Computer Animation Visualization

Lecture 6

Facial animation

Sebastian Starke

Overview

- Parke's parametric face

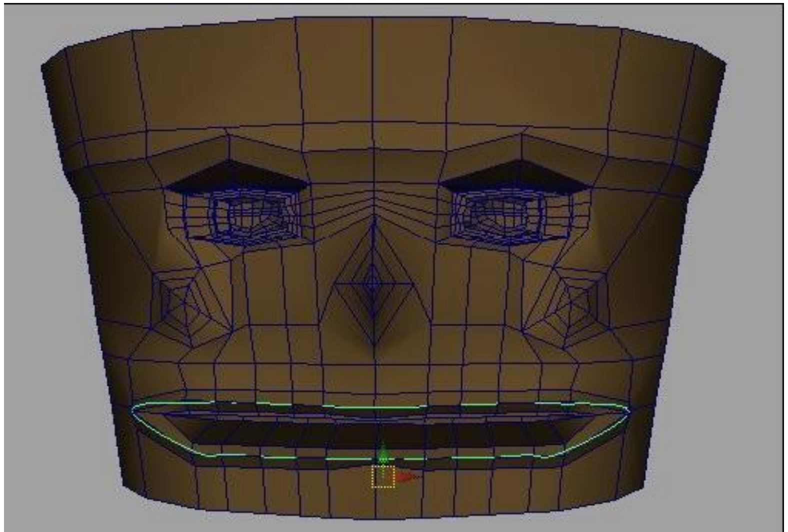
- Muscle-based models

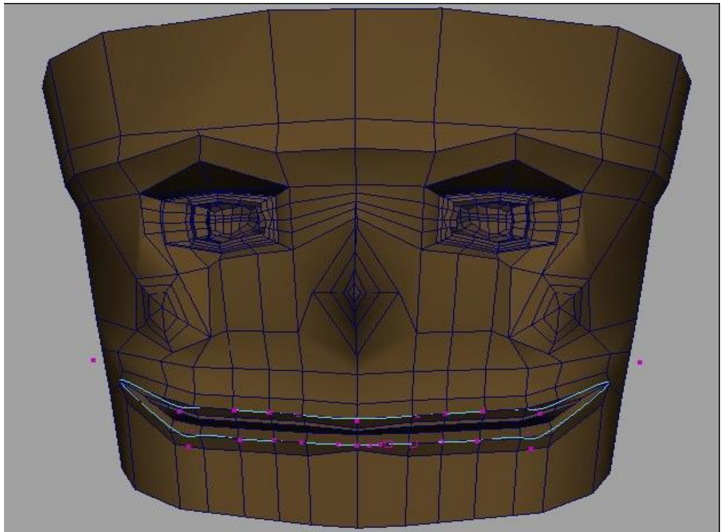
- Expression cloning

- Deformation Transfer

Creating Facial Expressions

- The number of points that compose the face is large – the dimensionality is high
- Can be very tedious and time consuming to manually produce each expression without an underlying structure





Parke's Parameteric Model

Fred Parke created the first 3D parametric model of a human face.

The model is discussed in his 1974 dissertation.

A parametric model for human faces

Frederic Parke, 1974 Ph.D. dissertation, Utah

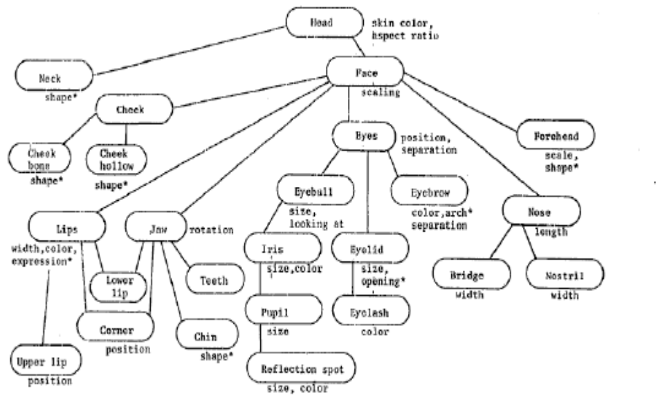
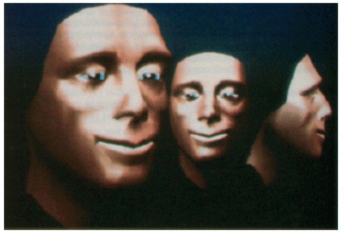


Figure 3.1 - The structure of the parametric model. The parameters affecting the various nodes are shown. An * indicates the use of interpolation to implement the parameter.

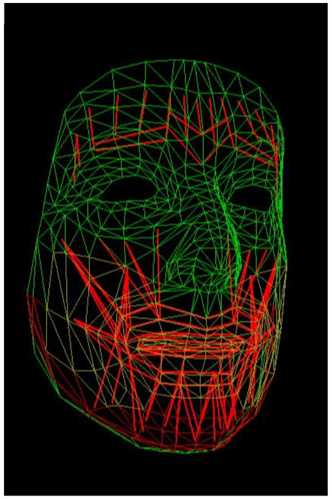
Overview

- Parke’s parametric face
- **Muscle-based models**
- Expression cloning
- Deformation Transfer

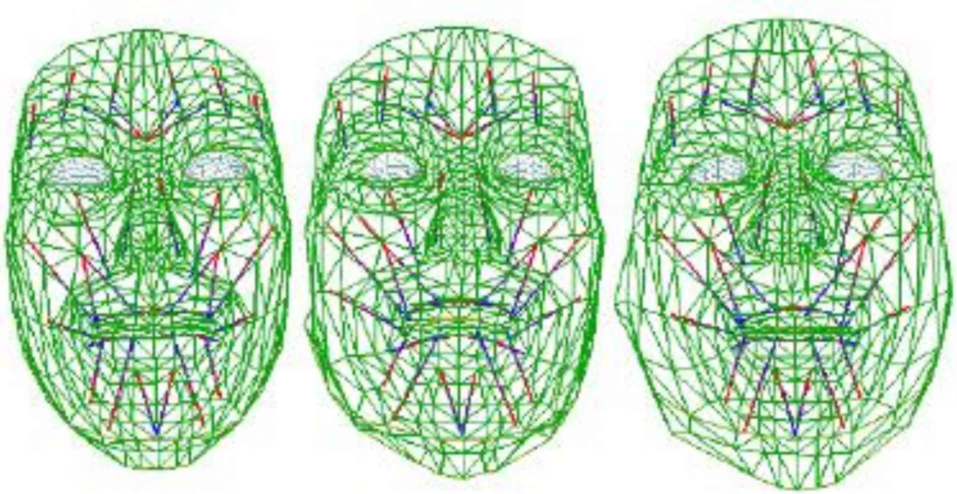


Muscle Based Animation

- Uses a mass-and-spring model to simulate facial muscles.
- Muscles are of two types: linear muscles that pull and elliptic muscles that squeeze.

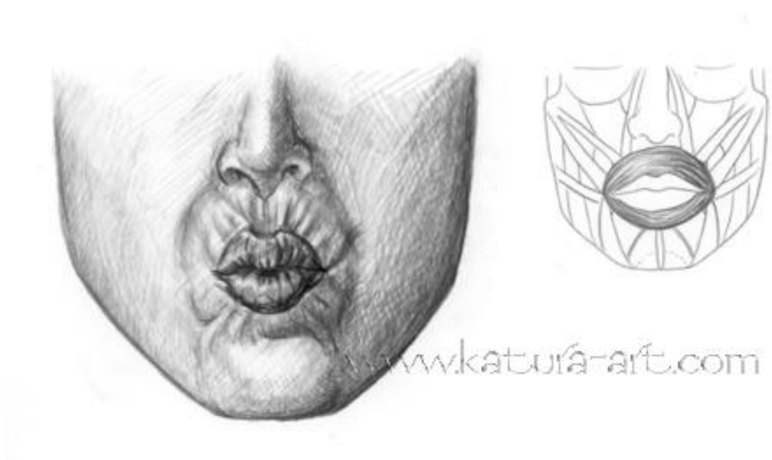


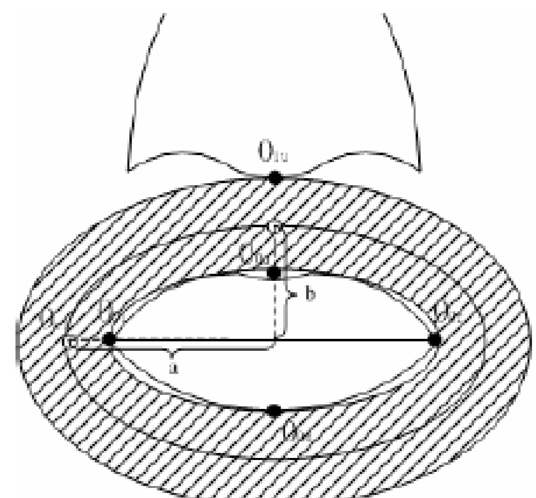
Polygonal surface



Elliptic Muscles

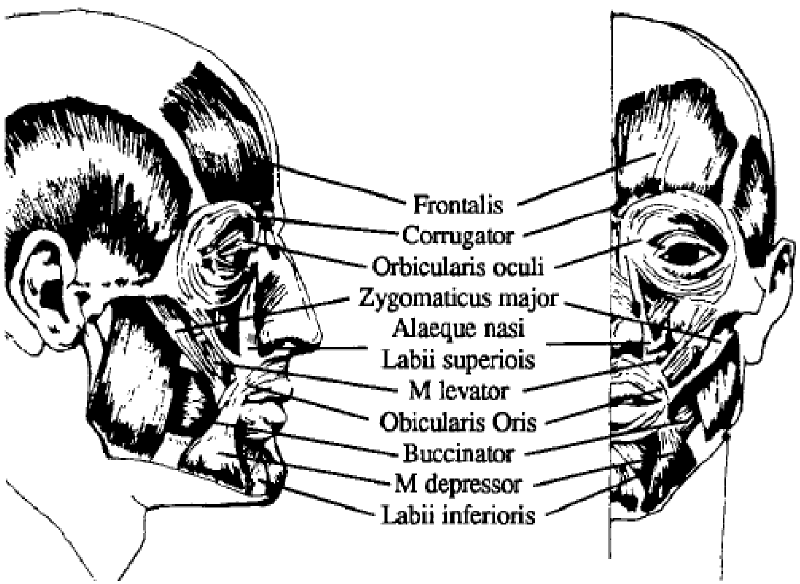
- Around the mouth (**Orbicularis oris)**
- The fibers encircle the mouth
- When contracted, it squeezes the mouth
- Functions: pressing together, tightening and thinning, a rolling inwards between the teeth, and a thrusting outwards





How to control the muscles?

- There are more than sixty muscles on the face
- There can be thousands of combination of activating the muscles
- Which muscles should be activated in which mood?



How to control the muscles (2)?

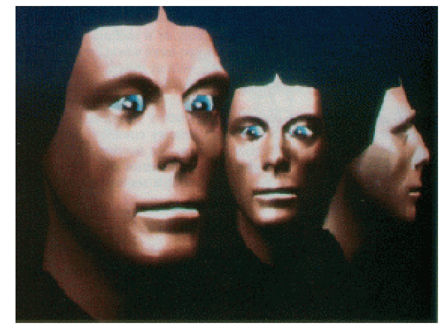
- Facial Action Coding System (FACS) :
  Ekman ‘77

- A widely used notation for the coding of facial articulation.
- 66 muscle actions and the resulting effects
- Describes the action units (muscles) involved in the six basic expressions

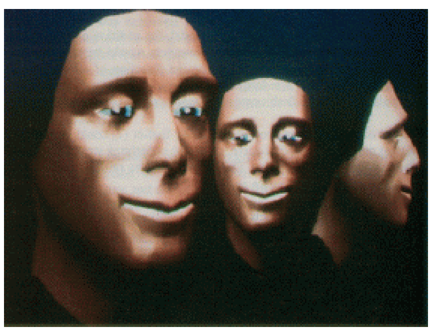
- Basic facial expressions that are considered to be generic to the human face:
  → *Happiness, Anger, Fear, Surprise, Disgust, Sadness*

Synthesized Facial Expressions
Waters SIGGRAPH '87

Neutral face

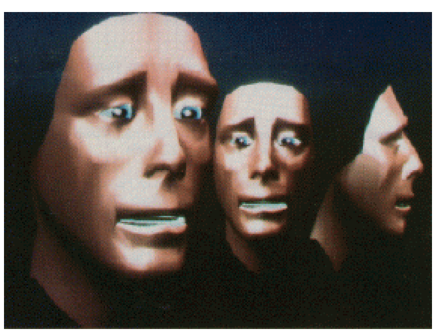


Anger



Happiness

Surprise



Fear

Disgust

Realistic models

- If we want to simulate the expressions of real humans, we need to scan the surface of faces

We need the
- **Geometry Data**
- **Texture**

of the face

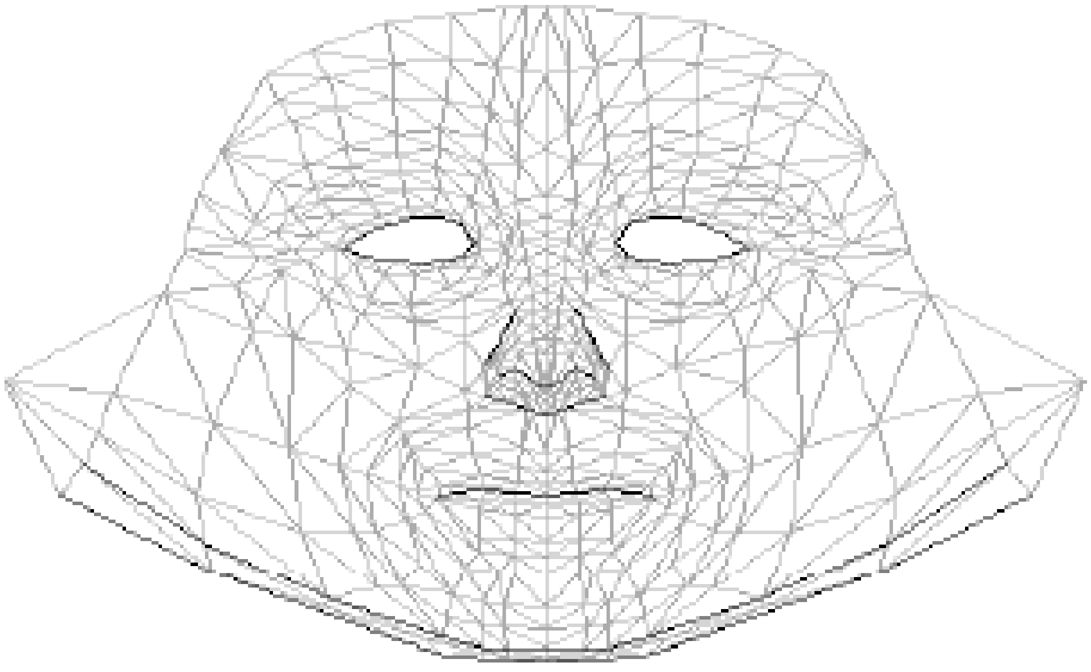
Cyberware Color Digitizer

- A laser range scanner
  - Rotates 360 degrees around the subject
  - Laser stripes are projected on to the head
- The range data is obtained
- The color texture data is obtained at the same time

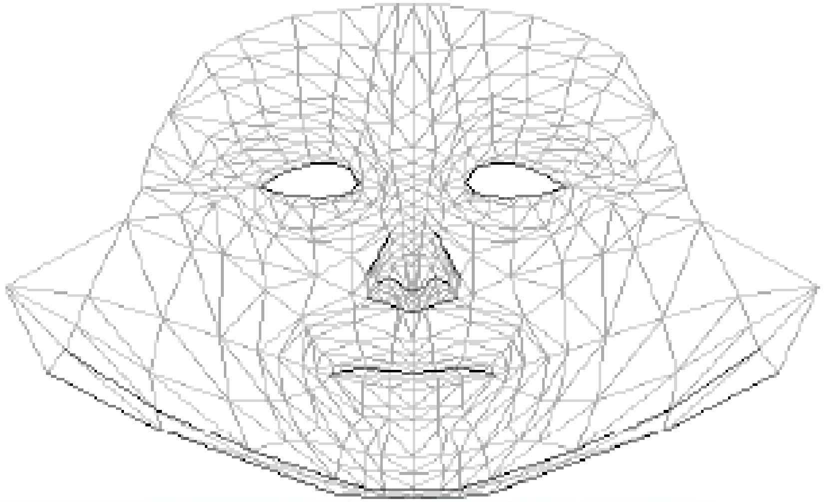
A Generic Face Mesh

- Reduce the large array of range data to a geometric surface model
- A generic face mesh is fit into the range data using feature points



Adaptation Procedure

- 1. Locate nose tip
- 2. Locate chin tip
- 3. Locate mouth contour
- 4. Locate chin contour
- 5. Locate ears
- 6. Locate eyes
- 7. Activate spring forces



(a) (b)

Figure 2: Range image (a) and positive Laplacian of range magnitude (b).

Locate the nose tip:

– the highest range data point in the central area, and globally translate the face mesh to achieve correspondence with the tip of the nose.

Locate the chin

– the point below the nose with the greatest value of the positive Laplacian of range.

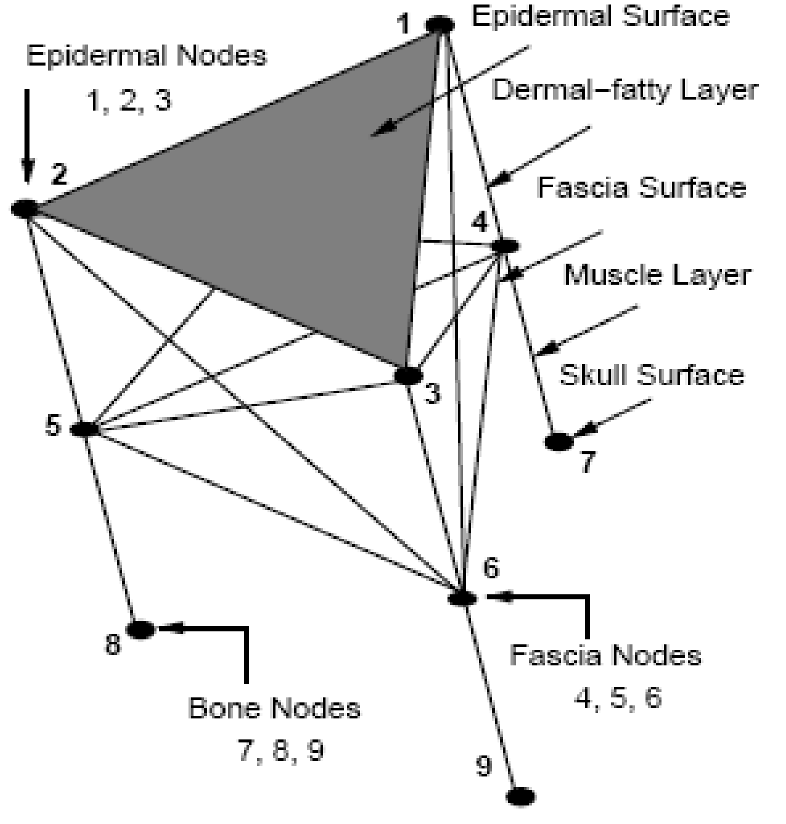
Locate the mouth

– the point of greatest positive Laplacian between the nose and chin

The Anatomical Model

- The face can be modeled by two layers and three surfaces
  - Dermal-fatty Layer
  - Muscle Layer

  - Epidermal surface
  - Fascia Surface
  - Skull Surface



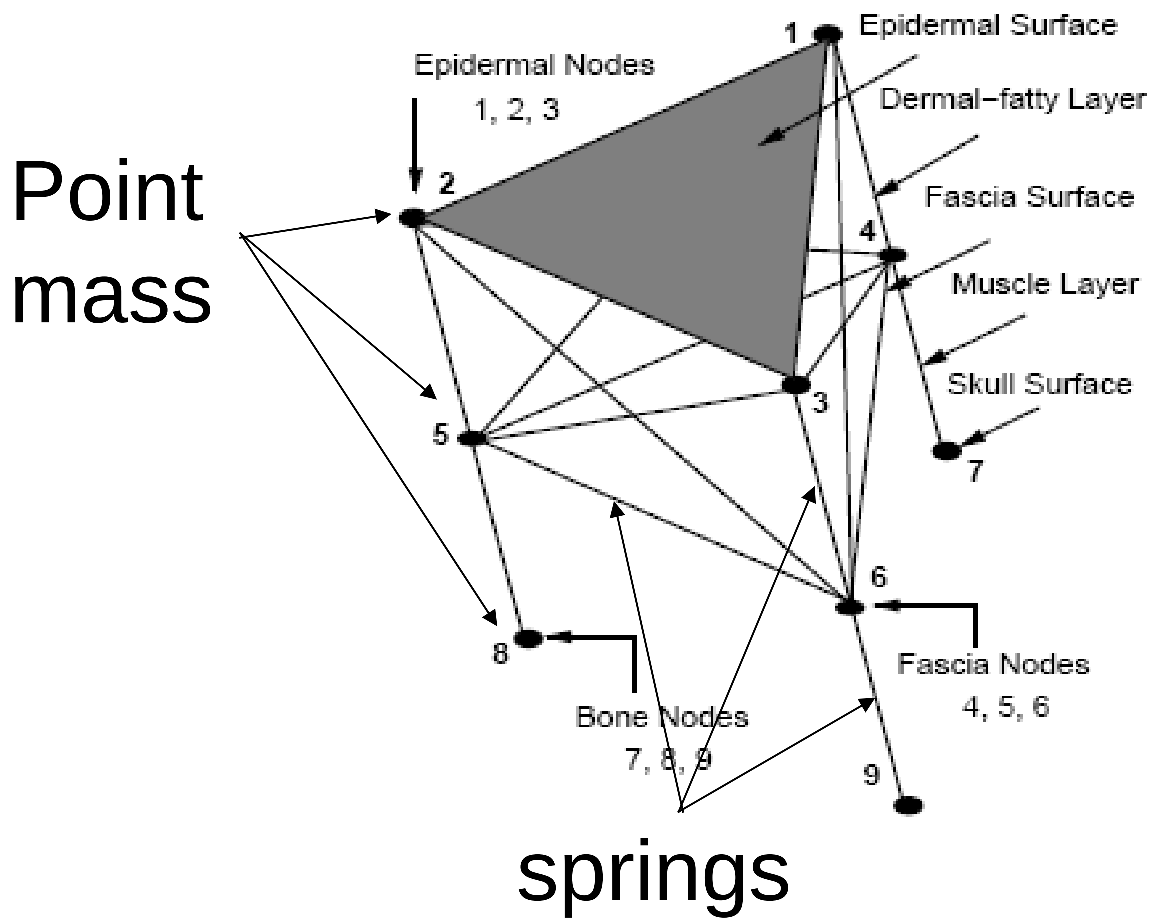
Point-Mass System

•The skin, fat and muscles are emulated by point masses connected by springs

elasticity, direction

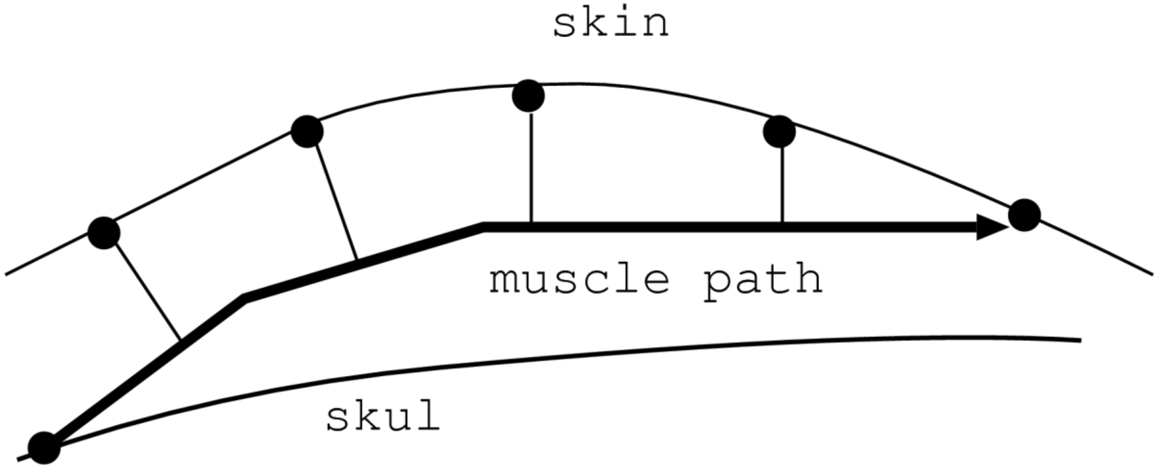
$$\mathbf{g}_j = c_j(l_j - l_j^r)\mathbf{s}_j$$

force, Length, Slack length



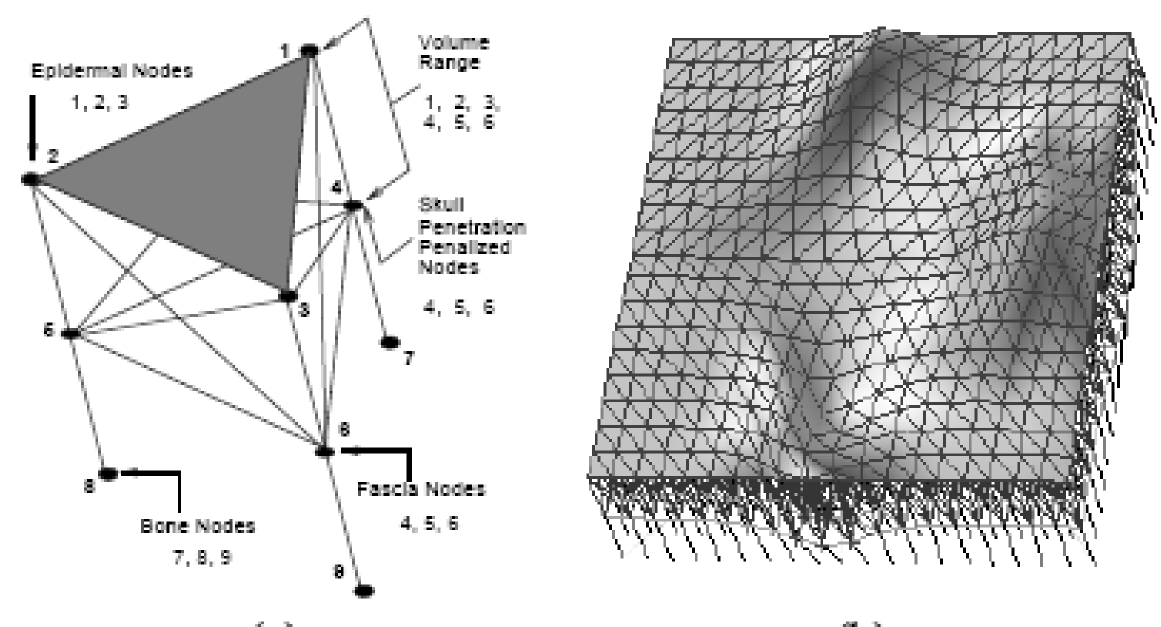
Muscle-Skin Attachment

- The muscle is connected to the skin at multiple points along its path
- Deforming the skin at multiple sites / not only at its end



The Volume Preservation Forces

- The human skin is incompressible
- Volume preservation force is needed to simulate the wrinkles
- Pressing the node upwards proportionally to the decrement of the volume



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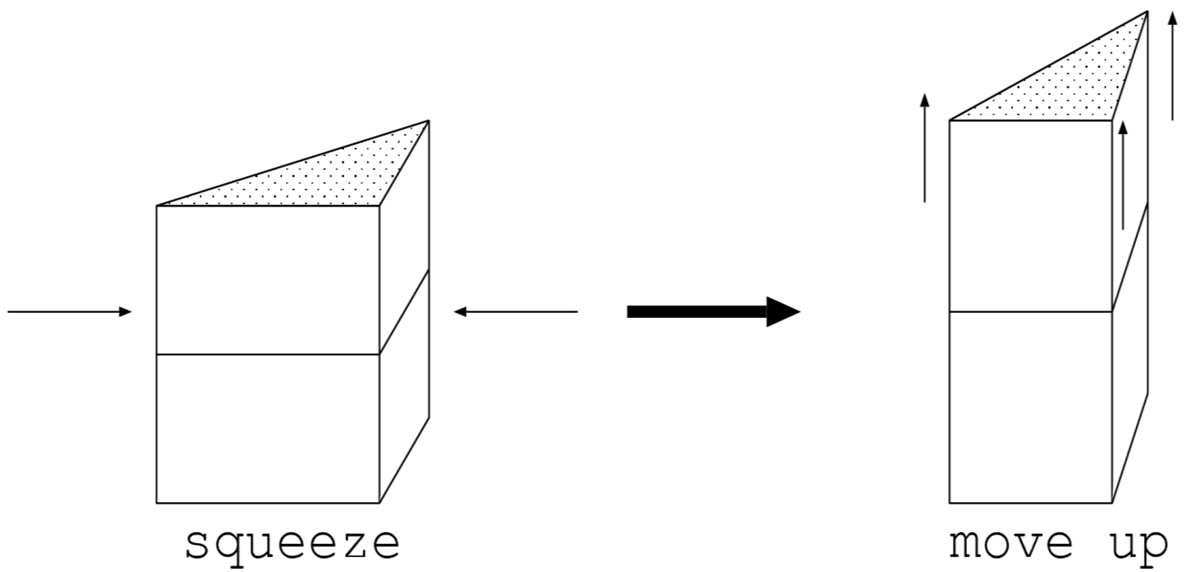
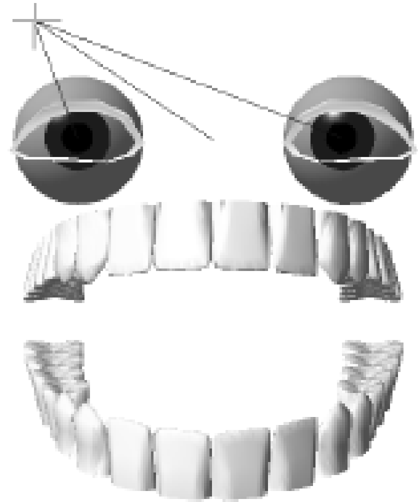
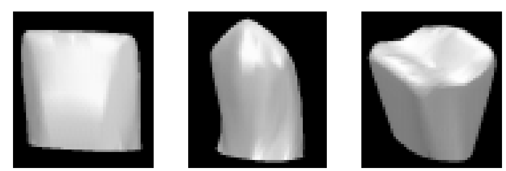


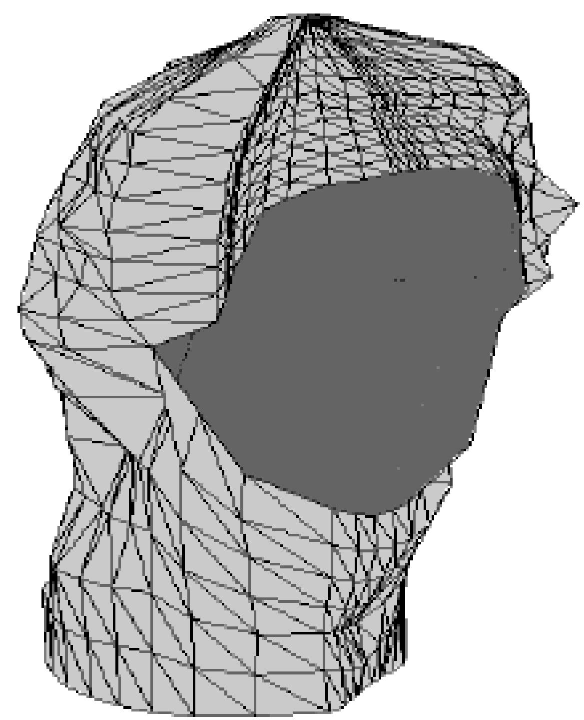
Geometry models for other head components

- Teeth, eyes, and neck need to be modeled separately
  - These data are difficult to be captured by the scanner



(a)





From Lee and Terzopoulos

http://www.youtube.com/watch?v=dQef4pM_vXU

Muscle-based animation

- Estimating the muscle activation from the motion capture data

"Automatic determination of facial muscle activations from sparse motion capture marker data", SIGGRAPH 2005

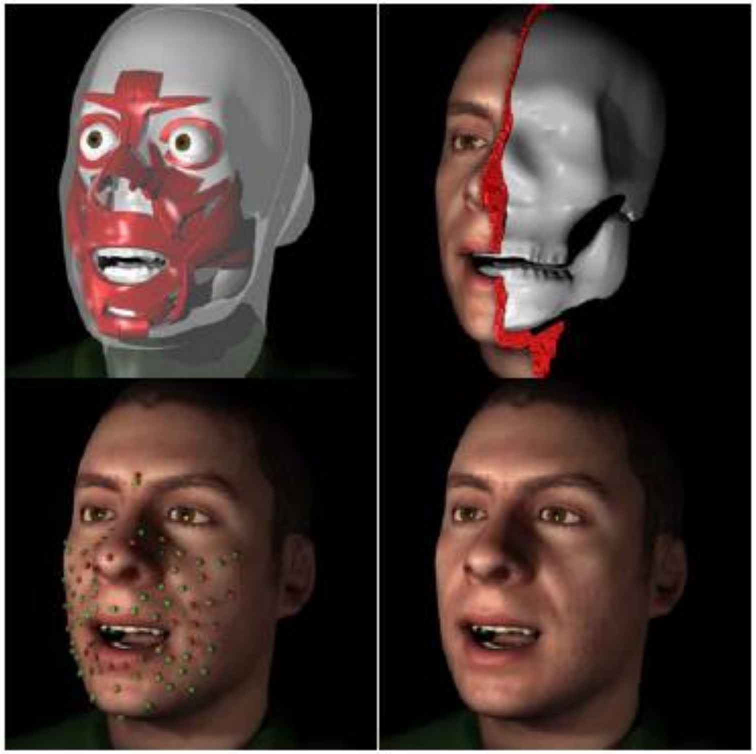
- First, a precise anatomical model is

Produced from Visible Human Motion Dataset

- Next, the muscles are activated so that the

simulated location of the marker overlaps with its real location

http://www.youtube.com/watch?v=9dkhxgt5QeQ



Face motion capture

- We can capture the facial movements by using optical trackers, or simply tracking the features of the face

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- But the geometry of the virtual actor is different from the actor – how to control the virtual actor

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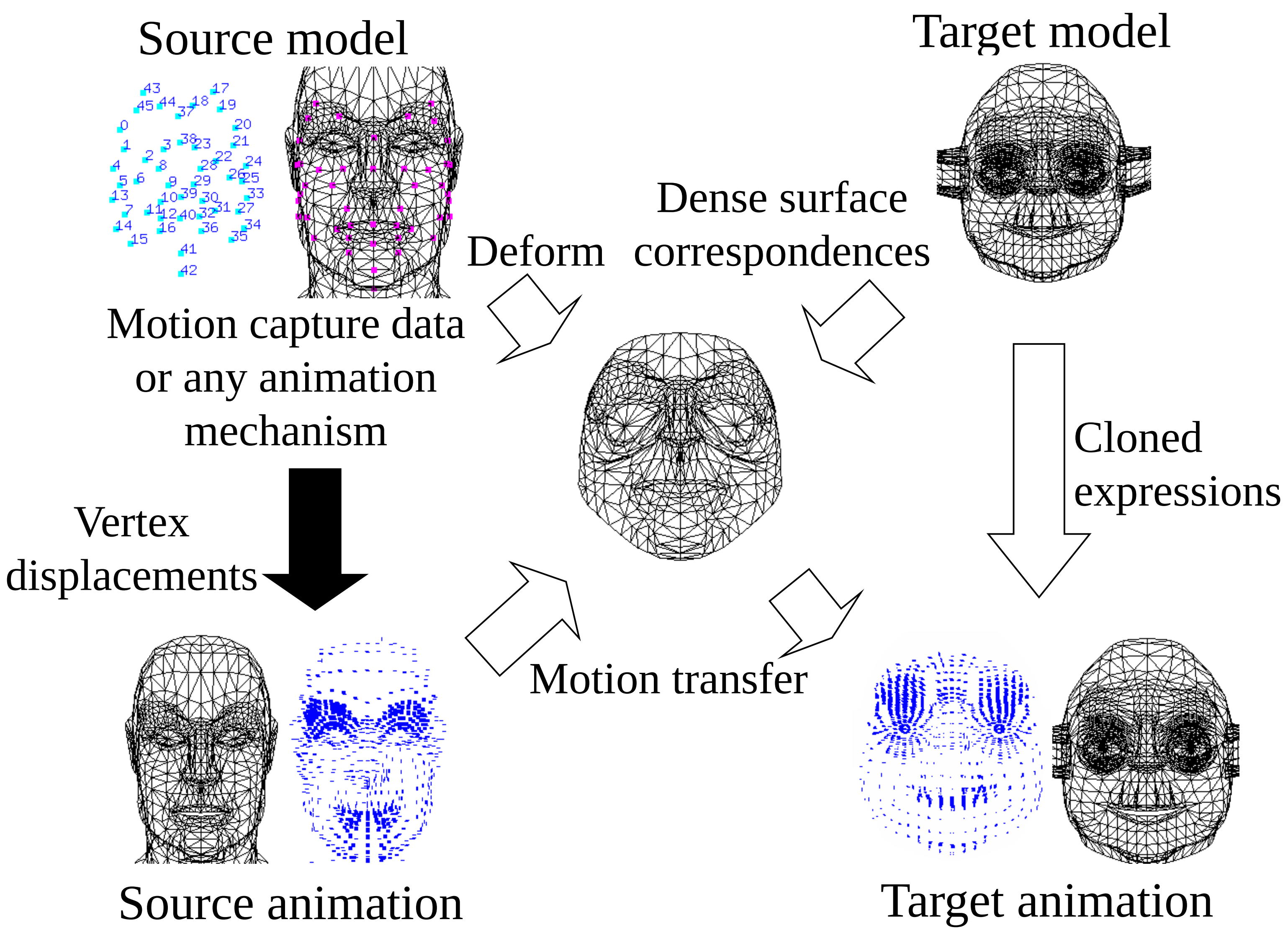
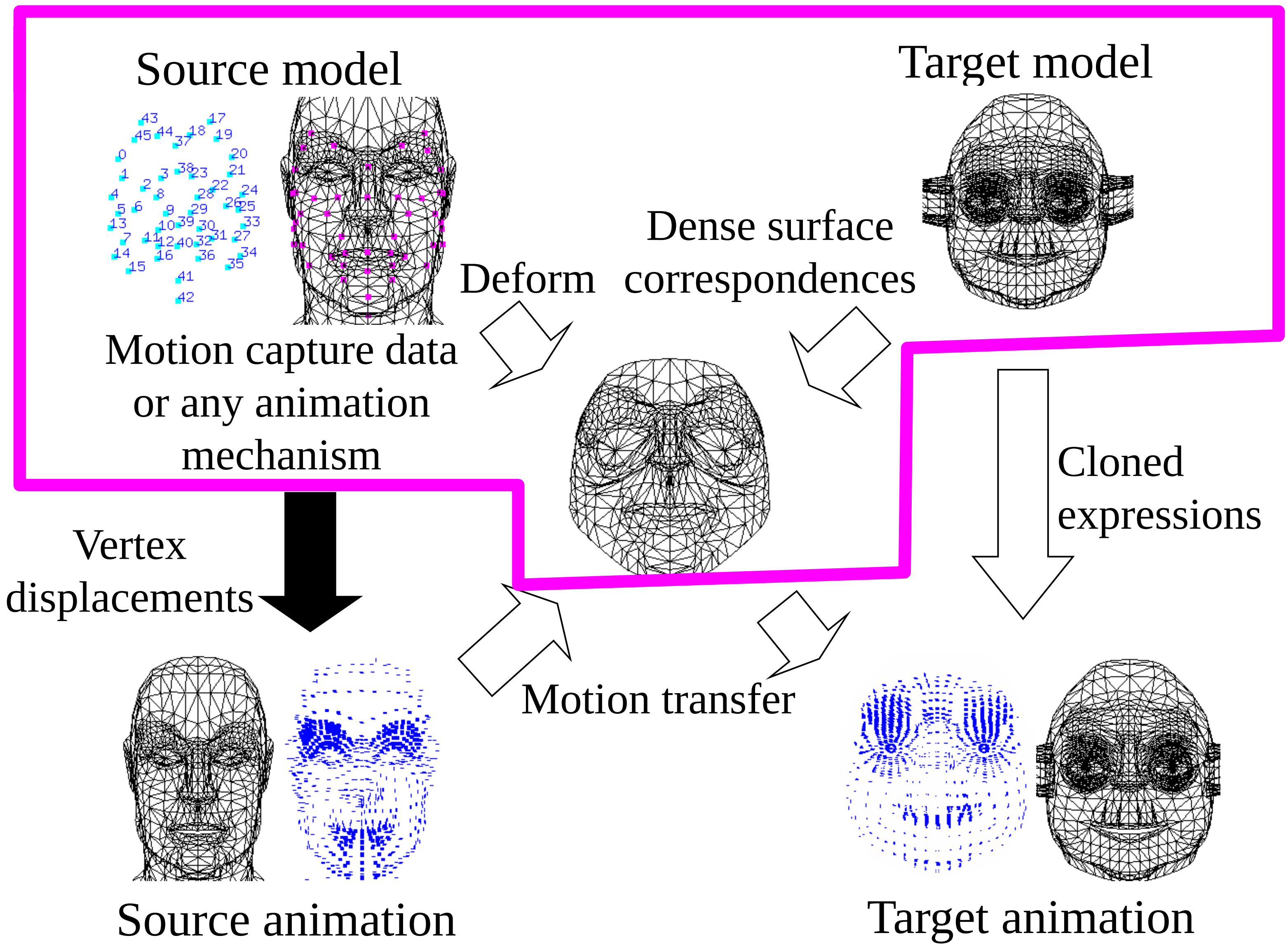
→ Expression Cloning,

Deformation Transfer

Expression Cloning Outline

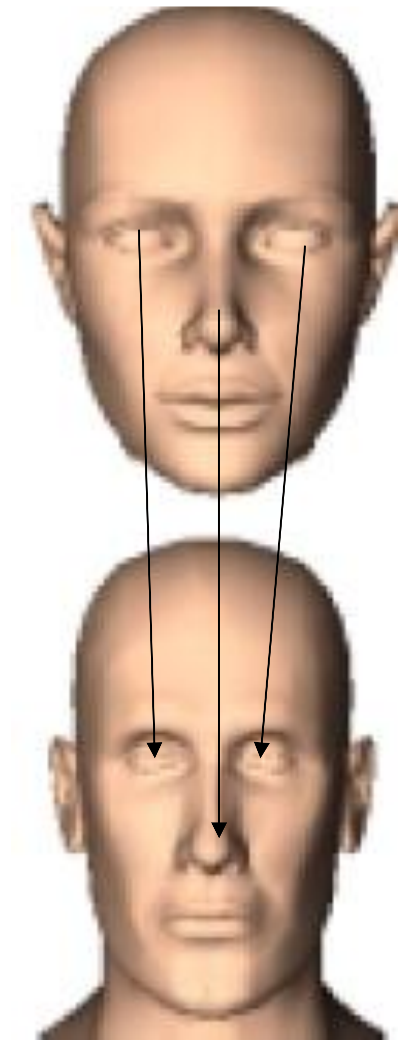


Expression Cloning Outline



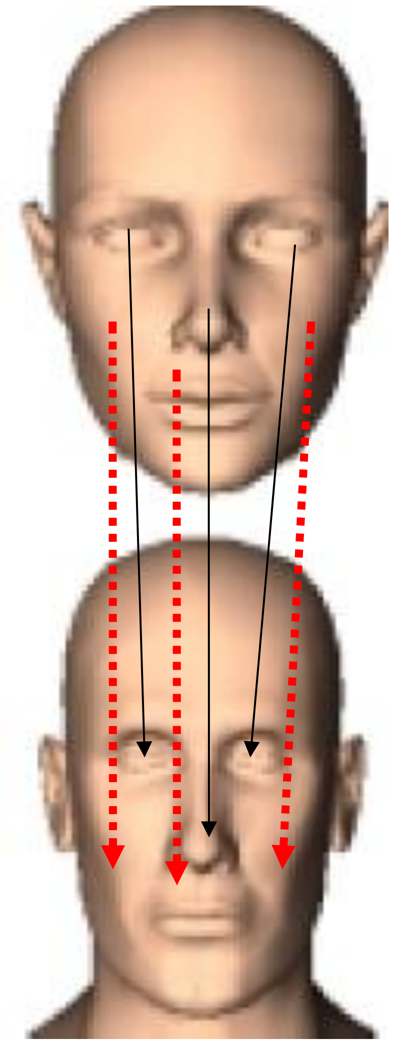
Mapping the original face mesh to the target face

- Specify some corresponding points on the target face, such as
  - Nose tip
  - Eye sockets
  - Lip contact line
  - Chin
  - etc



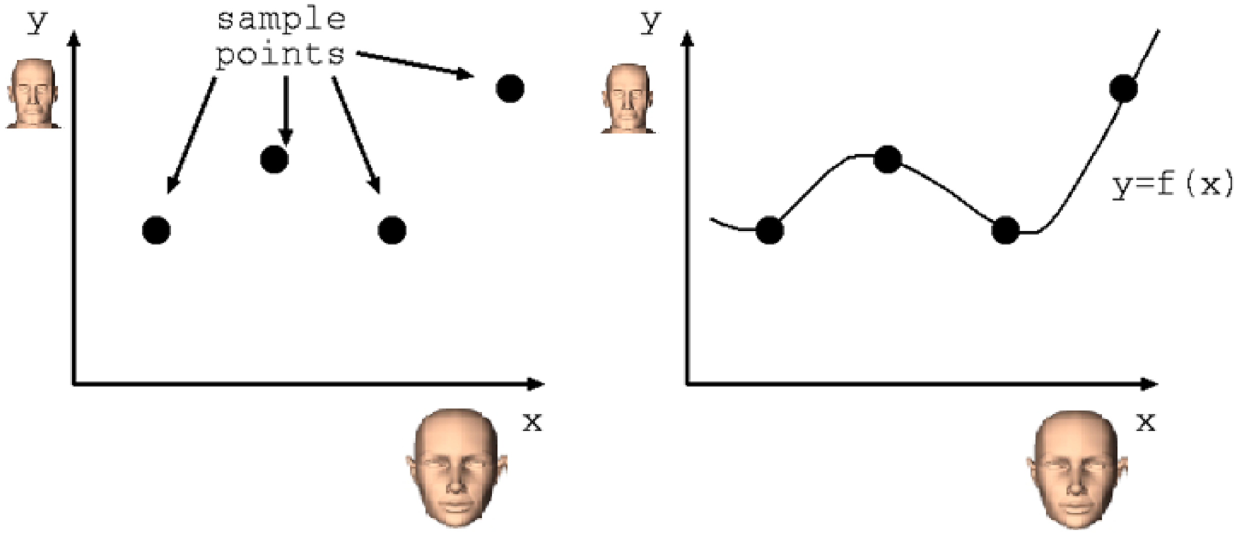
Correspondence of other areas

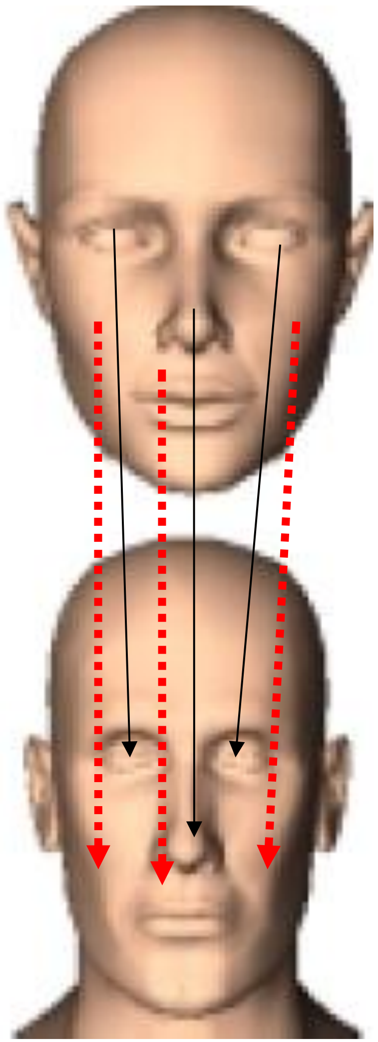
- We need to find the corresponding points for points other than the feature points
  - Area between the eyes
  - Cheeks
  - Area between the mouth and nose
  - etc



Correspondence of other areas

- This is like guessing a function based on a few number of inputs
- For a few number of sample points we know the corresponding outputs
- Input x_i   Output y_i   (I = 0,1,…,n-1)
- F(x_i) = y_i   what is y=F(x) like?
- We can use something called Radial Basis Function (RBF)

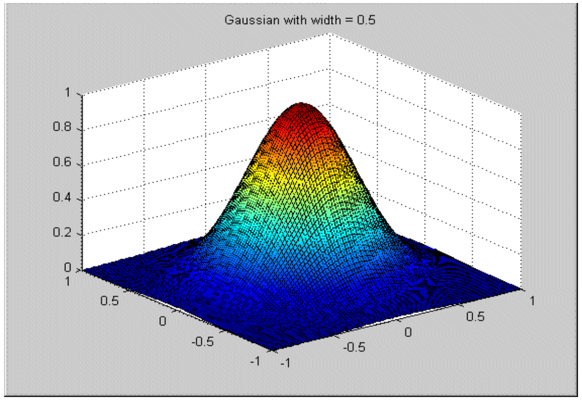


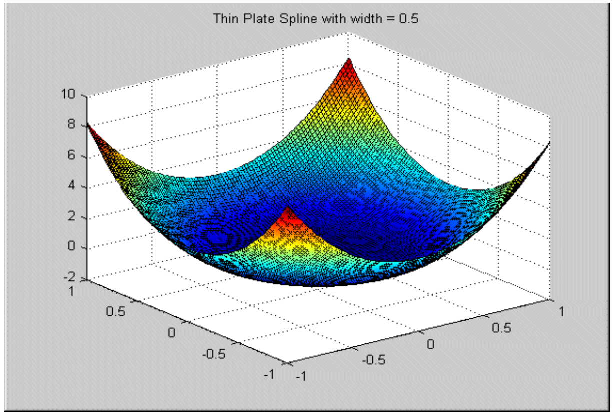


Using Radial Basis Functions to compute the dense correspondence

- A **radial basis function (RBF)** is a real-valued function whose value depends only on the distance from the center (sample) point

$$\phi(\mathbf{x}, \mathbf{b}) = \phi(\|\mathbf{x} - \mathbf{b}\|)$$





Gaussian

$$\Phi(r,b) = e^{\{-(x-b)^2 / \sigma\}}$$

Thin-plate spline

$$\Phi(r,b) = \{-(x-b) / \sigma\}^2 \log((x-b)/\sigma)$$

Using Radial Basis Functions to compute the dense correspondence

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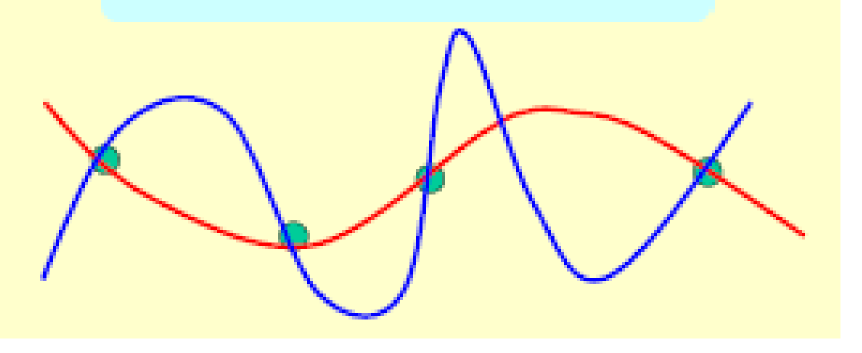
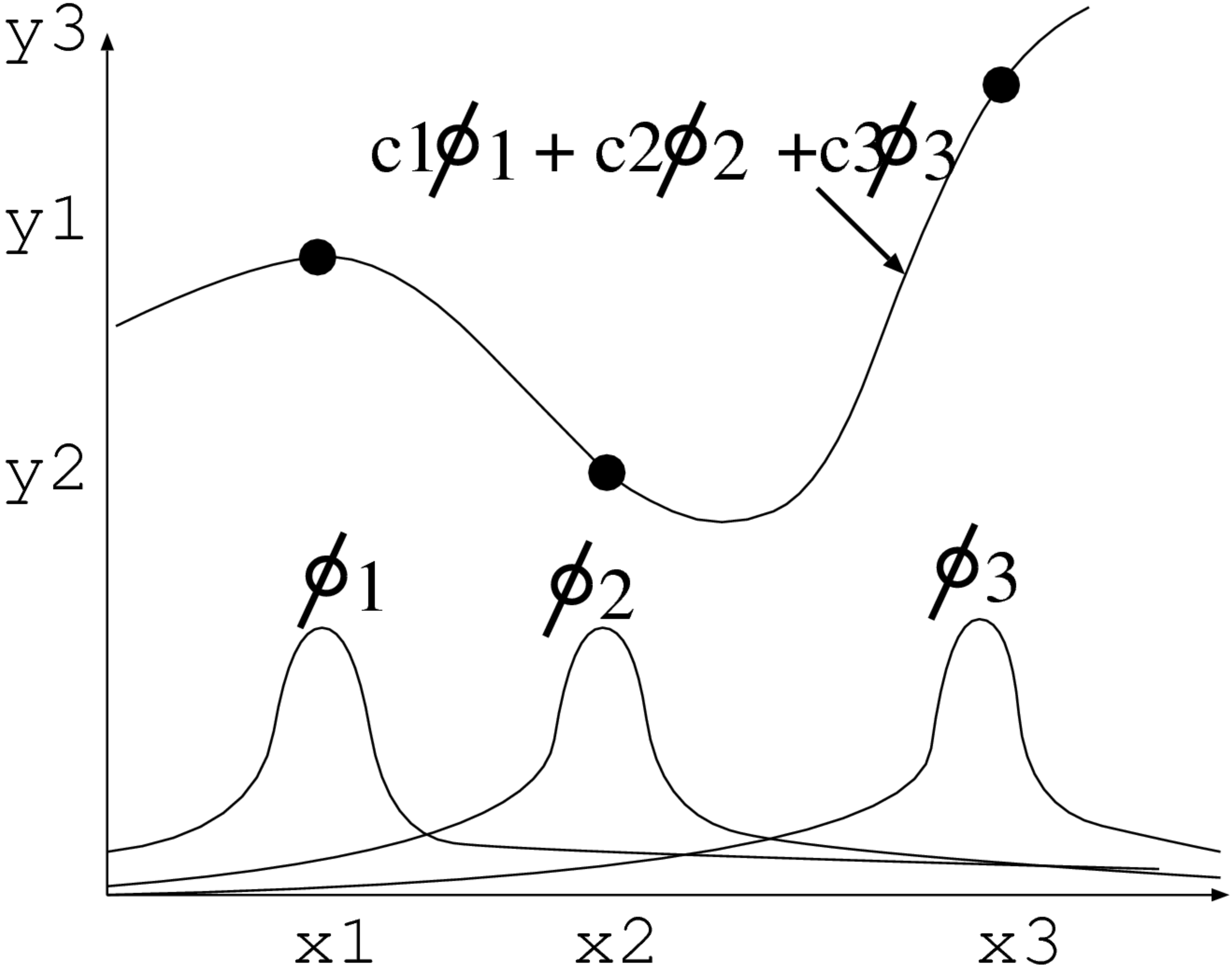
$$\phi(\mathbf{x}, \mathbf{b}) = \phi(\|\mathbf{x} - \mathbf{b}\|)$$

RBFs are often used to create a mapping for a given data

→ Regression

- Input x_i Output y_i (I = 0,1,…,n-1)
  - Want a continuous mapping that satisfies
    - $F(x_i) = y_i$
  - While minimizing the oscillation




y3
y1
y2
c1ϕ1 + c2ϕ2 +c3ϕ3
ϕ1
ϕ2
ϕ3
x1
x2
x3

Radial Bases Function

- Input, output

$$\{(\underline{x}_i, y_i)\}_{i=1}^{m}$$

- Represent F by sum of radial bases

$$f(\underline{x}) = \sum_{i=1}^{m} c_i \phi_i (\|\underline{x} - \underline{x}_i\|)$$

- Unknowns

$$\{c_i\}(i = 1, \cdots, m)$$

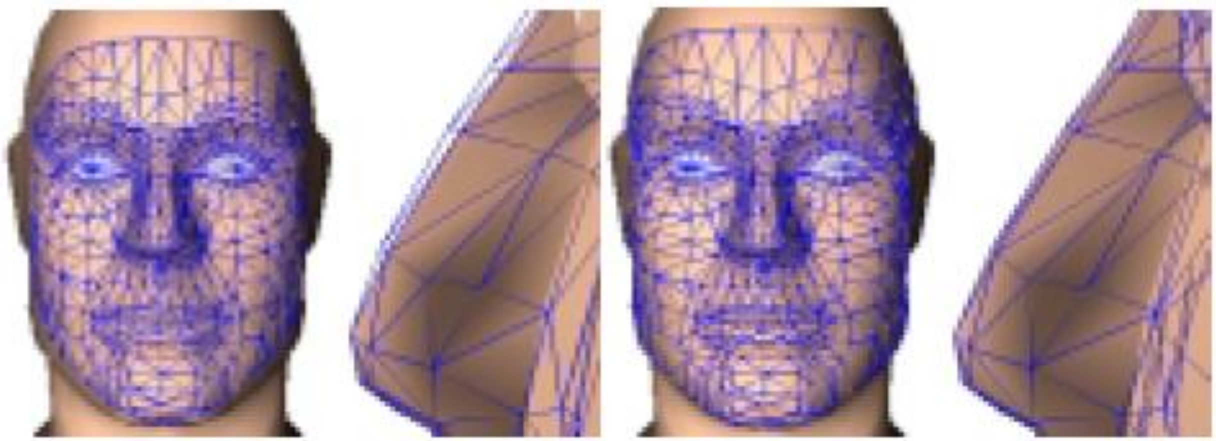
- constraints

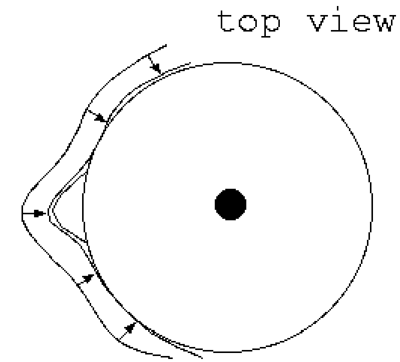
$$f(\underline{x}_i) = y_i \quad (i = 1, \cdots, m)$$

$$\begin{pmatrix} y_1 \\ \vdots \\ y_m \end{pmatrix} = \begin{pmatrix} \phi_{11} & \cdots & \phi_{1m} \\ \vdots & \ddots & \vdots \\ \phi_{m1} & \cdots & \phi_{mm} \end{pmatrix} \begin{pmatrix} c_1 \\ \vdots \\ c_m \end{pmatrix} \quad \phi_{ij} = \phi(\|\underline{x}_i - \underline{x}_j\|) = \phi_{ji}$$

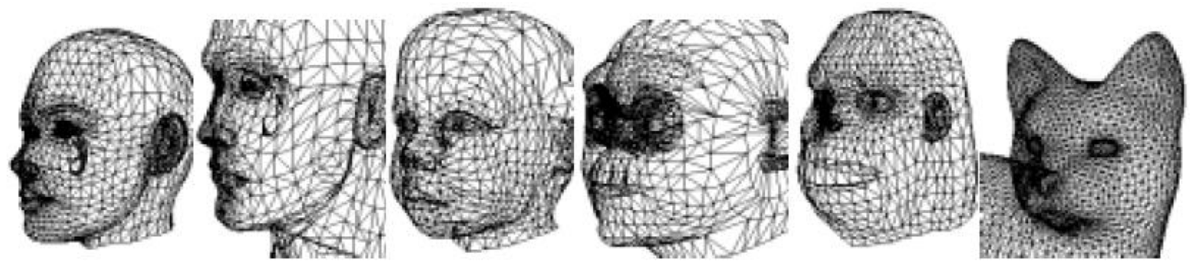
Automatic dense correspondence

- After the dense correspondence is done by RBF, the source model is fitted onto the target model by cylindrical projection
- Now we know the correspondence of all the points of the source and the target

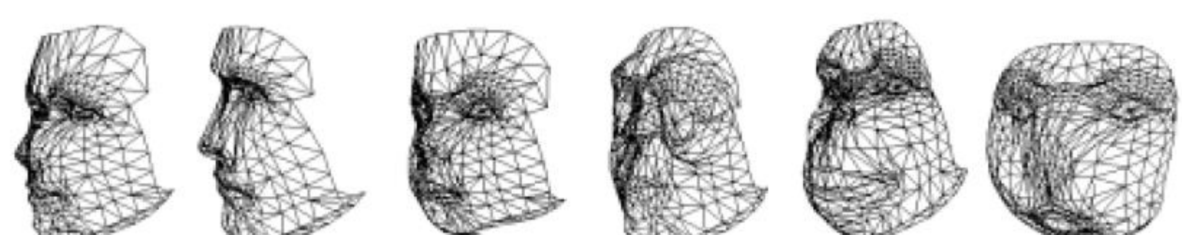




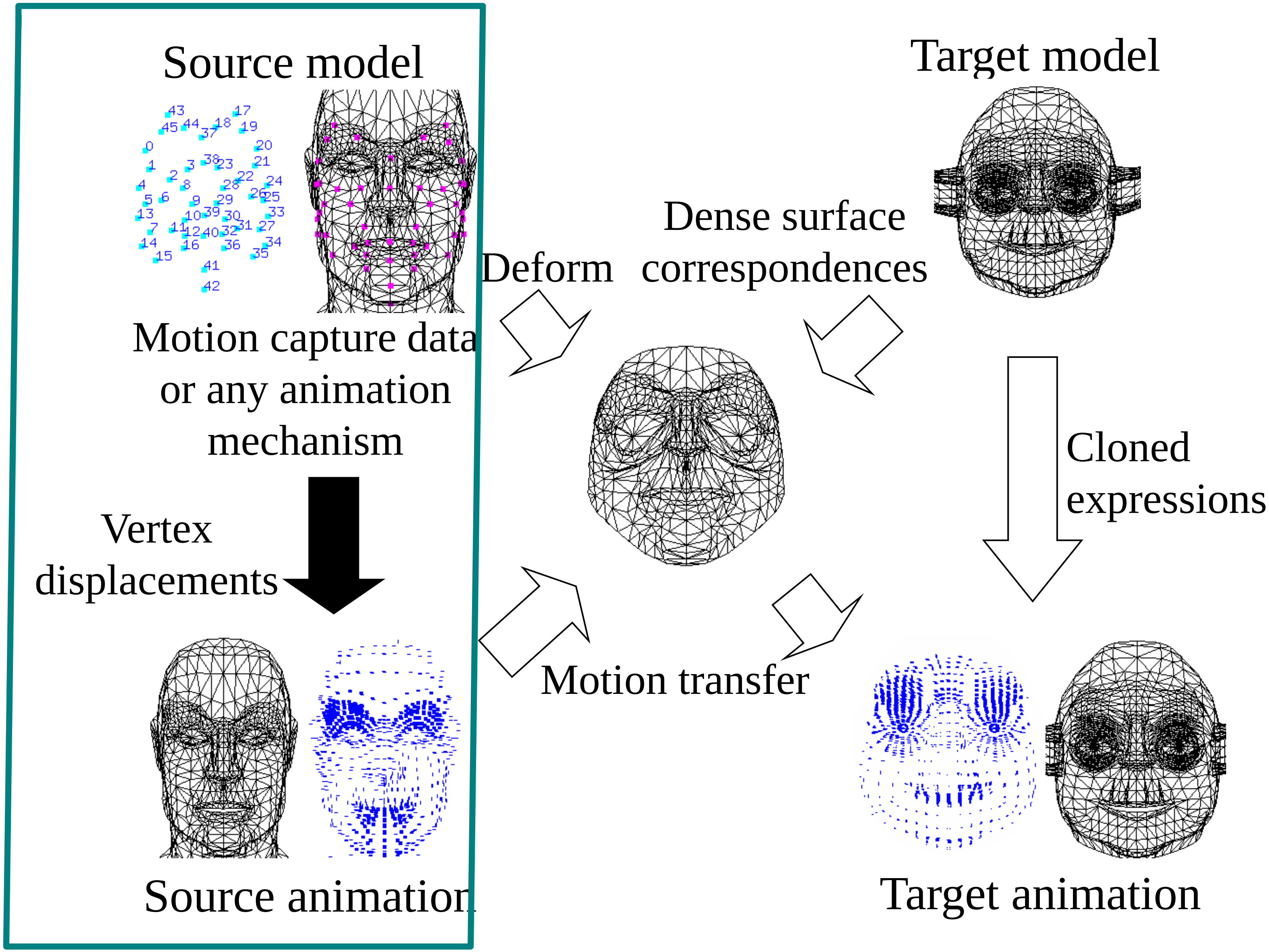
Target models



Generic models fitted to the target models

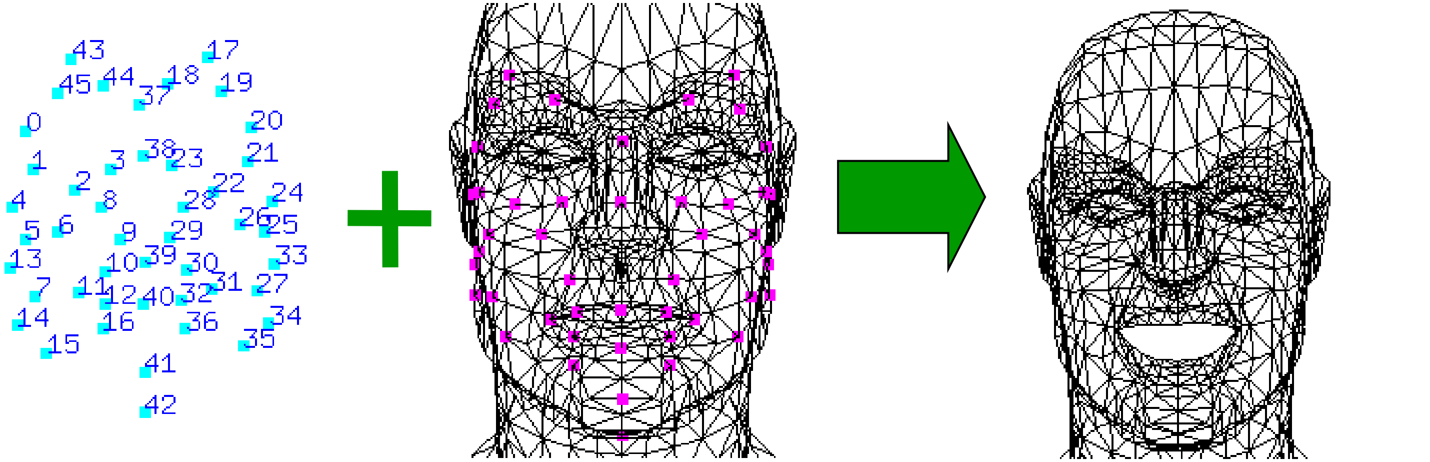


Expression Cloning Outline



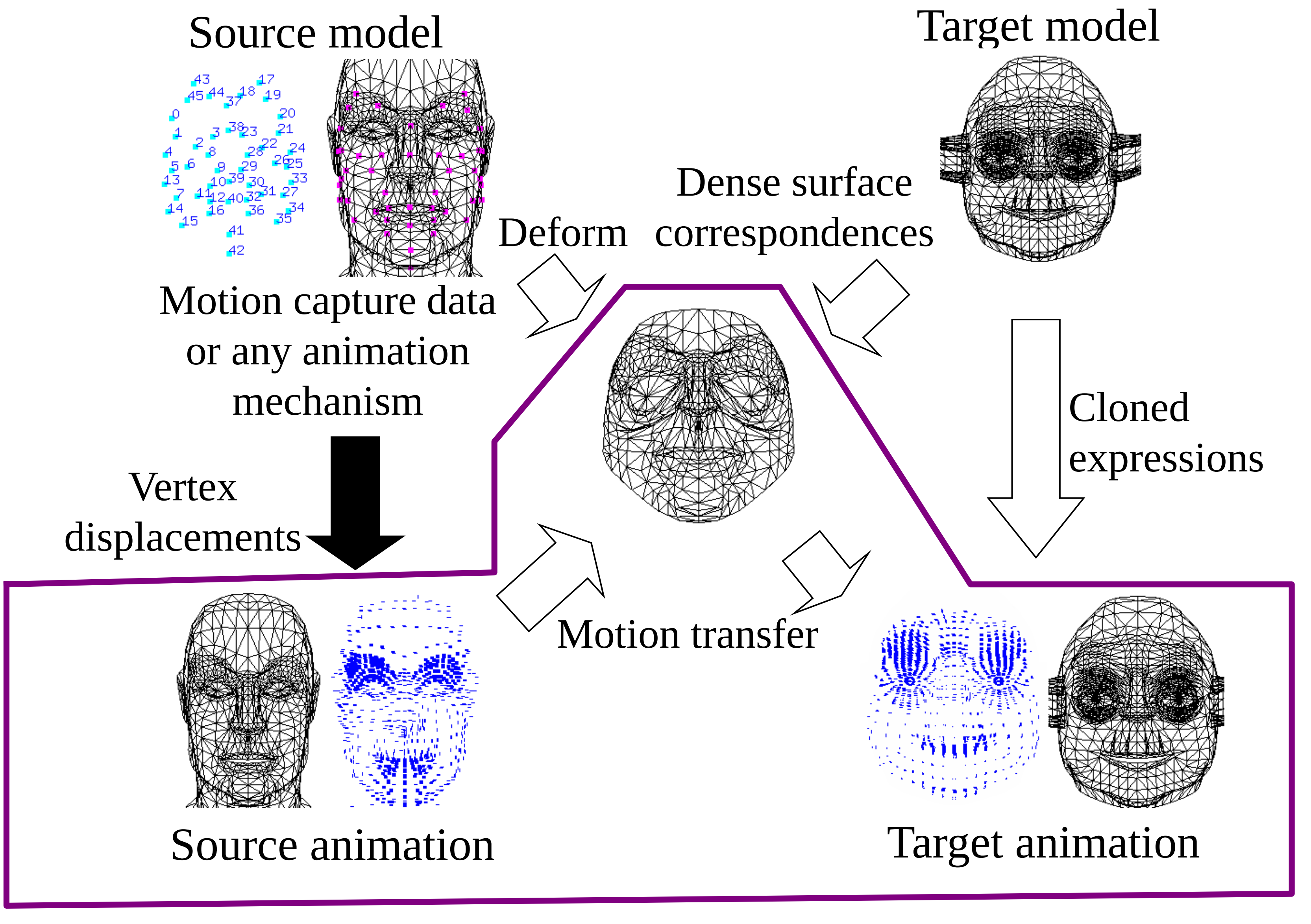
Source Animation Creation

- Use any existing facial animation method
- Motion capture data
  - can also be hand made expressions



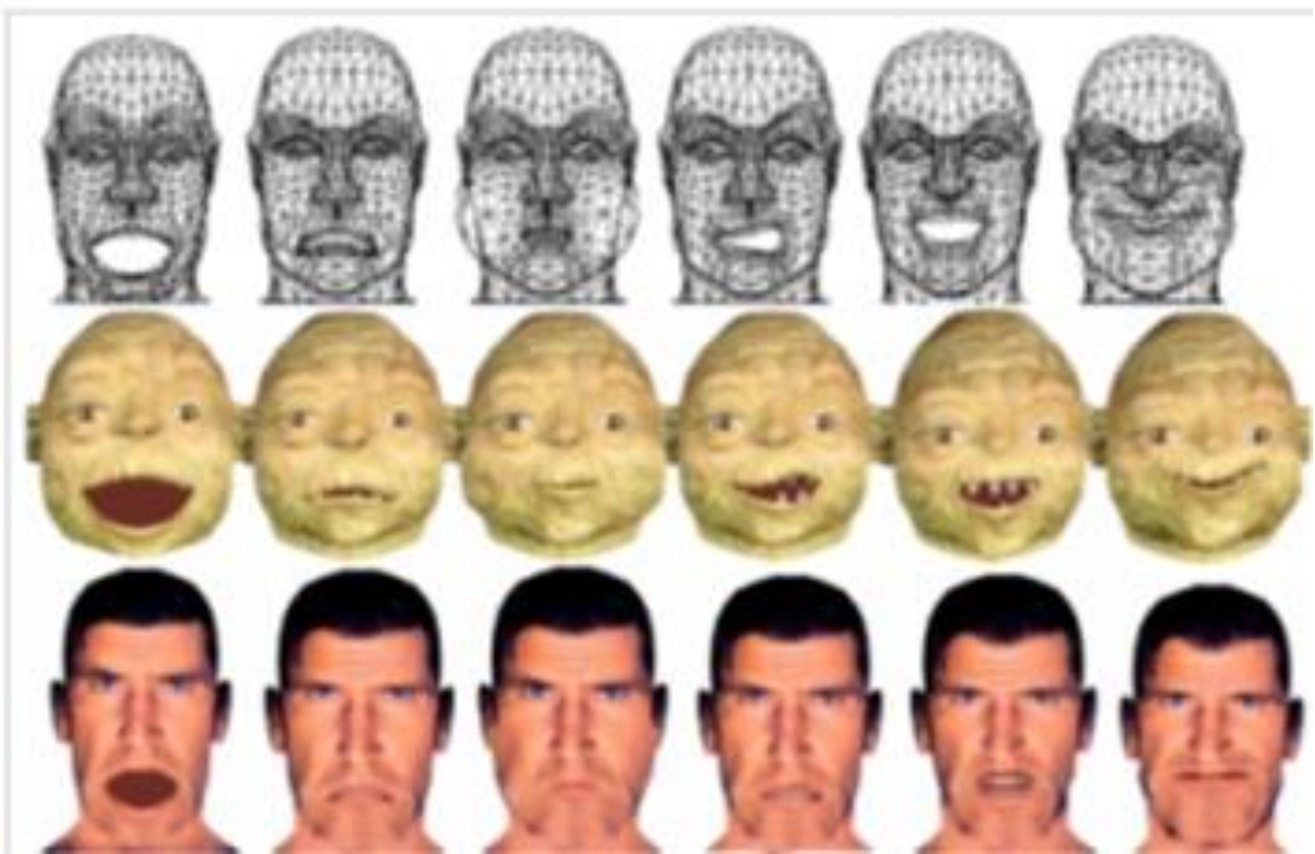
Motion capture data   Source model   Source animation

Expression Cloning Outline



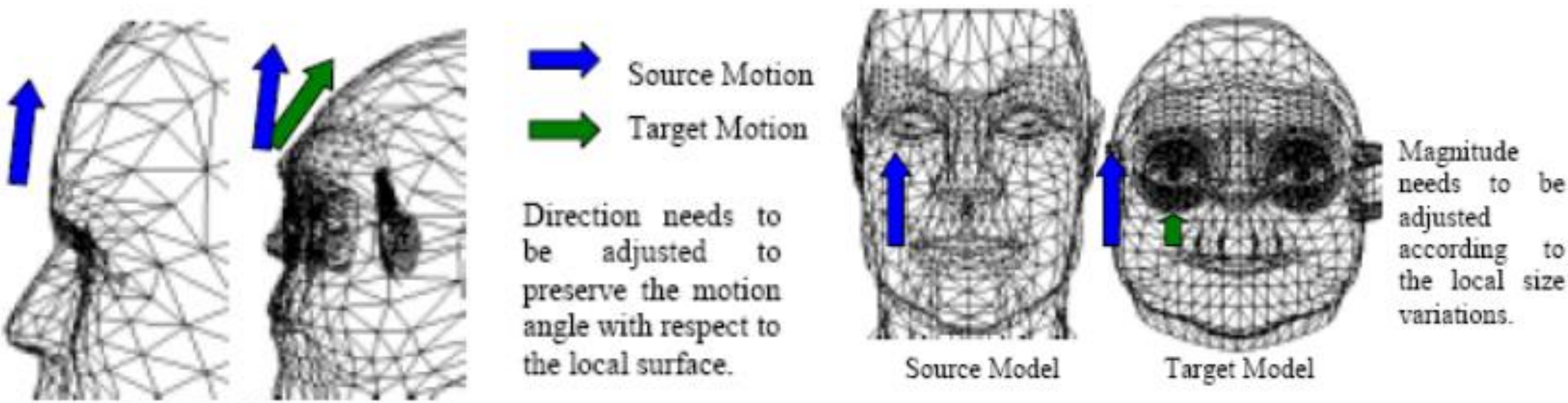
Amending the motion vectors

- The size and shape of the surface points are different between the source and target model
- We need to adjust the direction and magnitude of the motion vectors



Amending the motion vectors

- Rotation : adjusted by the difference of the normal vectors of the source and target
- Magnitude : Scaled by the local size variation
  - If the mouth is scaled smaller, the motion is also scaled smaller



Demo Animation

http://www.youtube.com/watch?v=zO4Ld5NG6LY&feature=channel

Overview

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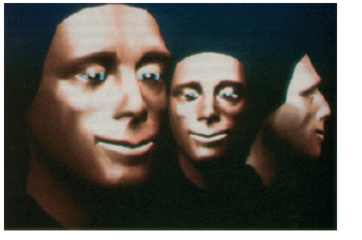
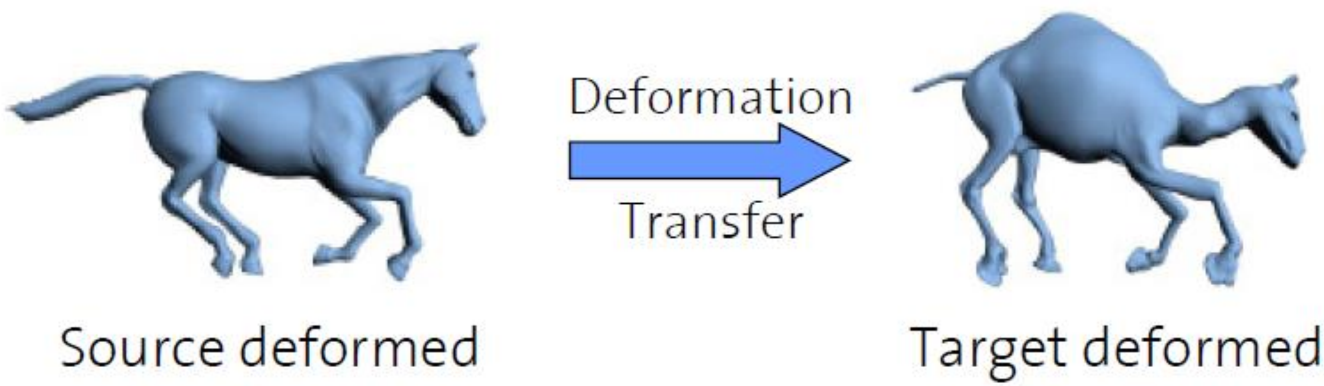
- Muscle-based models
- Expression cloning
- **Deformation Transfer**



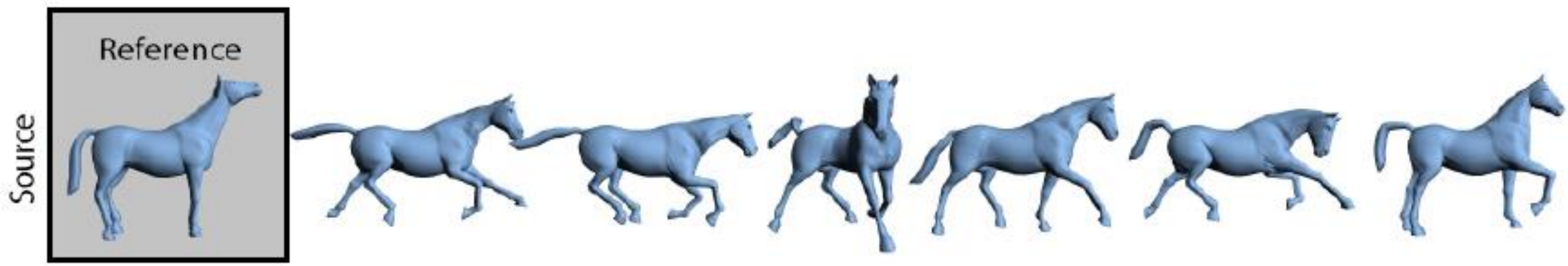
Deformation Transfer

- Deforming the source object to the target object
- Not targeting only faces, but arbitrary objects

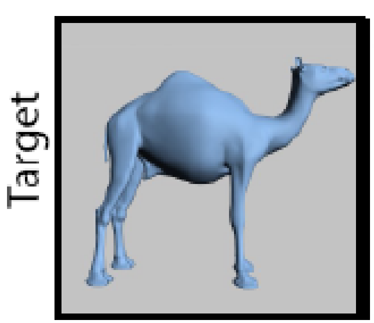


What is it about?

Given a source mesh in a reference pose and several deformations of it:

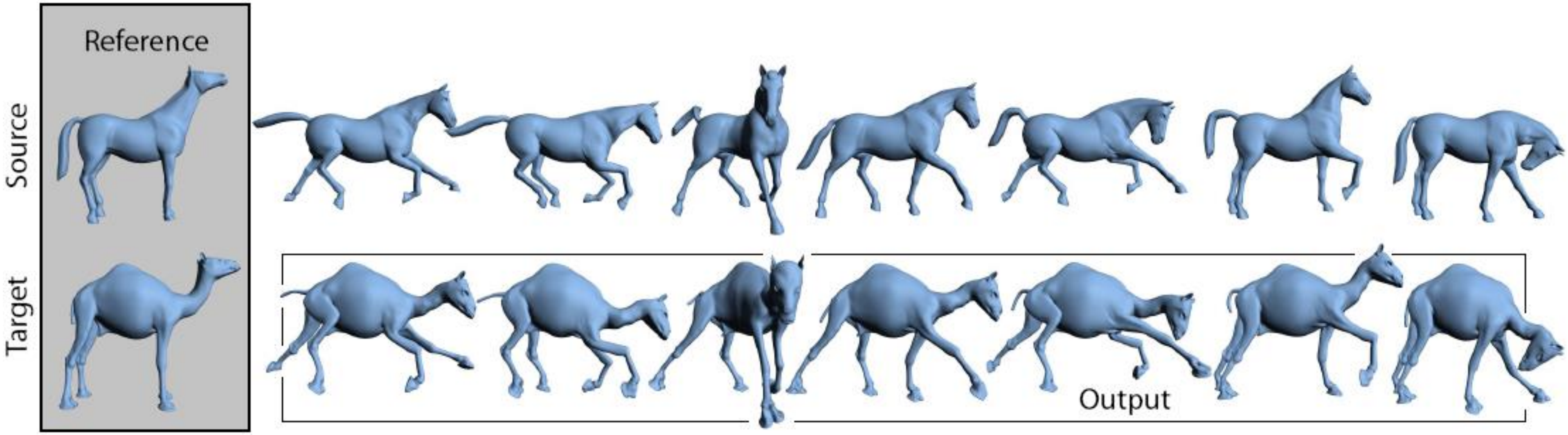


Given another mesh, called Target in same reference pose:



Deformation Transfer

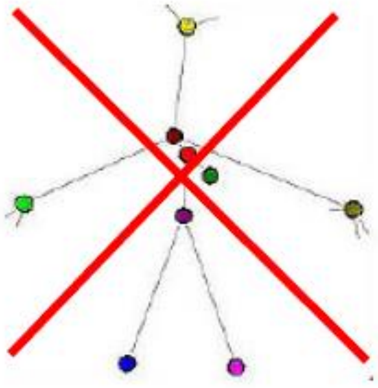
- Transfer the deformation to the target



- Reuse of deformations which were probably created with a lot of effort

Deformation Transfer

- Deforming Transfer is purely mesh-based
- No need of a skeleton



Deformation Transfer

- Not skeleton driven deformations
  - Applicable to non-rigid or facial deformations

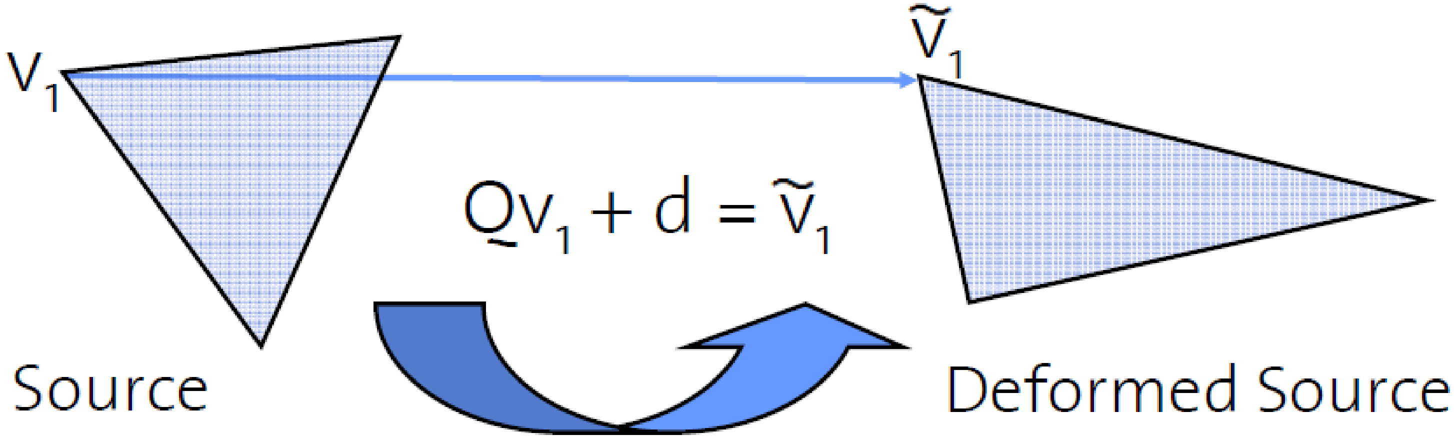
Approach

- Compute the deformation Si for every source triangle (orientation, scale, skew)
- Compute mapping from source to the target triangles (correspondence)
- Apply Si to the corresponding target triangles

Deformation Details

- Deformation based on per-triangle transformation

$$\mathbf{Q}\mathbf{v}_i + \mathbf{d} = \tilde{\mathbf{v}}_i, \quad i \in 1 \ldots 4$$



Closed Form Solution

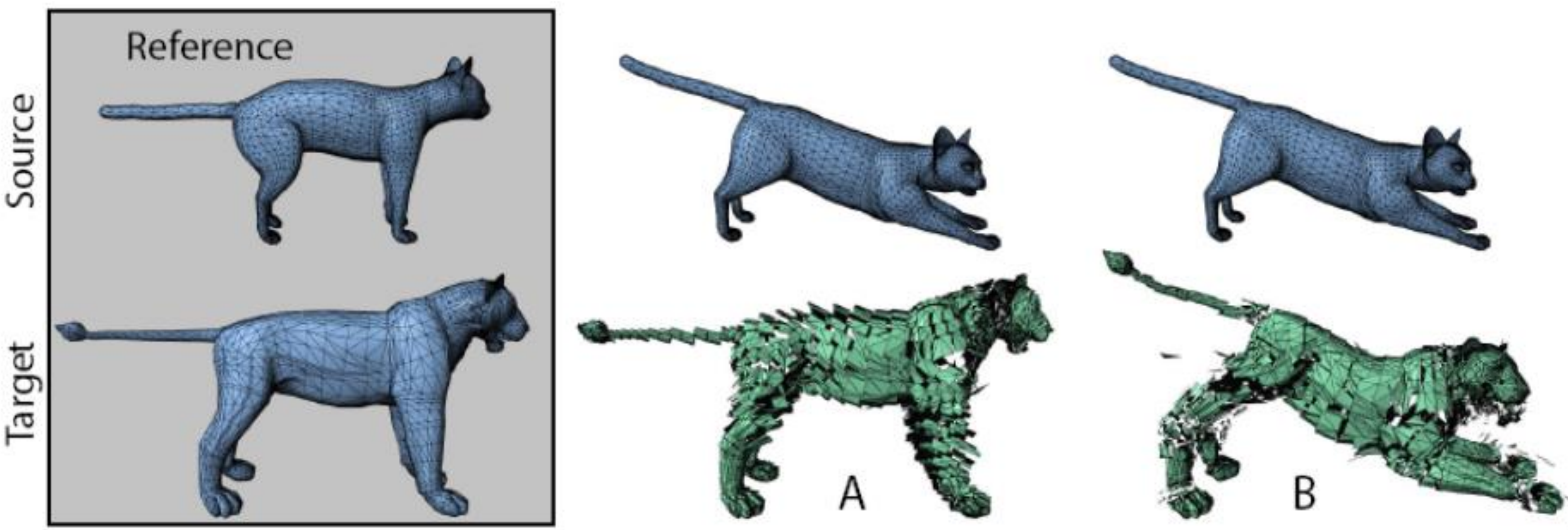
- Closed form solution of Q:

$$\mathbf{Q} = \tilde{\mathbf{V}}\mathbf{V}^{-1}$$

- “Deformation Gradient” Q depends on
  - Triangle in reference pose
  - Triangle in deformed pose

Resulting Meshes

- Leads to holes in the resulting mesh
- Used representation affords too many degrees of freedom



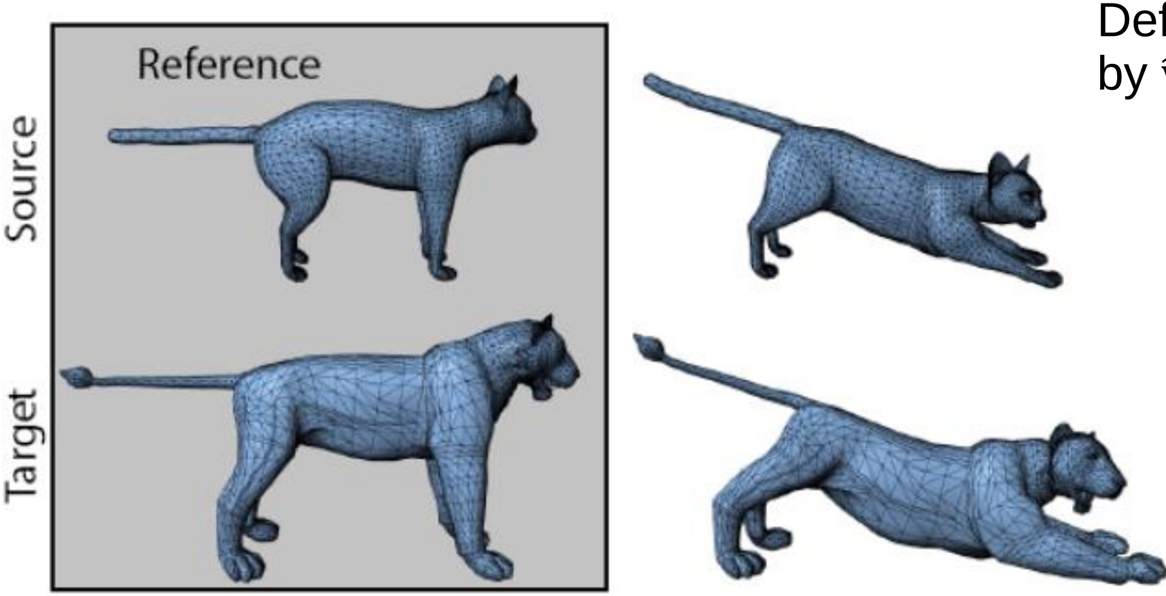
Minimization Problem

- Preservation of consistency leads to an optimization problem

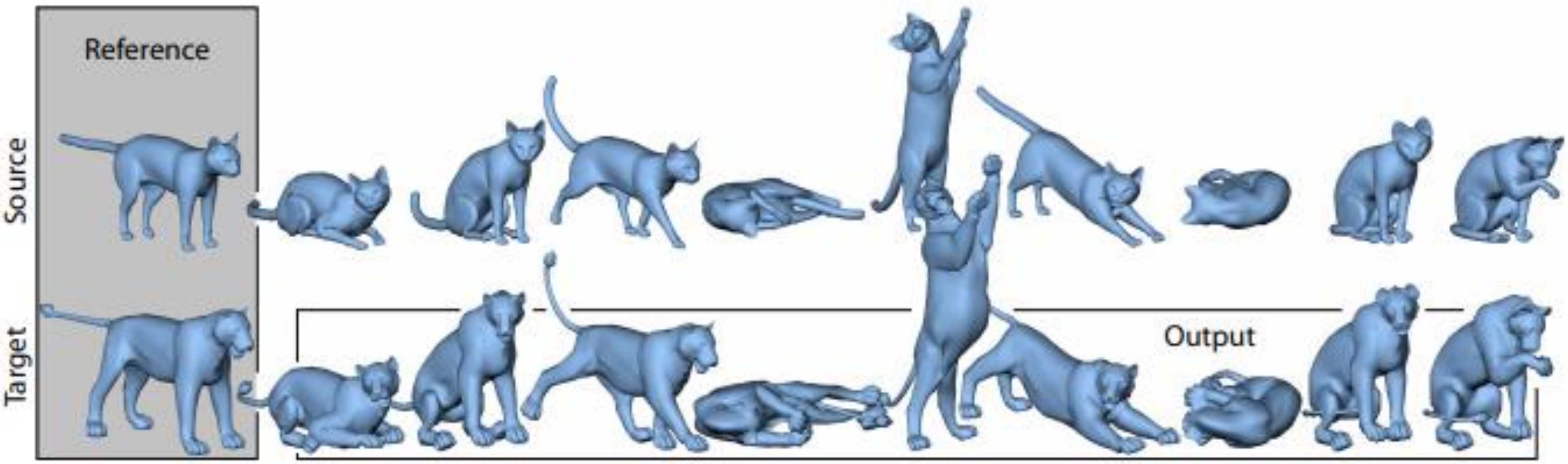
$$\min_{\tilde{\mathbf{v}}_1 \ldots \tilde{\mathbf{v}}_n} \sum_{j=1}^{|M|} \left\| \mathbf{S}_{s_j} - \mathbf{T}_{t_j} \right\|_F^2$$

Deformation gradient by $\widetilde{\mathbf{v_1}}, \ldots, \widetilde{\mathbf{v_n}}$

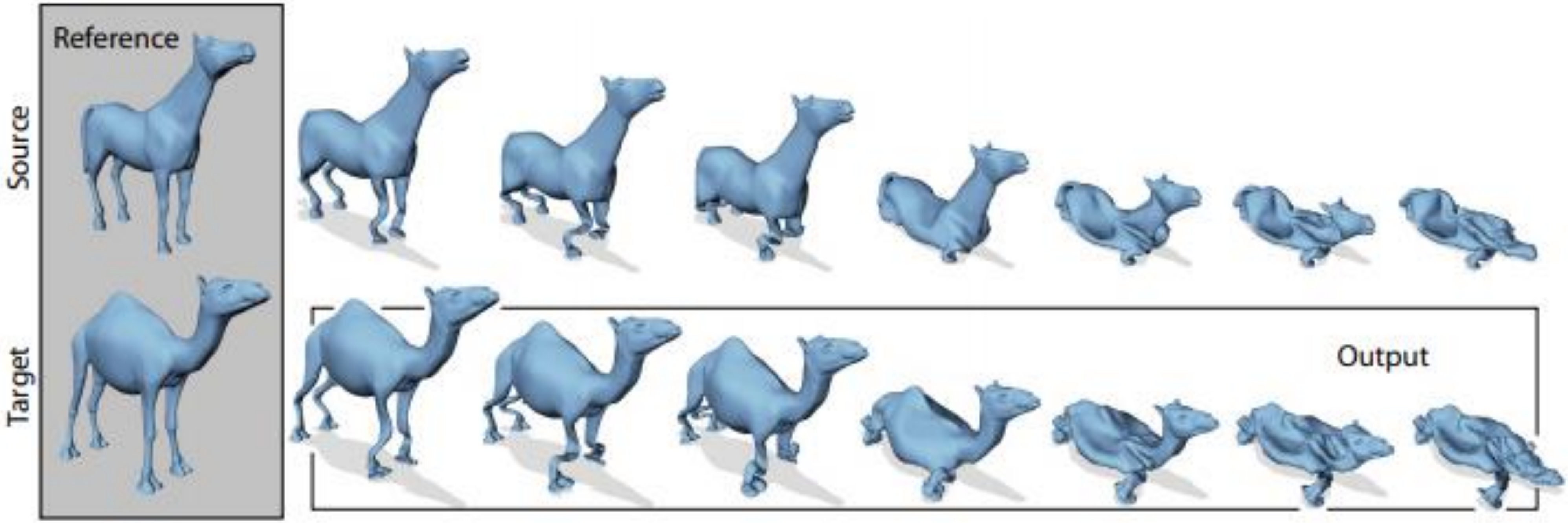
Deformation gradient of the target



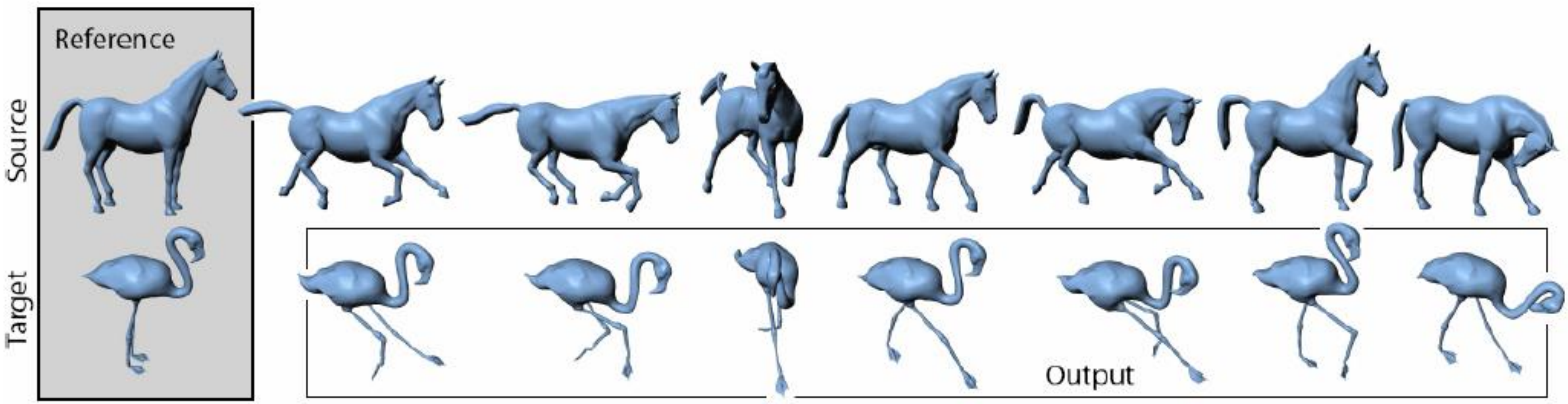
Results : Horse to Flamingo



Results : Horse to Camel



Results : Horse to Flamingo



Results: Face to Face

Summary

- Expression cloning
  - Transferring the facial expression to another
  - Using RBF for computing the correspondence
  - Specialized for face transfer
- Deformation Transfer
  - Standard approach for transferring geometry to another shape
  - Applicable to faces as well as full-body characters

Readings

Yuencheng Lee, Demetri Terzopoulos, and Keith Waters, **Realistic Modeling for Facial Animation** SIGGRAPH '95

K. Waters. A muscle model for animating three-dimensional facial expression. *Computer Graphics*, 22(4):17–24, 1987.

- Sifakis et al. **Automatic determination of facial muscle activations from sparse motion capture marker data**, SIGGRAPH 2005
- Ekman P and Friesen W "Manual for the the Facial Action Coding System" *Consulting Psychologist* 1977 Press Palo Alto California
- **Expression Cloning,** Jun-yong Noh Ulrich Neumann SIGGRAPH 2001
- **Park et al., A feature-based approach to facial expression cloning CASA2005**
- **Deformation Transfer for Triangle Meshes, Sumner et al. SIGGRAPH 2004**