Main Paper

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 ≠ 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,

\[
x = \bar{x} + \Phi b
\]

shape parameters

- Hutton et al. used

\[
x = \bar{x} + \Phi W b
\]

unwhitening matrix

\[
W = \text{diag}(\sqrt{\lambda_1}, \ldots, \sqrt{\lambda_k})
\]
Model Fitting

- 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:
      \[
      b = W^{-1} \Phi^T (x_2 - \bar{x})
      \]
    - Restrict $b$ to probable values $b'$ according to model.
    - Generate new shape $x_3$ with $b'$ from
      \[
      x_3 = \bar{x} + \Phi W b'
      \]

for generating $y$ close to $y$
Questions

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