Registration of 3D Faces

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Main Paper

- T. J. Hutton, B. F. Buxton and P. Hammond. Automated Registration of 3D Faces using Dense Surface Models.
  In *Proc. British Machine Vision Conference*, 2003.

Motivation

- 3D face model useful for many applications:
  - animation
  - motion tracking
  - face recognition
  - face reconstruction
  - surgery planning & simulation
  - forensic reconstruction
  - …

Motivation

- Build 3D face model from training samples:

- Need to align them: registration.

Motivation

- Can't just align spatially:

Everything is messed up!

Need to align nose to nose, eyes to eyes, …

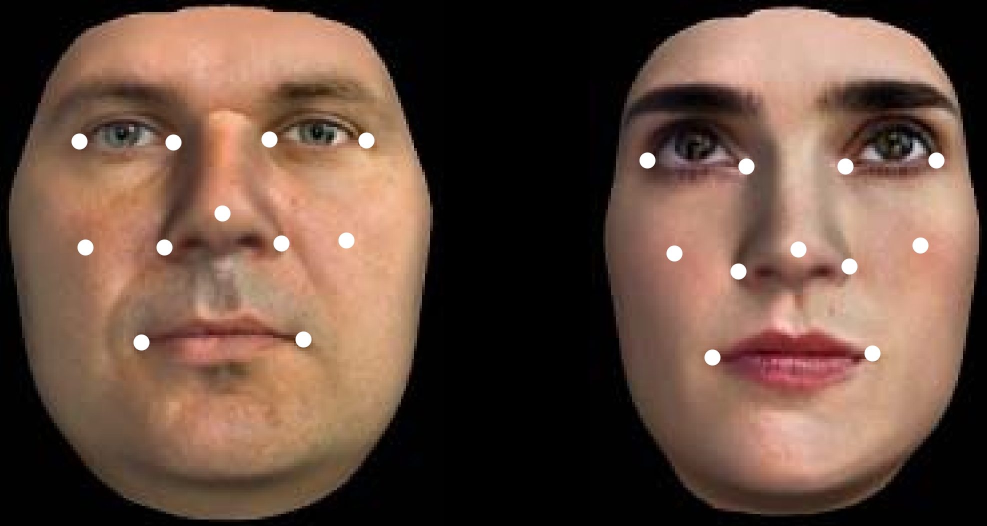
Motivation

Two general kinds of registration:

- Rigid registration
  - Objects differ by scale, rotation, translation.
  - No change in shape during registration.
  - Easy to solve.
- Non-rigid registration
  - Objects differ by scale, rotation, translation, shape.
  - Must change shape during registration.
  - Harder to solve.

Motivation

- One possibility: manually mark landmark points.

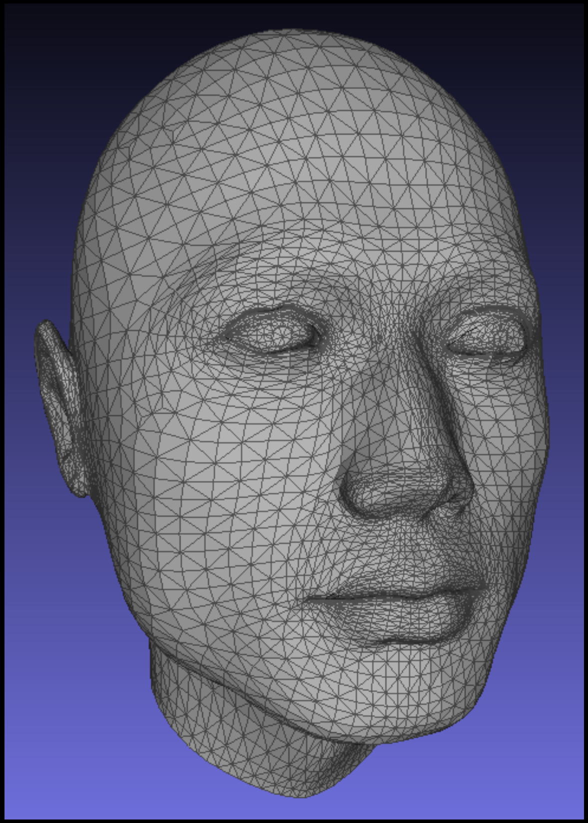


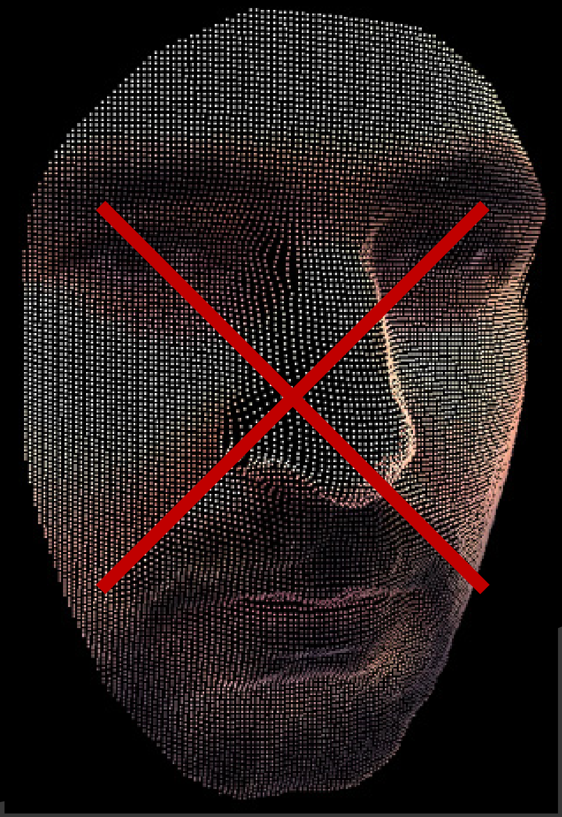
Very tedious and time-consuming!

Need automatic method!

Focus

- 3D model has shape and texture.
- Focus on shape, leave out texture



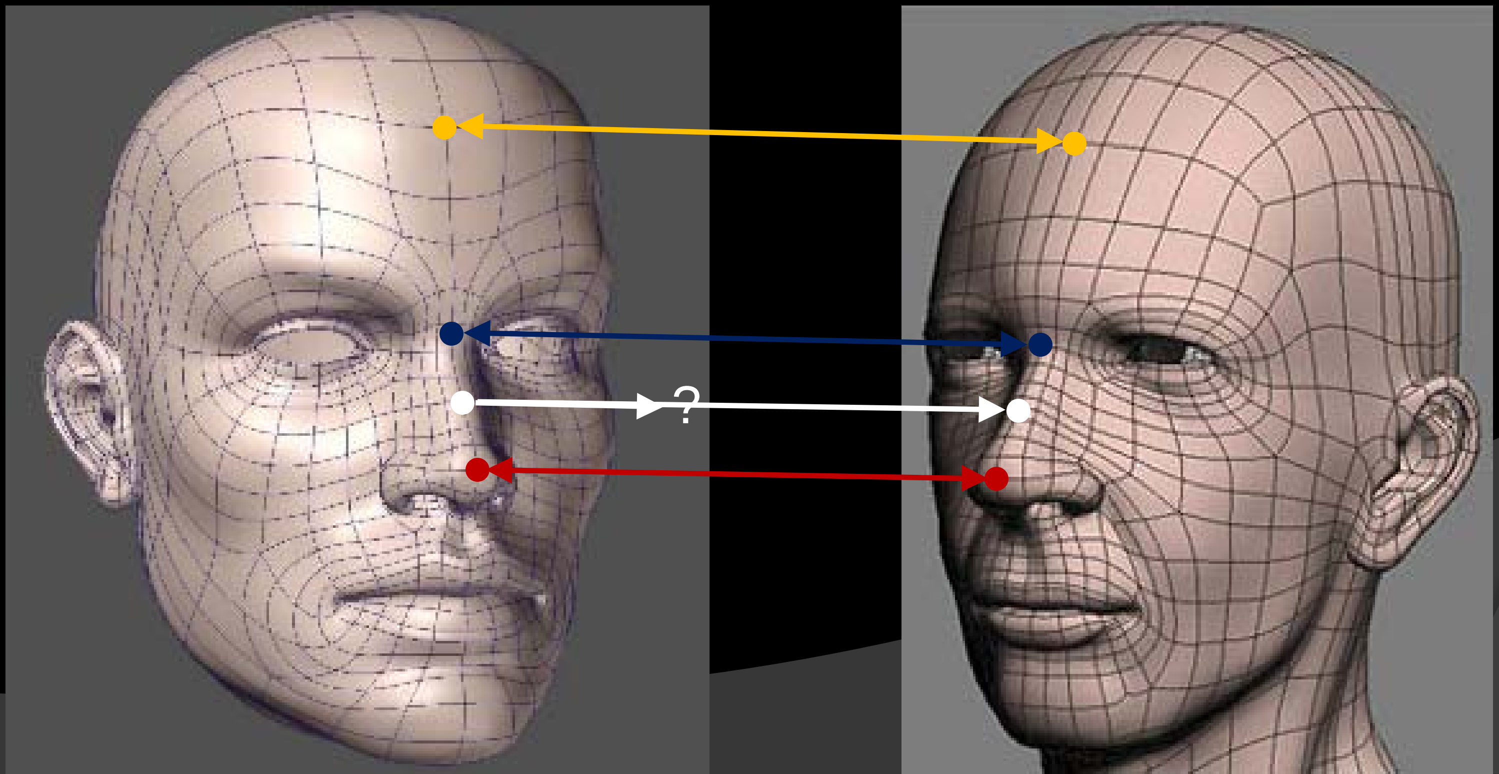


Related Work

- ICP [Besl92, Feldmar96]
  - Global alignment, not landmark correspondence.
- Mesh parameterisation [Brett97,98; Lorenz99,00; Praun01, Davies02]
  - Re-mesh, rearrange mesh points consistently
  - Their landmark = re-parameterised mesh points $\neq$ facial landmark.
- Shape features [Johnson99, Wang00, Yamany02,]
  - Surface curvature, geodesic distance, spin image; not landmark correspondence.

3D Face Registration

- Main ideas of Hutton et al.:
  - Manually place 10 landmarks on training samples.
  - Use landmark correspondence to compute mapping.
  - Interpolate other points: thin-plate spline.

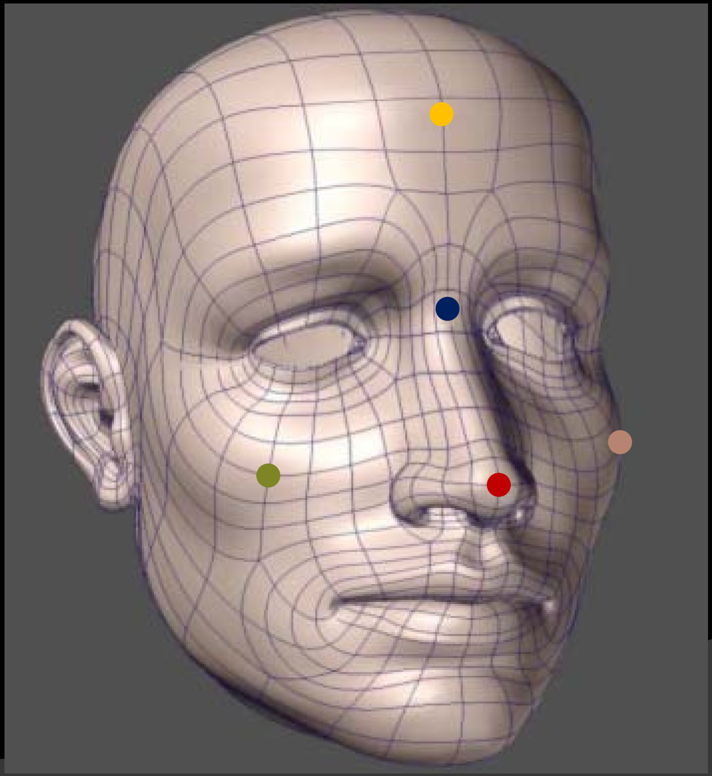


Mean Landmarks

- Compute mean landmarks of training samples.
- Procrustes alignment:
  - Compute best alignment by similarity transformation, i.e., scaling, translation, rotation.
  - Align landmarks of all training samples.
  - Compute mean of landmarks.

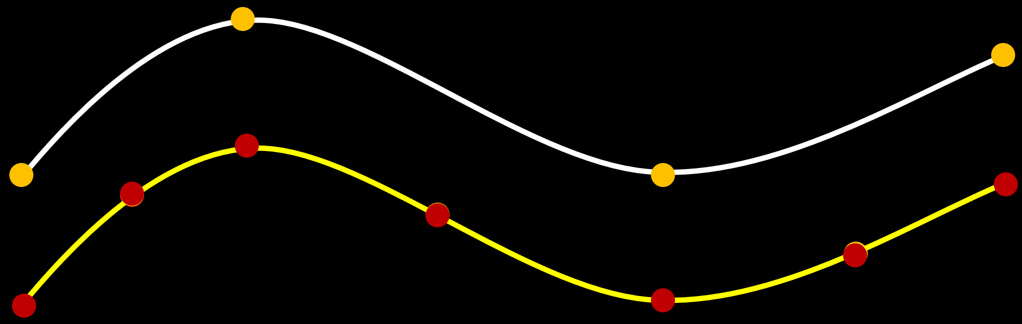
Dense Correspondence

- Main steps:
  - Warp mesh by thin-plate spline so that landmarks coincide with mean landmarks.



Dense Correspondence

- Resample warped mesh using reference mesh.
- Unwarp resampled mesh.
- Now, training samples have consistent mesh vertices.
- Some mesh vertices are facial landmarks.
- Now, can apply PCA on all mesh vertices.



Statistical face model

- Main steps:
  - Align all resampled training samples.
  - Perform PCA.
  - Keep top principal components.
  - Normally,

shape parameters

$$\mathbf{x} = \bar{\mathbf{x}} + \boldsymbol{\Phi}\mathbf{b}$$

  - Hutton et al. used

unwhitening matrix

$$\mathbf{x} = \bar{\mathbf{x}} + \boldsymbol{\Phi}\mathbf{W}\mathbf{b}$$

$$\mathbf{W} = \mathrm{diag}\left(\sqrt{\lambda_1}, \ldots, \sqrt{\lambda_k}\right)$$

Model Fitting

no facial landmark

- Fit mean shape x to input shape y.
  - Apply ICP to align x to y (align global pose).
  - Repeat until convergence:
    - Map vertices on x to closest surface points on y.
    - New x_1 has similar shape as y.
    - Align x_1 to $\bar{x}$ giving x_2.
    - Find shape parameters b of x_3 wrt face model:

$$\mathbf{b} = \mathbf{W}^{-1}\mathbf{\Phi}^{T}(\mathbf{x}_2 - \bar{\mathbf{x}})$$

    - Restrict b to probable values b' according to model.
    - Generate new shape x_3 with b' from

$$\mathbf{x}_3 = \bar{\mathbf{x}} + \mathbf{\Phi}\mathbf{W}\mathbf{b}'$$

close to y

for generating y

Questions

- Can it work for skulls?
- How many skull landmarks?
- Strengths?
- Weaknesses?