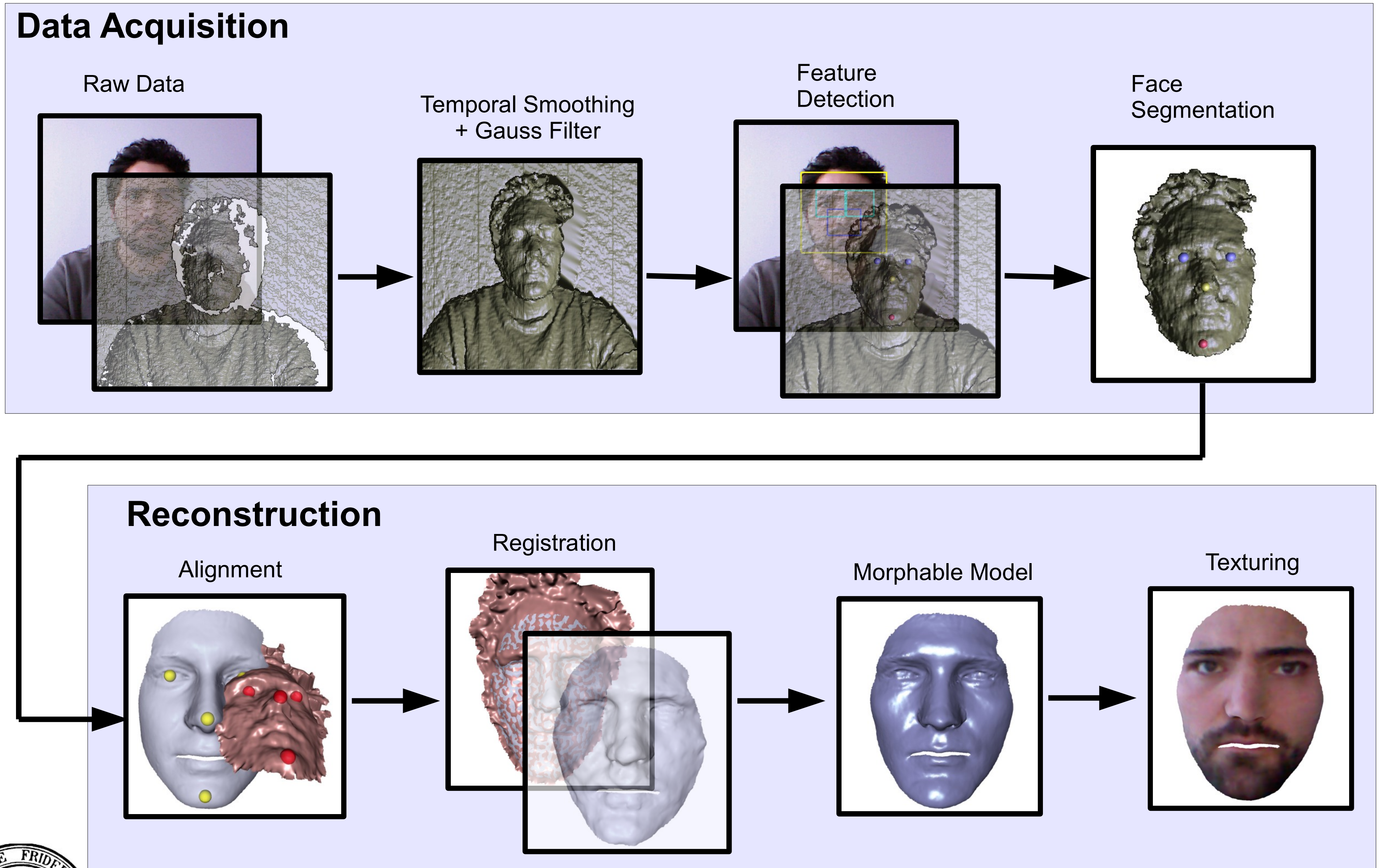
- Some applications provide editors
  - Limited expressibility
  - Difficult to model oneself


- 3D face scan + reconstruction
  - *In the past:* 3D scanning was expensive and required expertise
  - *Now:* The Kinect enables 3D scanning for home use.

Cyberware PX: **$ 67,000**


Microsoft Kinect: **$ 150**

# Algorithm pipeline

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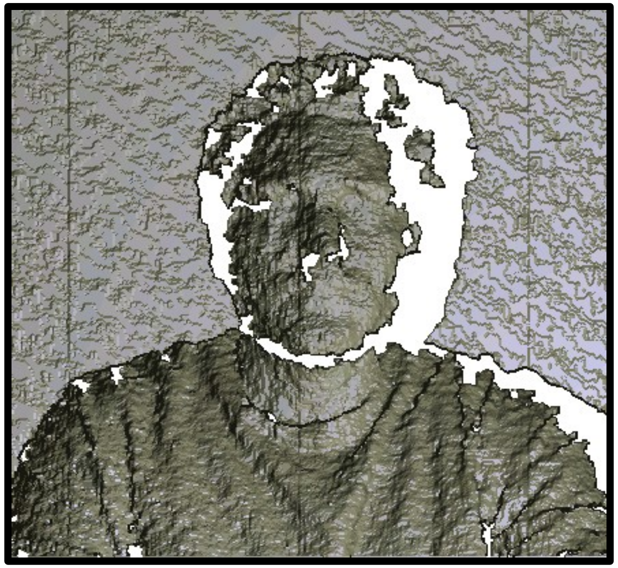
# Part I
## Data Acquisition

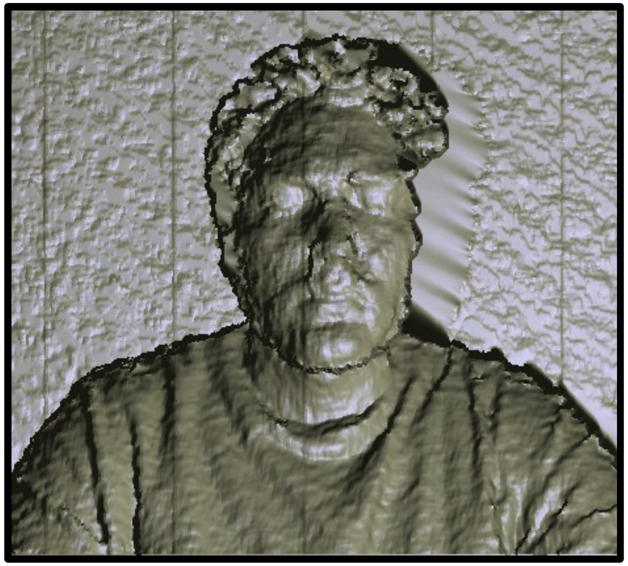
# Temporal Smoothing + Gauss Filter

- Improves the noisy and hole-containing raw data
  - Take the average values of 8 successive frames
  - Apply an (advanced) 3x3 Gauss Filter to the smoothed data



Raw data

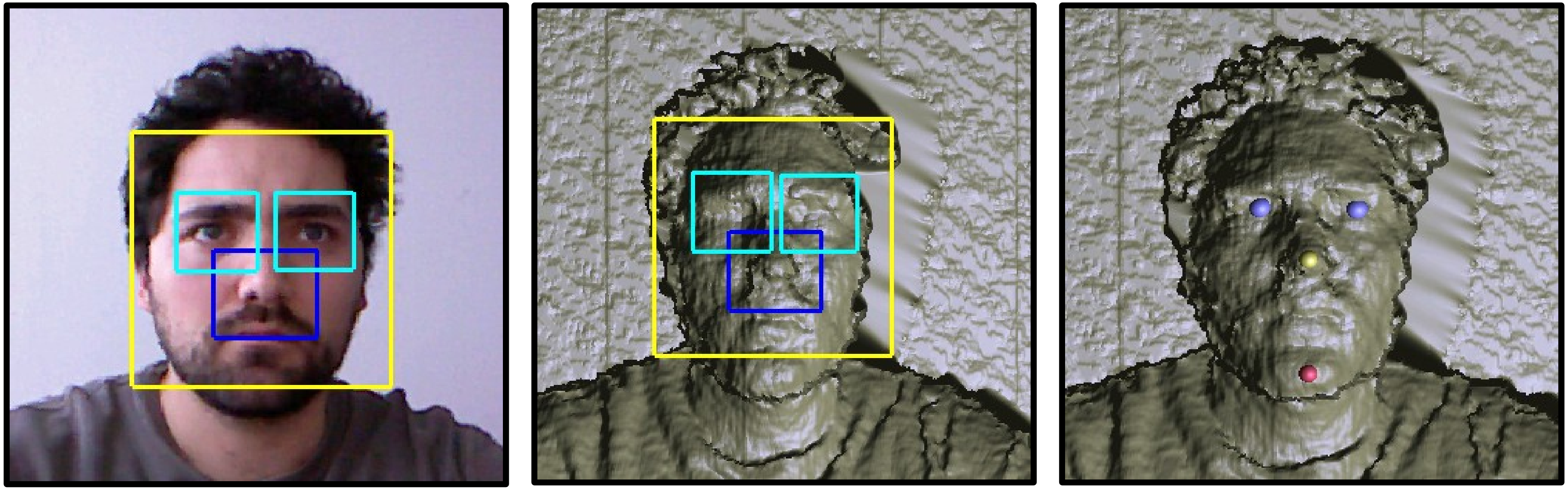
Temporally smoothed



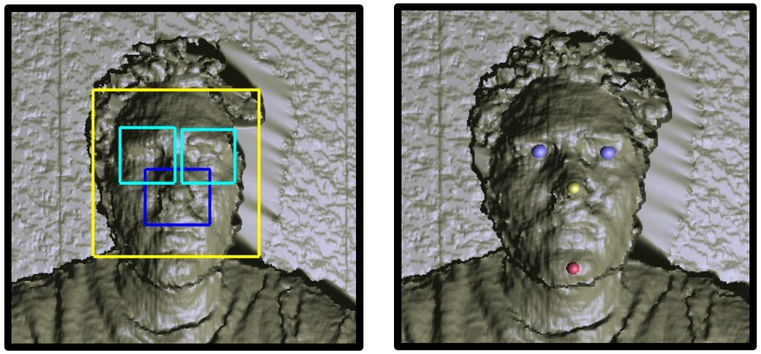
Gauss-filtered

# Feature Detection

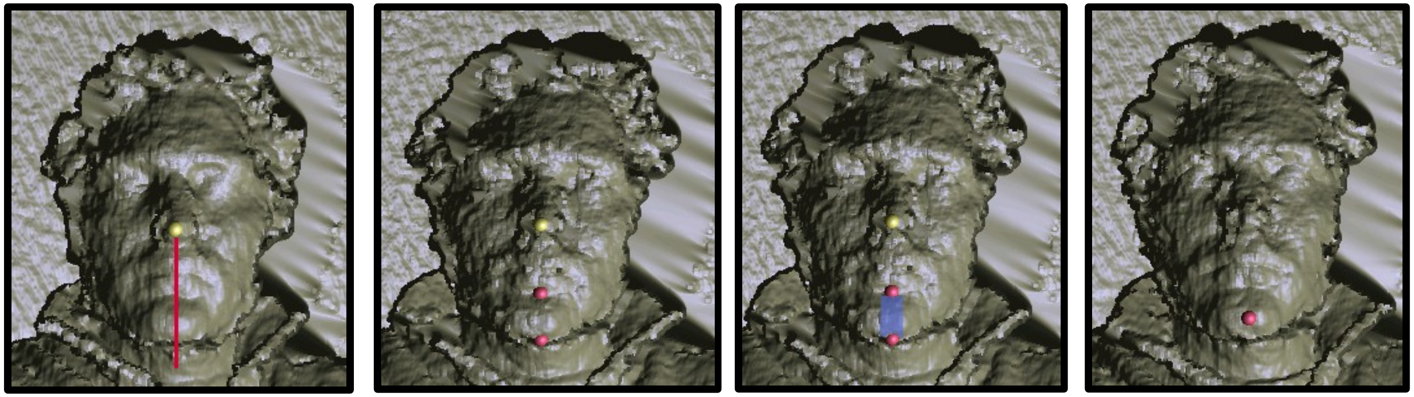
- Use OpenCV to detect bounding boxes of face, eyes and nose.
- Map detected regions onto the geometry.
- Detect feature points on the geometry data.



# Feature Detection

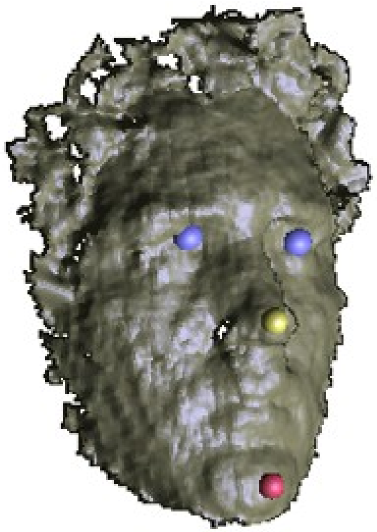


- Eyes
  - Center of bounding boxes
- Nose tip
  - Point in Nose-region with lowest z-value
- Chin
  - Detect chin region, then search point with lowest z-value



# Face Segmentation

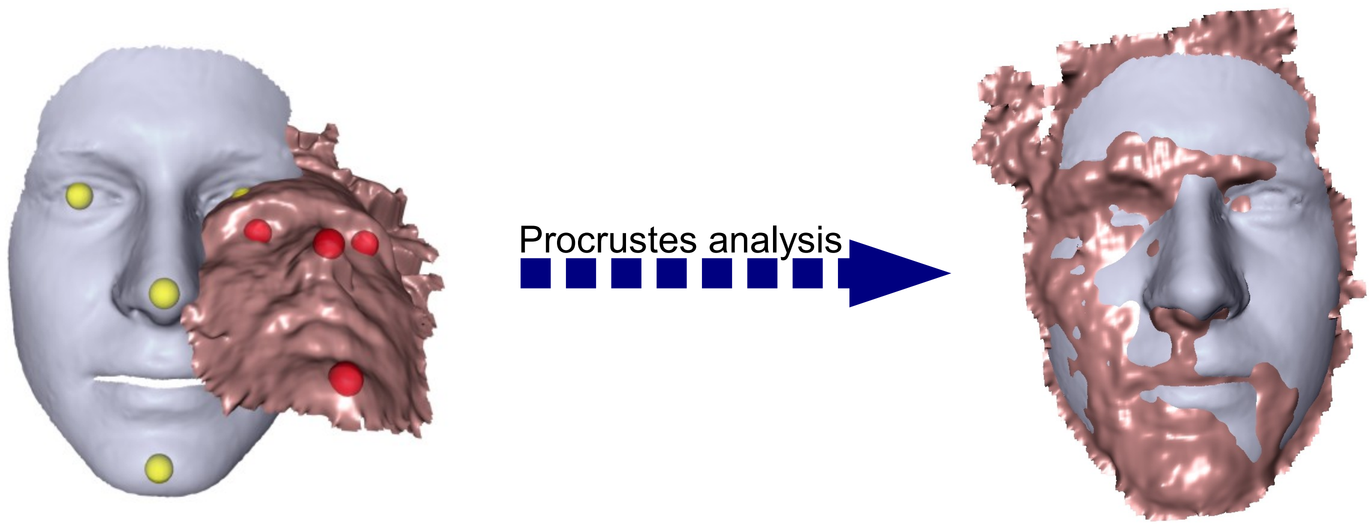
- Separate the face from the rest of the input data
  - Floodfill-like algorithm
  - Use detected feature points as seed points
  - Only proceed to a neighboring point, if z-values are close together



# Part II
## Geometry Reconstruction

# Initial Rigid Alignment

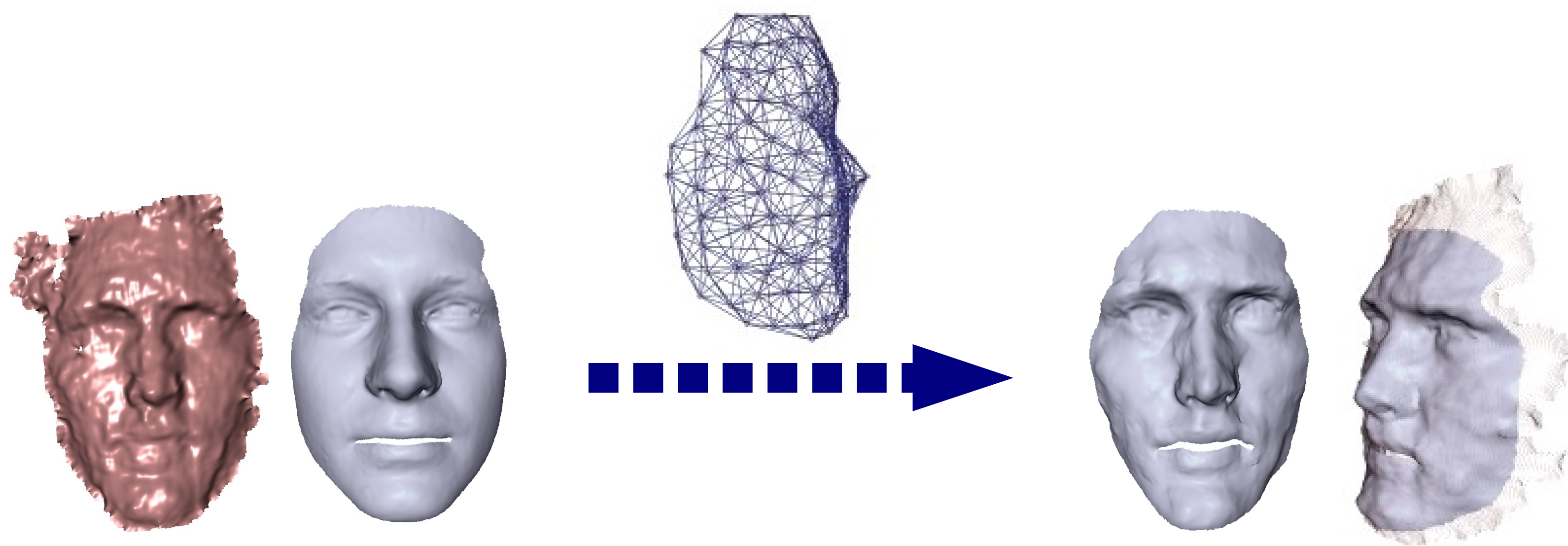
- Input point cloud and template mesh live in different spaces
- Use detected feature points to compute a rigid alignment



# Non-Rigid Registration

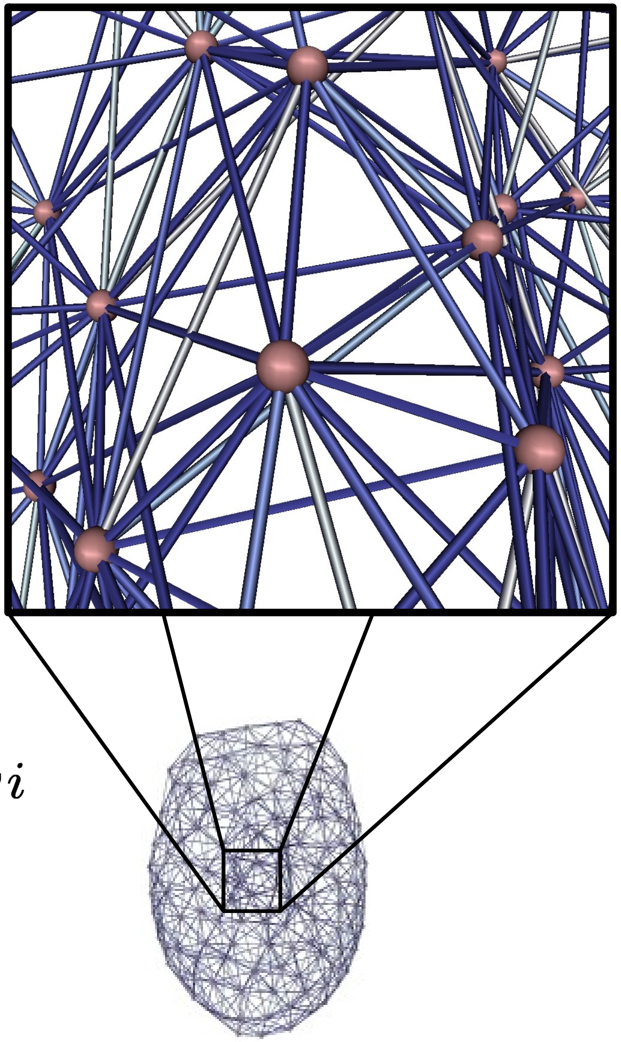
- Minimize graph-based energy function

$$E_{\text{reg}} = \alpha E_{\text{fit}} + \beta \sum_i E_{\text{rot}}(\mathbf{M}_i) + \gamma \sum_{e_{ij}} E_{\text{con}}(e_{ij})$$



# Deformation Graph (Sumner et al.)

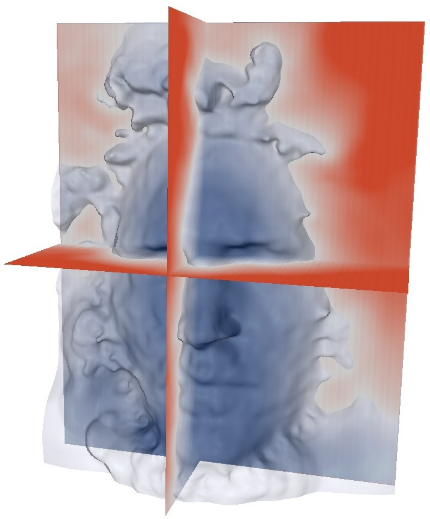
- One affine transformation per node
- Each node locally deforms the surrounding space
- Global transformation obtained by blending



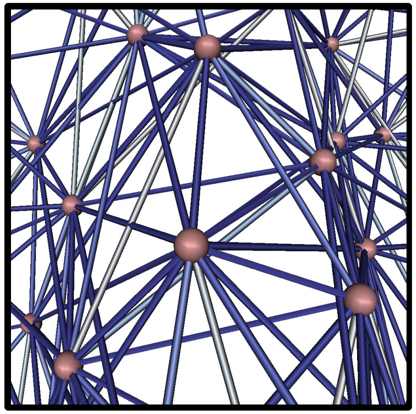
$$A_i(\mathbf{x}) = \mathbf{M}_i(\mathbf{x} - \mathbf{p}_i) + \mathbf{p}_i + \mathbf{t}_i$$

# Non-Rigid Registration – Details

$$E_{\text{fit}} = \sum_{\hat{\mathbf{v}}_i \in \Phi(\mathcal{T})} \left( \frac{|f(\mathbf{v}_i)|}{\|\nabla f(\mathbf{v}_i)\|_2} \right)^2$$

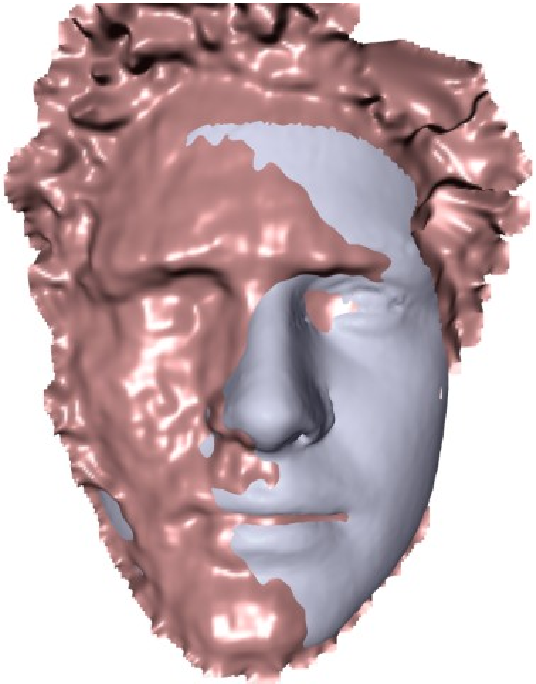


$$E_{\text{rot}}(\mathbf{M}_i) = \|\mathbf{M}_i^T \mathbf{M}_i - \mathbf{I}\|_F^2$$



$$E_{\text{con}}(e_{ij}) = \|A_i(\mathbf{p}_j) - A_j(\mathbf{p}_j)\|_2^2 + \|A_j(\mathbf{p}_i) - A_i(\mathbf{p}_i)\|_2^2$$

# Modified Gauss-Newton Optimization



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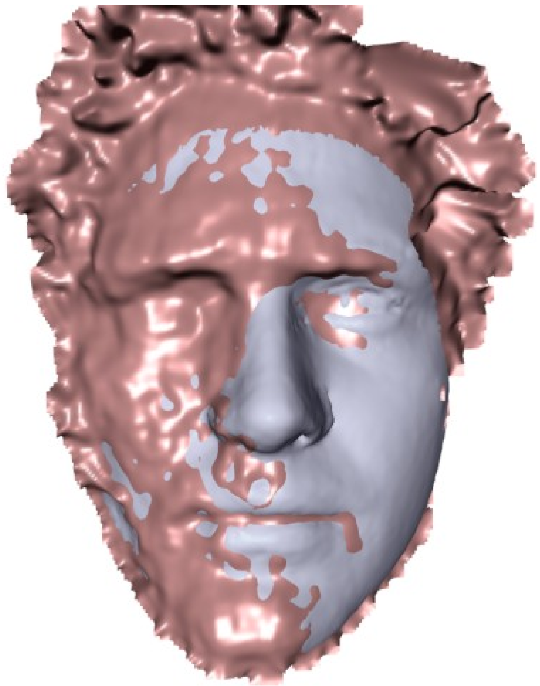

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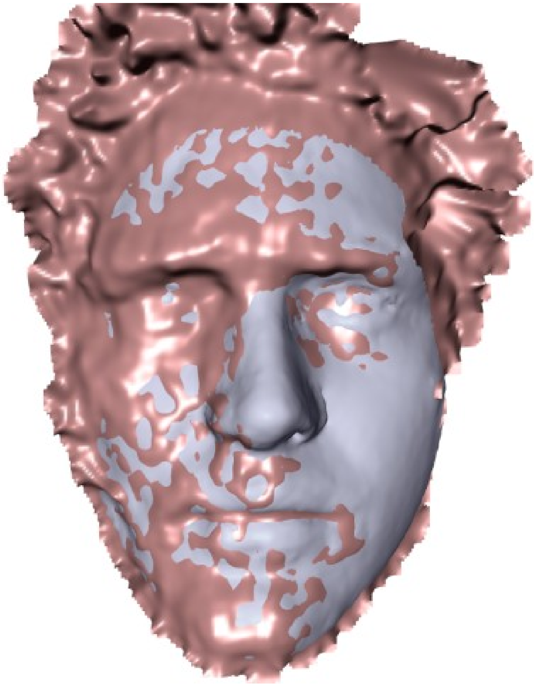

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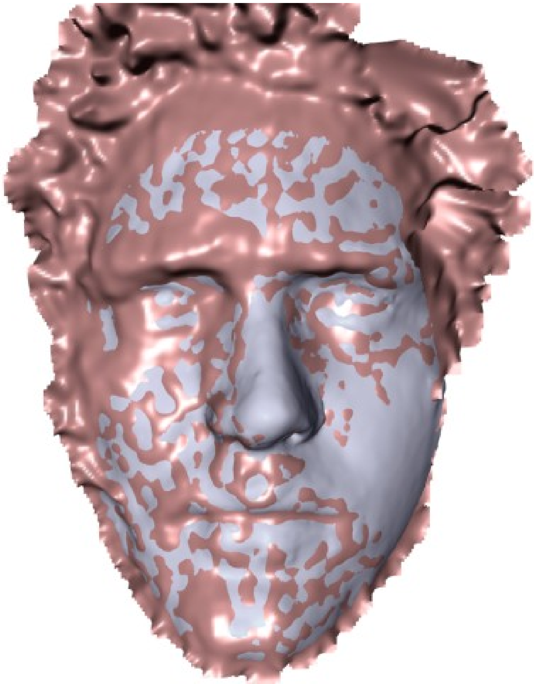

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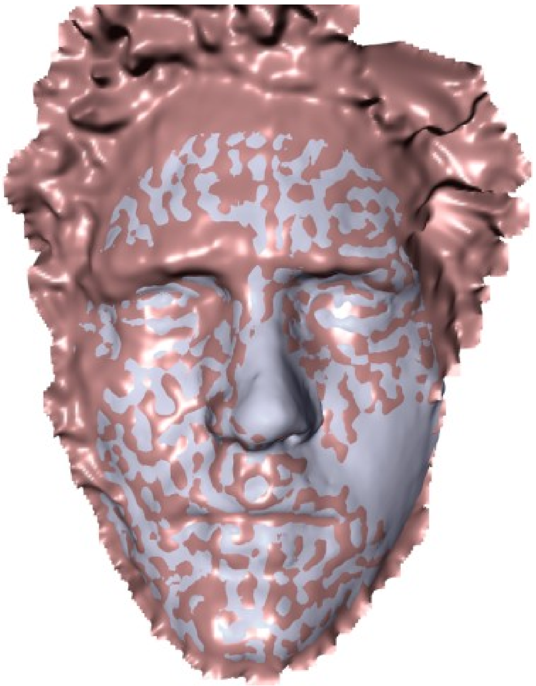

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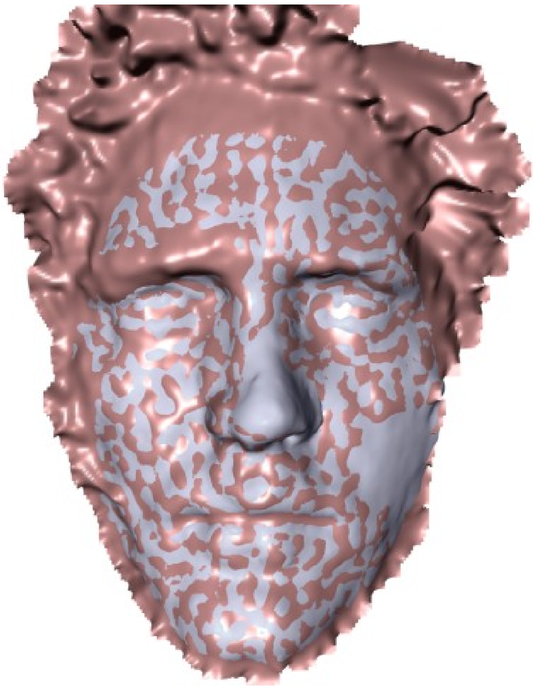

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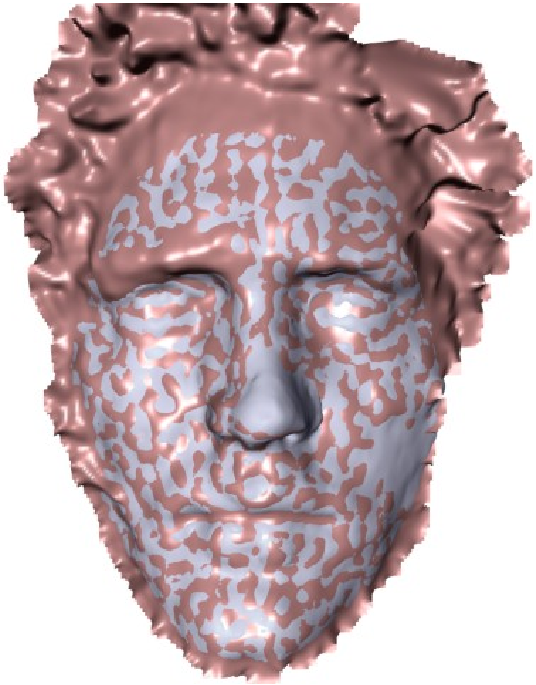
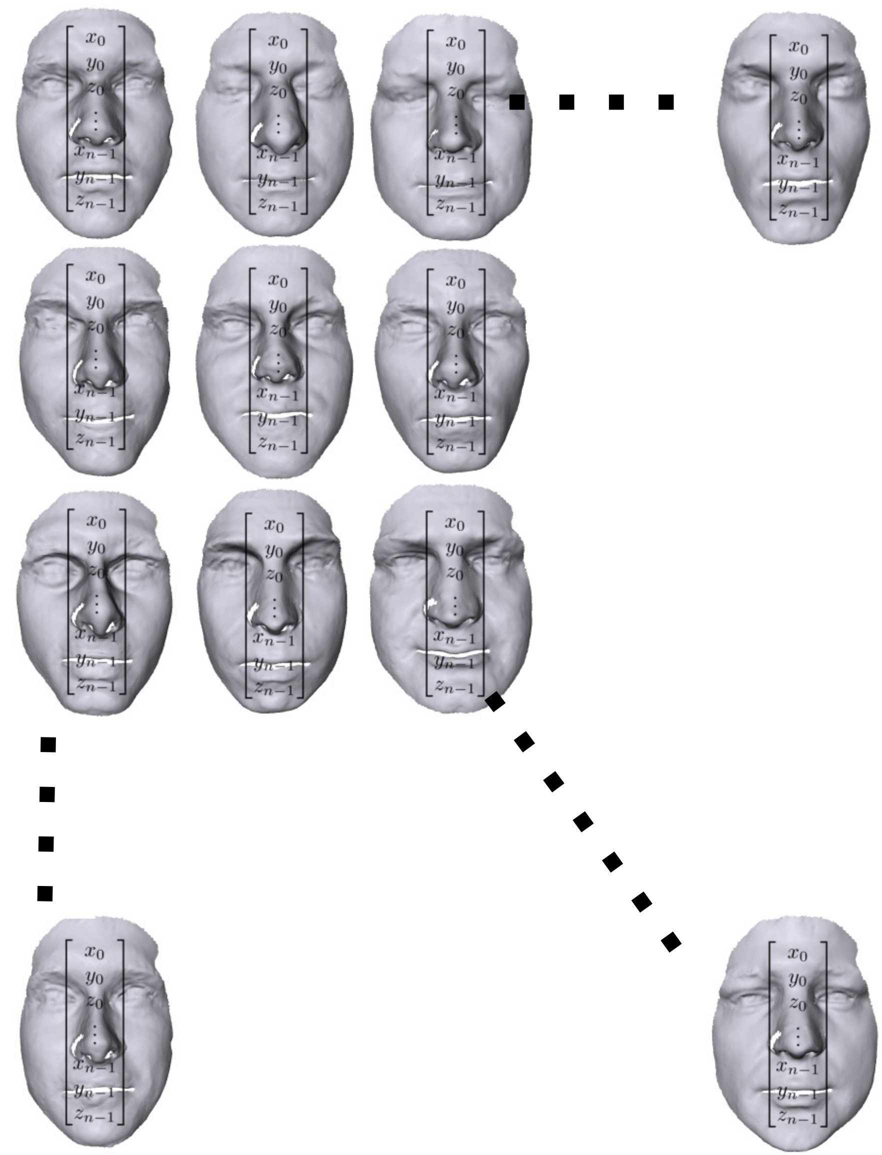


# Morphable Model (V. Blanz and T. Vetter)

- Face database
- One-to-one correspondences
- High dimensional vector space
- Components can be interpreted as random variables



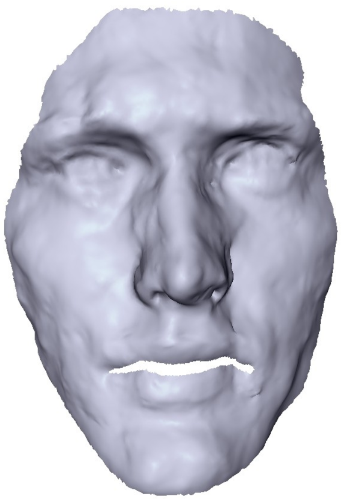
# Morphable Model – Details

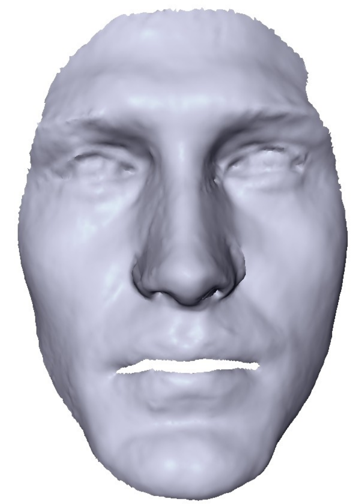
- Compute principal axes (PCA)
- Use the k axes with the highest variance for data compression
- Resulting shape can be controlled using a few coefficients

$$\mathcal{F} = \mathcal{T} + \mathbf{E} \cdot \mathbf{c}$$

# Morphable Model – Fitting

$$\min_{\mathbf{c}} ||(\mathcal{T} + \mathbf{E} \cdot \mathbf{c}) - \hat{\mathcal{T}}||_2^2$$





# Part III

## Results

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