3D face reconstruction from a single 2D image
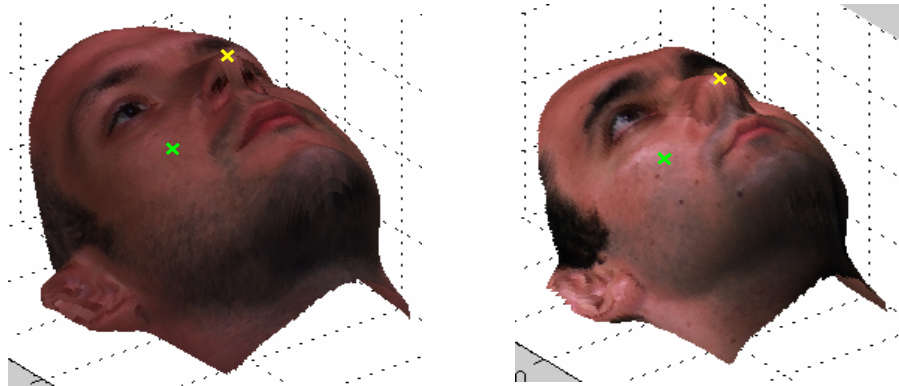
Tan Chek Tien

Contents

- **Morphable Model**
  - Problem Analysis
  - Problem Definition
  - Algorithm
  - Results

- **Model Fitting**
  - Problem Analysis
  - Problem Definition
  - Algorithm
  - Results

- Summary

Morphable Model – Problem Analysis

- Building the morphable model
  - Ill-posed problem

- Inputs
  - Hi-res surface points
  - Cheek, temples uniform
  - Hard to match single points
  - Corresponding points are
    - Near
    - Similar color
    - Similar surrounding shape

- Output
  - Dense correspondence
  - Shape/Texture

Morphable Model
– Problem Definition

Search for corresponding point in reference face to example face model

- Assume all models aligned

- Inputs
  - r : 3D surface point in the reference face.

  - $\{p_i\}$: Set of 3D surface points in the example face model.

- Output
  - x : 3D surface point in $\{p_i\}$ that best matches r

Morphable Model
– Problem Definition

- **Problem Definition**
    - Let $W(y)$ be a <u>known</u> function that defines a window of points centered at y.
    - Let $S(y)$ be a <u>known</u> function providing shape information at y.
    - Let $C(y)$ be a <u>known</u> function providing color information at y.

Hence, problem is to find the point x on the example face that minimizes E:

$$E = \lambda_C \sum_{r_i \in W(r), p_i \in W(x)} \| C(r_i) - C(p_i) \|^2 + \lambda_S \sum_{r_i \in W(r), p_i \in W(x)} \| S(r_i) - S(p_i) \|^2$$

where $\lambda_p, \lambda_C, \lambda_S$ are weighting factors

And $x \in R(r)$ where $R(r)$ defines a region around r

Morphable Model
– Algorithm

- Search Process

Reference

$W(r)$

r

$R(r)$

Example

X

$R(r)$
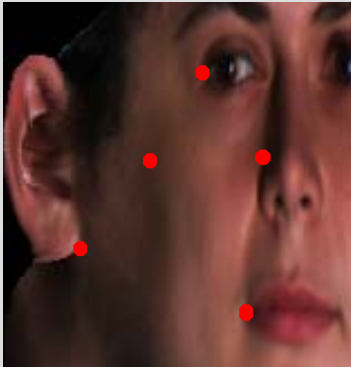
- C(y) – RGB values
- S(y) – Gaussian Curvature

Morphable Model
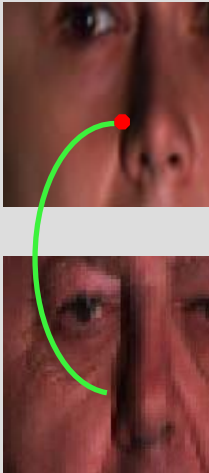## – Algorithm

- Enhancement

Feature Detection
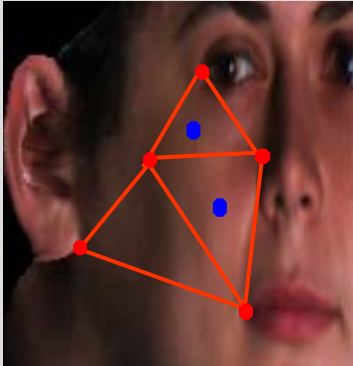
- Corner detection
- By Gaussian Curvature
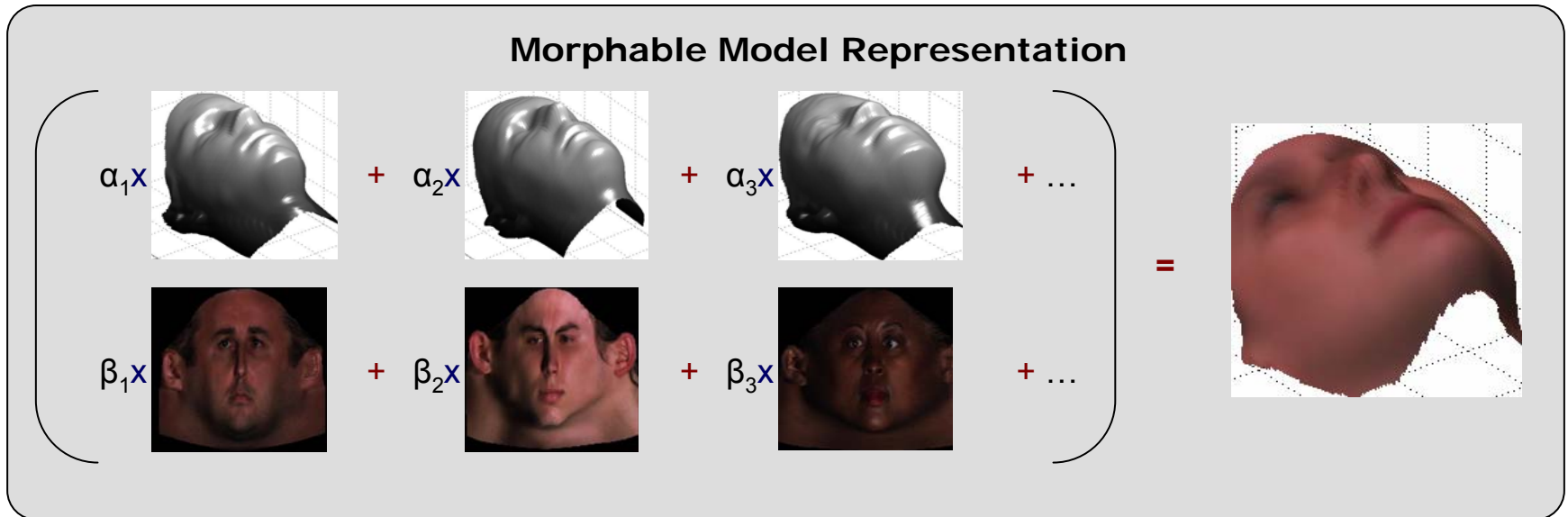
Matching

- Min E
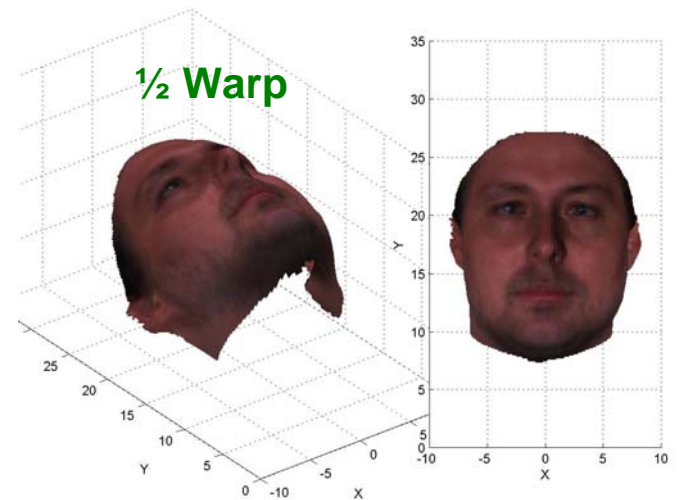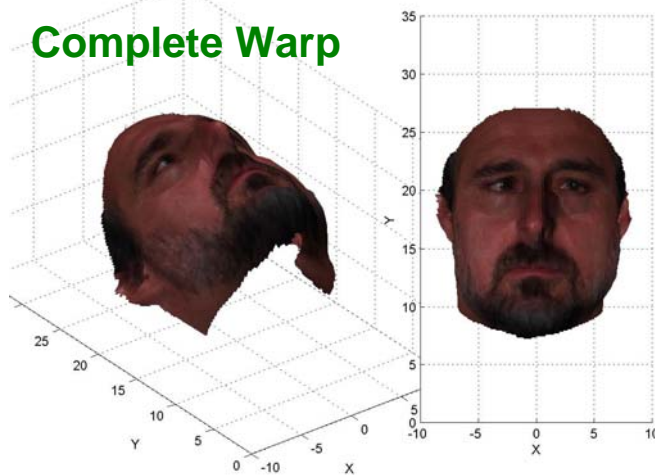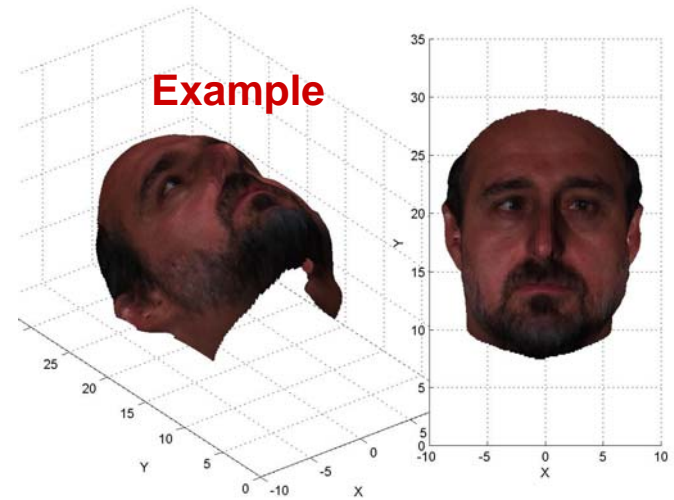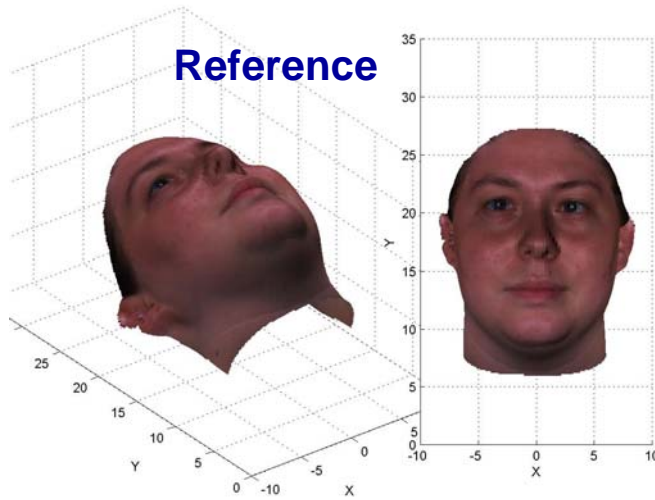
Interpolation

- Delaunay Δ
- Interpolation

Morphable Model
– Algorithm

- Deformable Model

Morphable Model Representation

$$\left(\alpha_1 x \quad + \quad \alpha_2 x \quad + \quad \alpha_3 x \quad + \ldots \right)$$
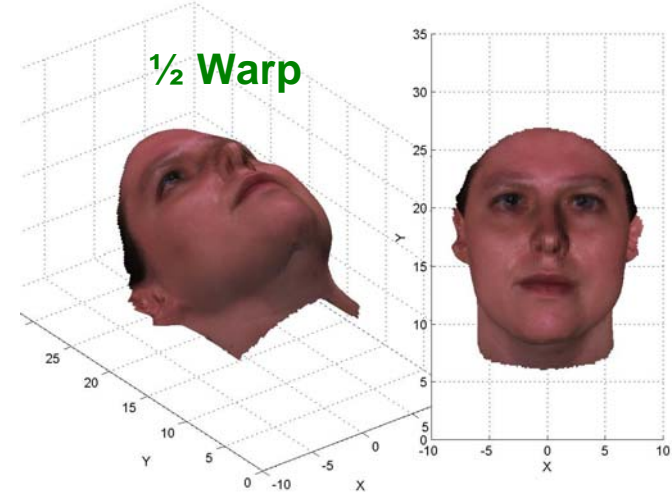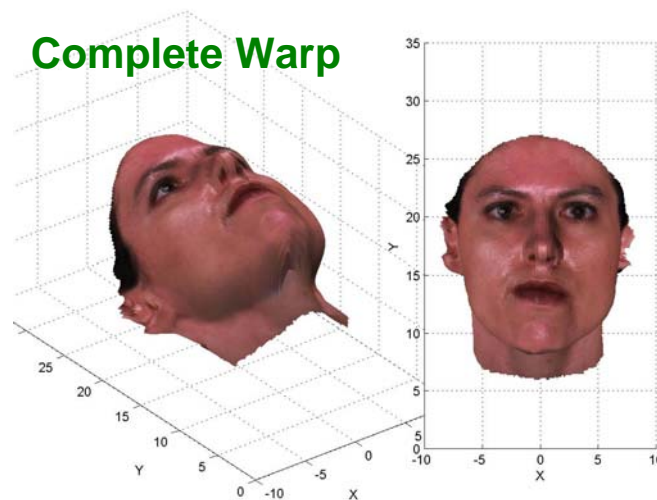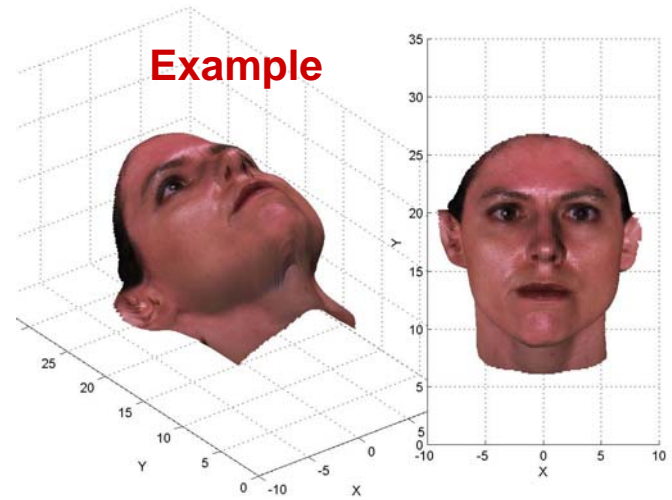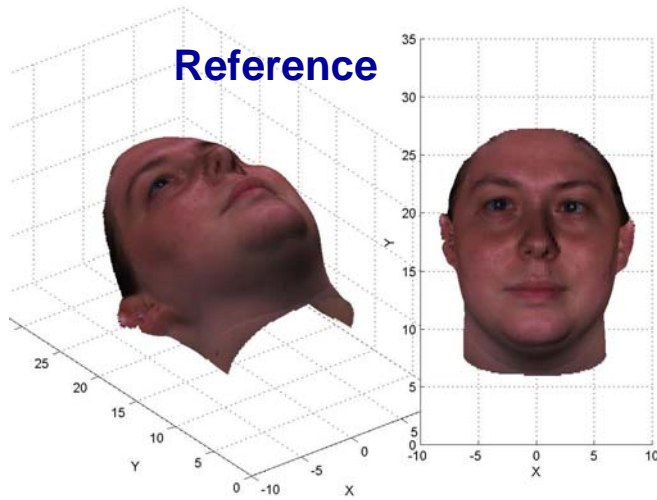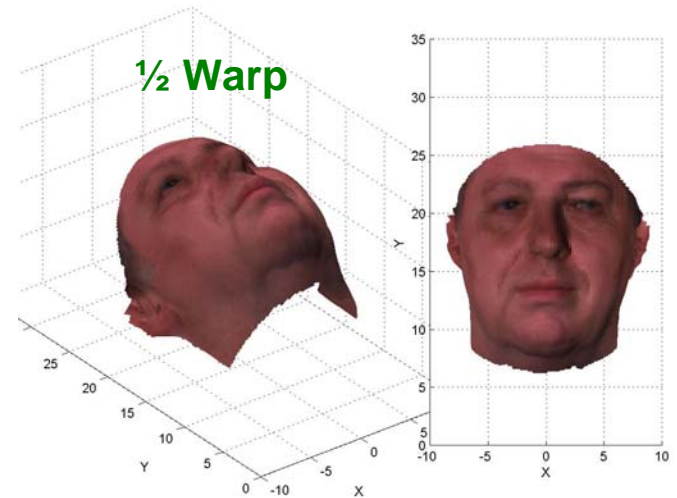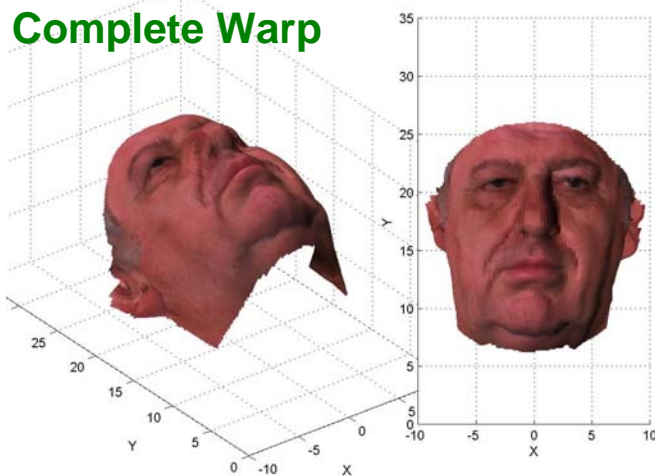$$\left(\beta_1 x \quad + \quad \beta_2 x \quad + \quad \beta_3 x \quad + \ldots \right) = $$

Morphable Model – Results

- +ve

Morphable Model – Results

- +ve

Reference   Example

Complete Warp   ½ Warp

Morphable Model – Results
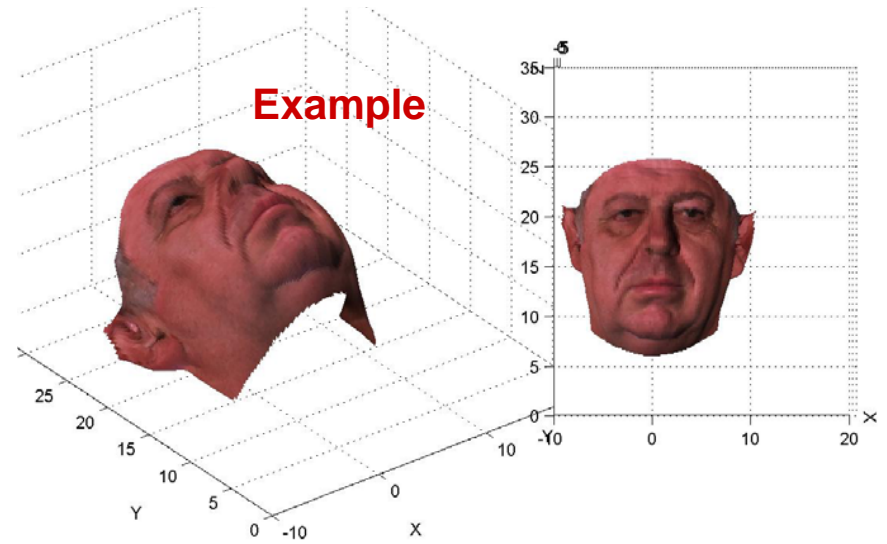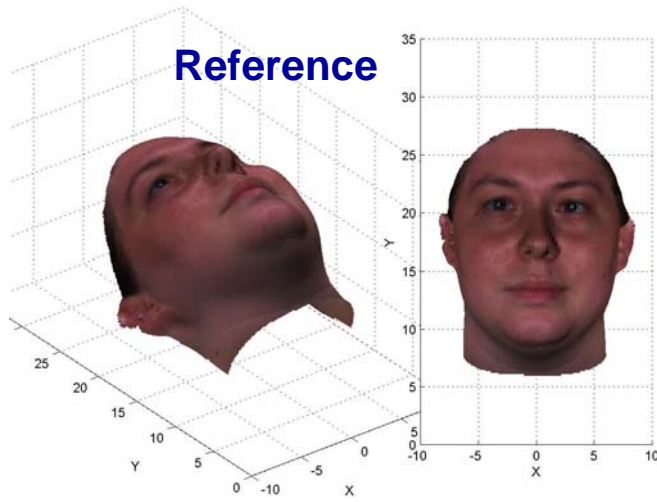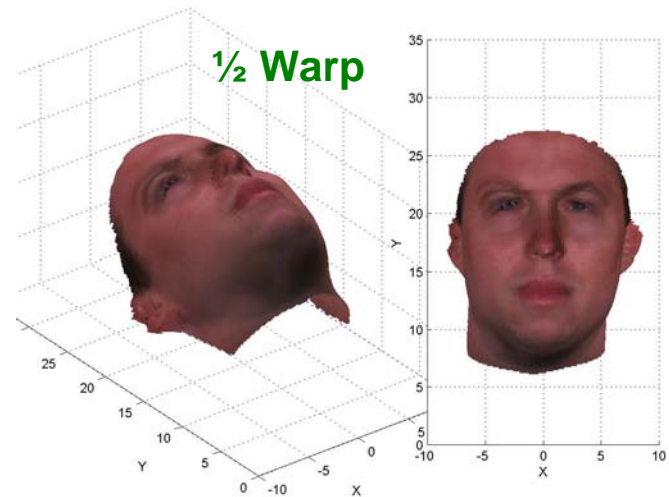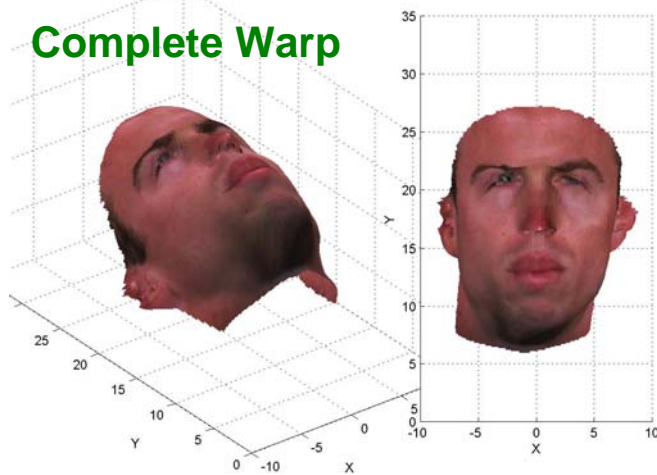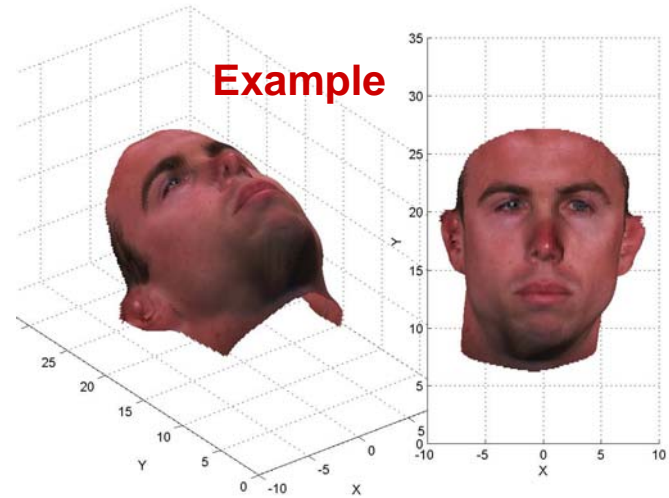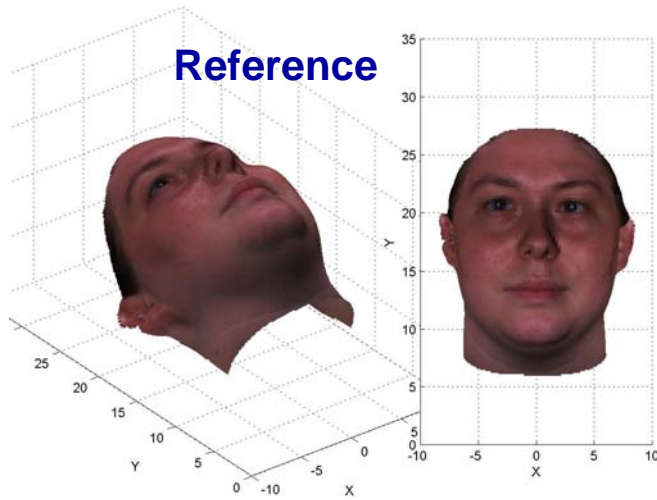
- +ve

Reference   Example

Complete Warp   ½ Warp

Morphable Model – Results

- -ve

Morphable Model – Results

- -ve

Reference

Example

Complete Warp

½ Warp
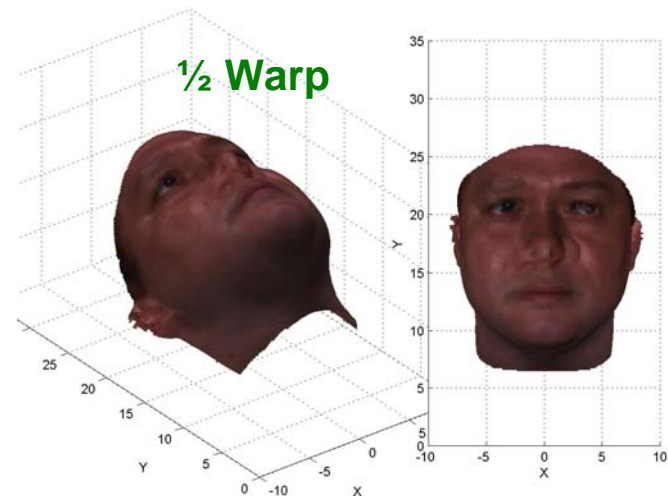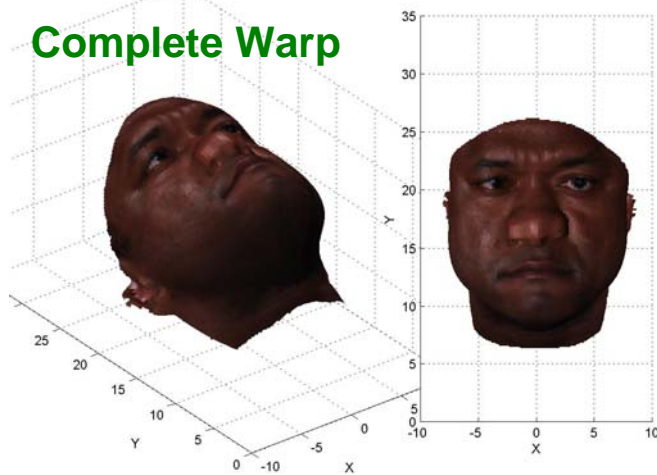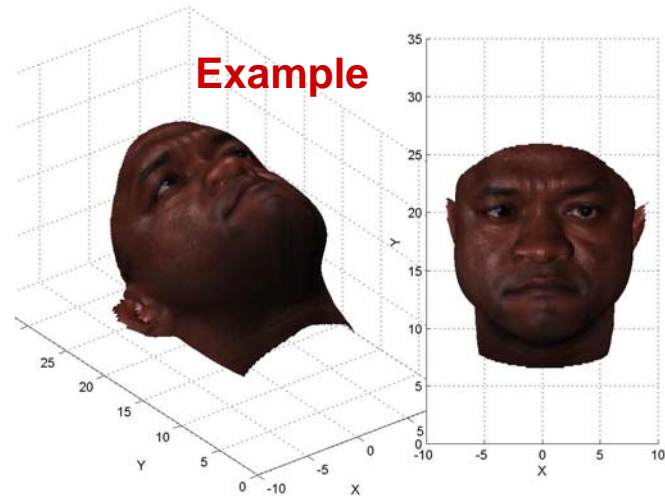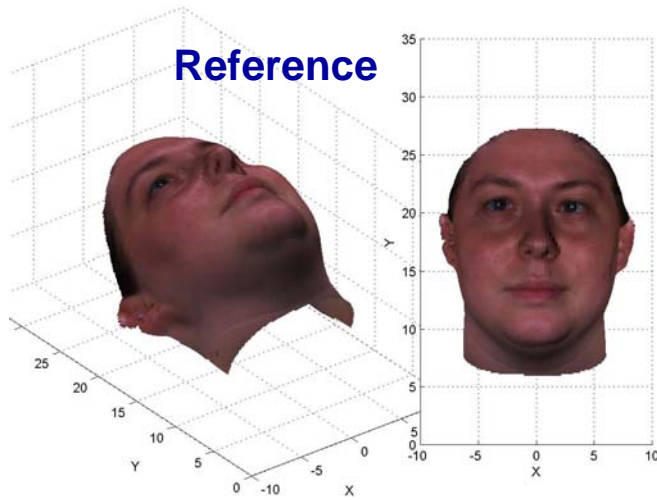
Model Fitting
– Problem Analysis

Input

Single 2D facial image.
- Contains unwanted regions
- Illumination, Pose, Camera
- Assume no facial artifacts

Deformable Model
- Interact with surroundings
- Within Face Space

Output

3D face model of person in image(s)
- Should look like the person
- Limited angle of view

Model Fitting

– Problem Definition

Registration of a deformable model to an image with known correspondences

- **Inputs**
  - Set of 2D points, $\{e_j\}$, on the 2D input image.
  - Set of 3D points, $\{m_i\}$, on the deformable model

- **Outputs**
  - $\{m_i'\}$, the deformed version of $\{m_i\}$

Model Fitting
– Problem Definition

- **Problem Definition**
  - Let f be a <u>known</u> correspondence function from $\{m_i\}$ to $\{e_j\}$, i.e $f(m_i) \in \{e_j\}$
  - Let D be a deformation function such that optimally $m_i' = D(m_i)$
  - Let T be a rigid transformation function on the model
  - Let P be a <u>known</u> projection function on the model
  - Let R be a rendering function on the model which includes camera intrinsic params and illumination params
  - Let S be a <u>known</u> function providing shape information.

Hence, problem is to find D, T and R that minimizes E:
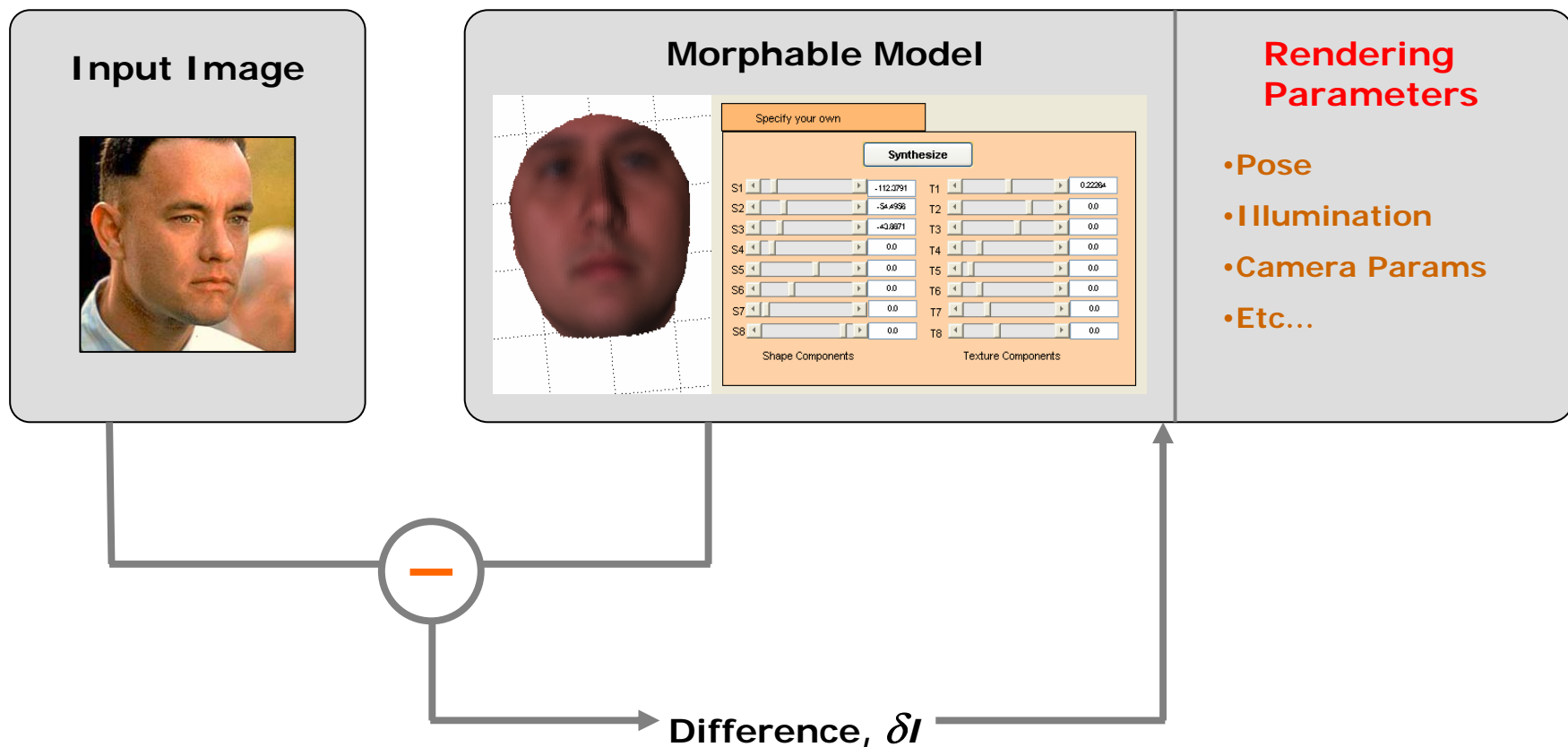
$$E = \lambda \sum_i \| P(R(T(D(m_i)))) - f(m_i) \|^2 + (1-\lambda)\sum_i \| S(m_i) - S(D(m_i)) \|^2$$

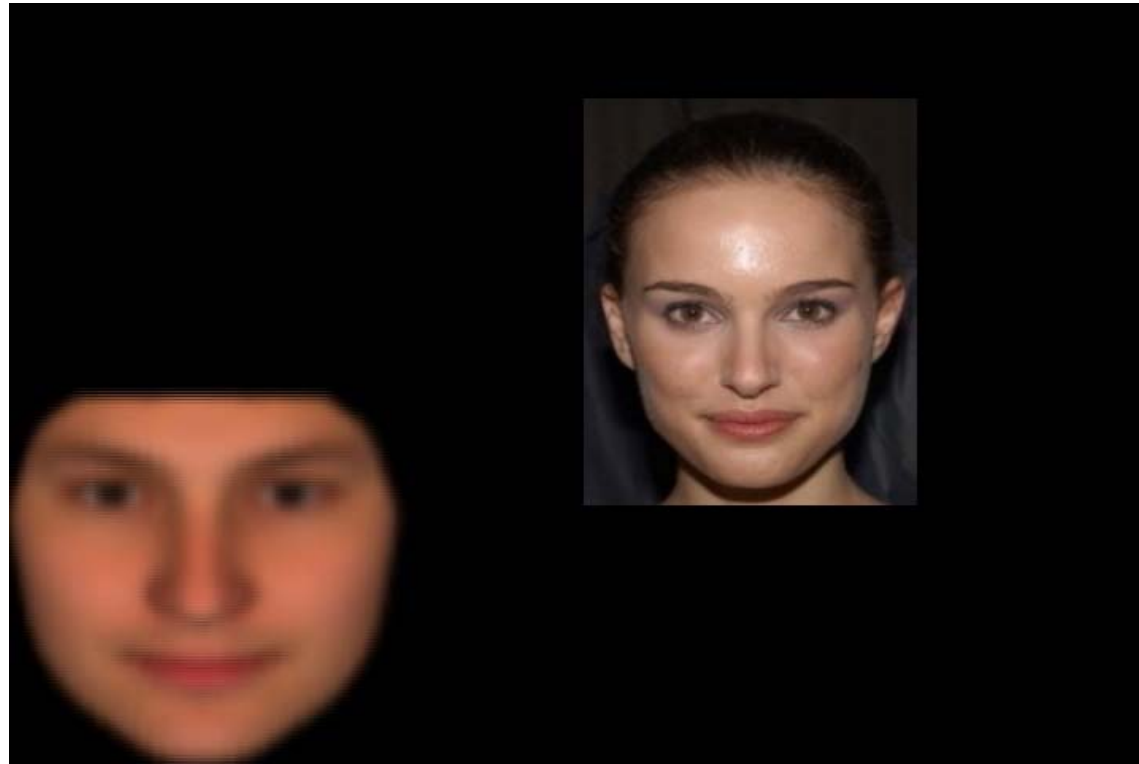where λ is a weighting factor

Model Fitting
– Algorithm

- ## Optimization Process
  - ### – Stochastic Newton Optimization [2] [5]
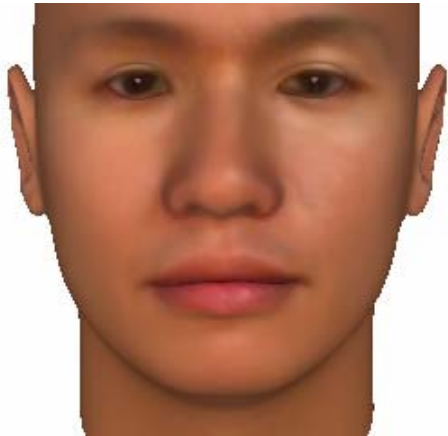
Model Fitting
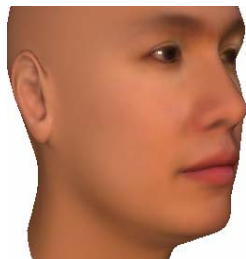## – Results

Model Fitting
– Results

Model Fitting
– Results

Summary

- Accuracy dependant on how well variance is captured in 3DMM
  - Database must be large and well distributed.

- Comparison with Blanz and Vetter [1]

This	Blanz & Vetter [1]
3DMM has curvature	3DMM only by position and texture
3DMM – 90 faces	3DMM – 200 faces
~10mins	~4.5mins
Texture dependant on 3DMM	Texture extracted from image

References

- [1] A Morphable Model for the Synthesis of 3D Faces (1999)
  - V.blanz and T. Vetter

- [2] Face recognition based on fitting a 3D morphable model (2003)
  - V.blanz and T. Vetter

- [3] Equivalence and Efficiency of image alignment algorithms (2001)
  - S. Baker and I.Matthews

- [4] Three-Dimensional Correspondence (1998)
  - C. Shelton

- [5] FaceGen (1998)
  - Singular Inversions

- [6] Metrics and Visualization Tools for Surface Mesh Comparison. (2001)
  - Zhou, L and Pang, A.