Animation of 3D surfaces

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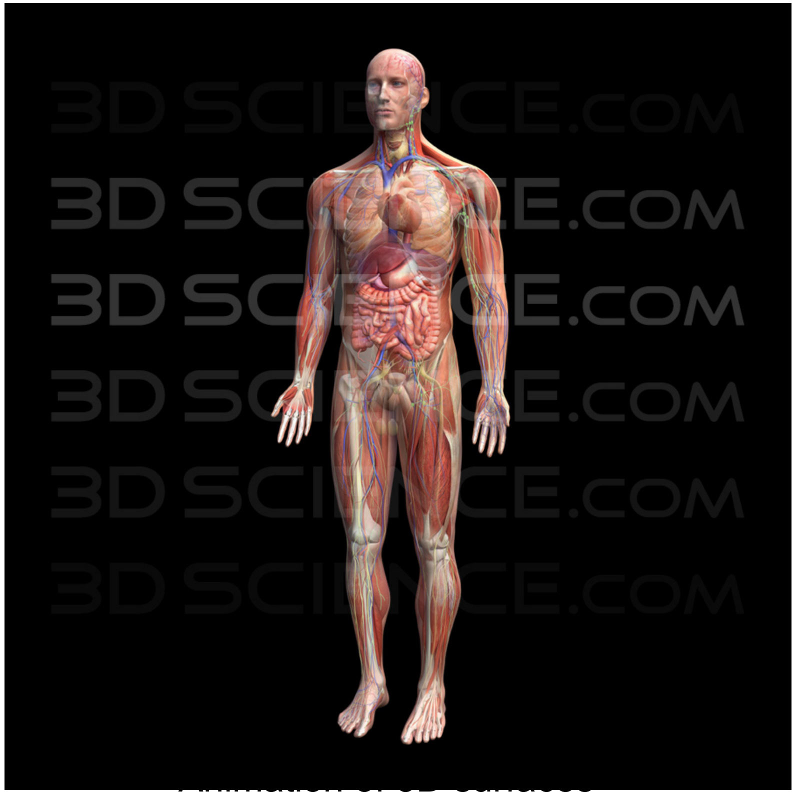
Motivations

- When character animation is controlled by "skeleton"…
  - set of hierarchical joints
  - joints oriented by rotations

- the character shape still needs to be visible:
  - visible = to be rendered as a continuous shape
  - typically, a **surface** is rendered

Motivations

- Is a 3D surface the “real’ thing ?
  - the visible shape is made of organic tissues



Motivations

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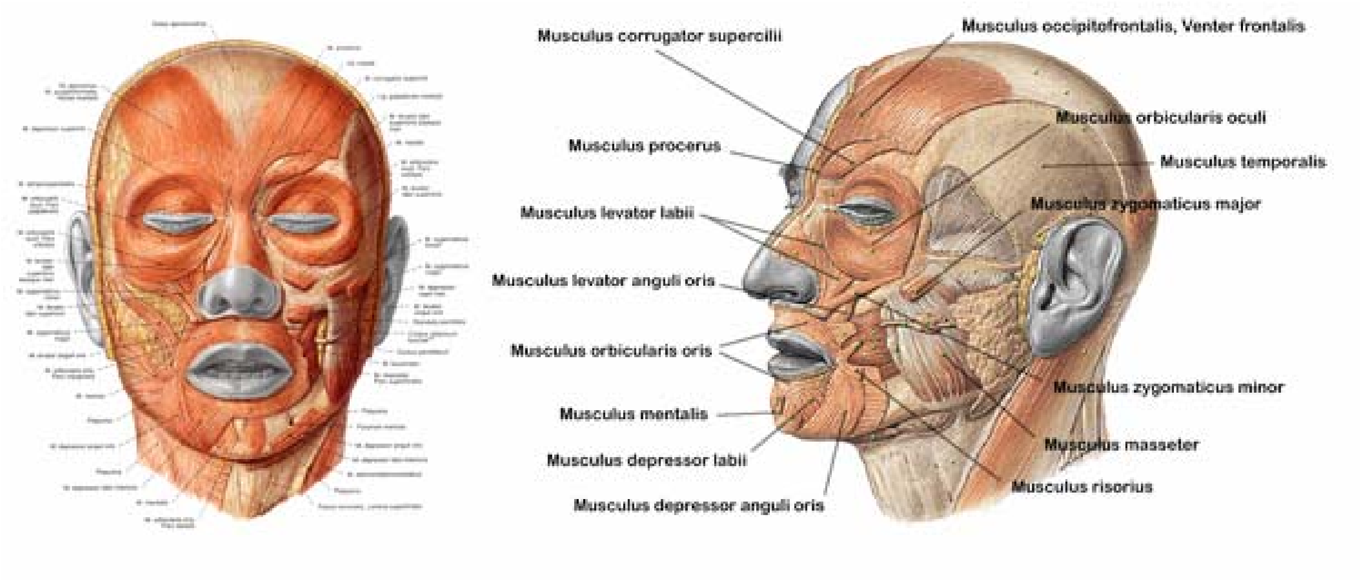
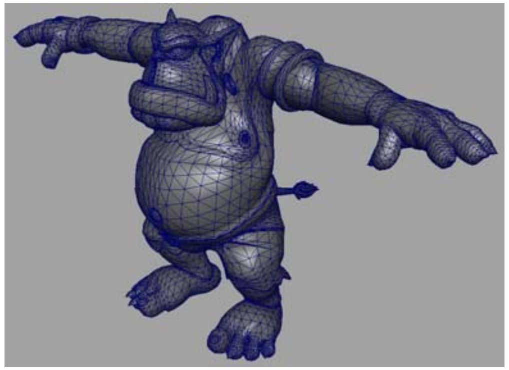


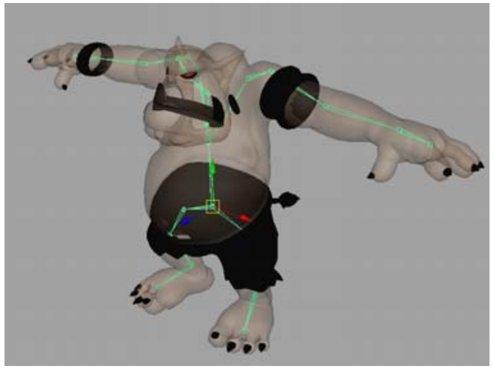
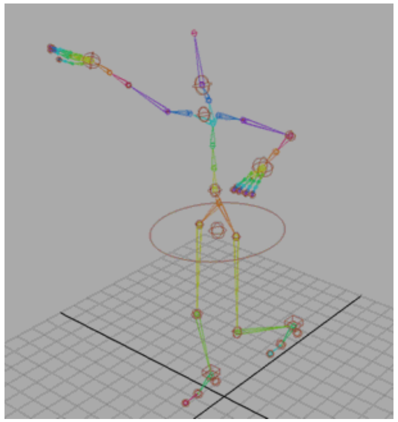
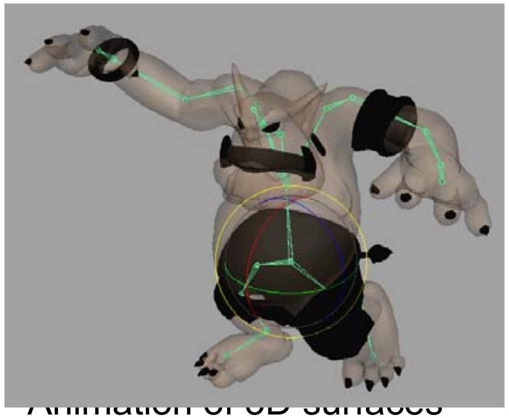
Motivations

- What is the goal of 3D animation ?

Motivations

- 3D animation workflow




Motivations

- Animation of 3D surface is actually the most “practical” thing:
  - direct connection with modeling phase
    - shape and texture
  - light structure, easy to animate
    - possibly real-time
  - works will be focused on workarounds to cope with this approximation of reality

Overview

- “Skinning”
- Non-linear deformers
- Shape morphing
- Laplacian mesh edition

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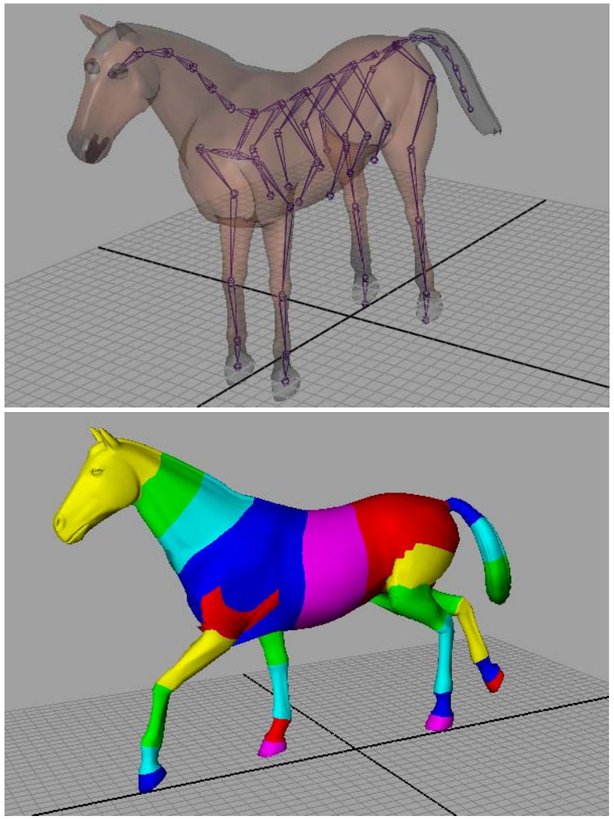
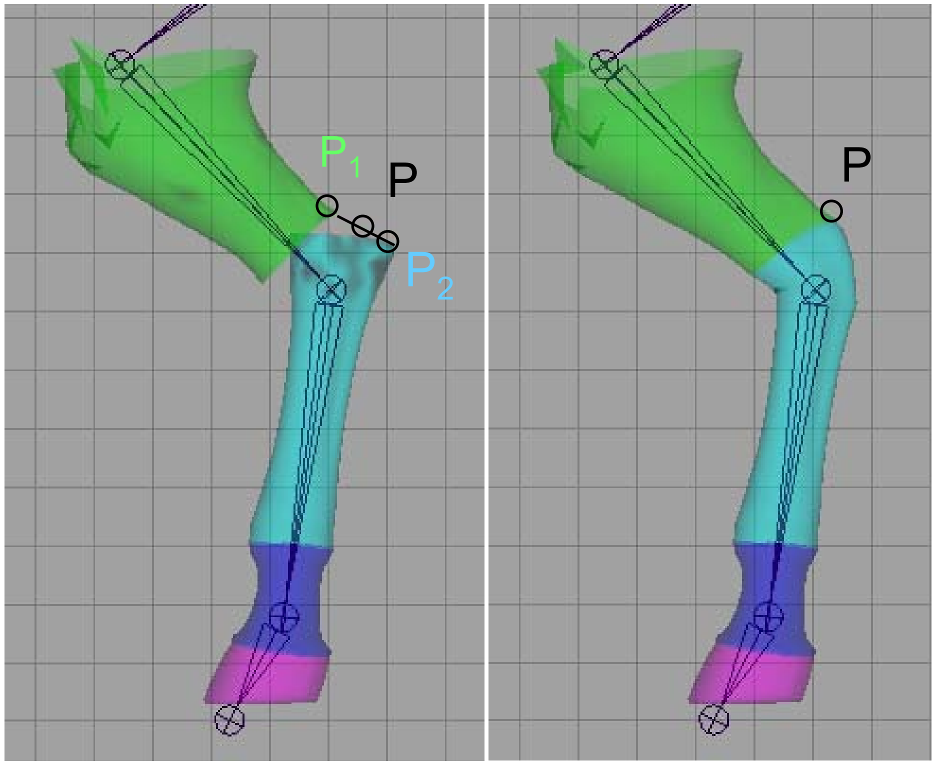
Skinning

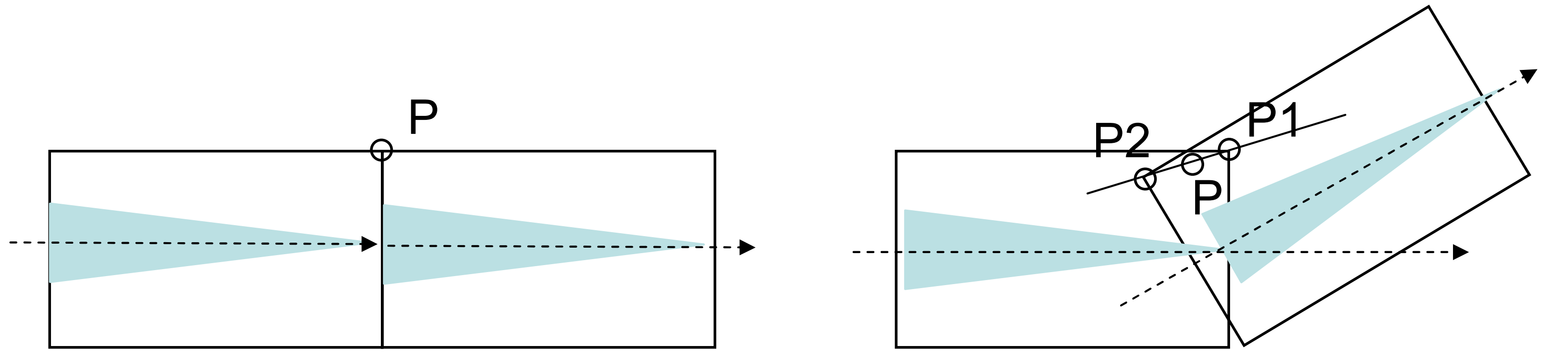
- Goal: bind a skeleton and a shape





Skinning

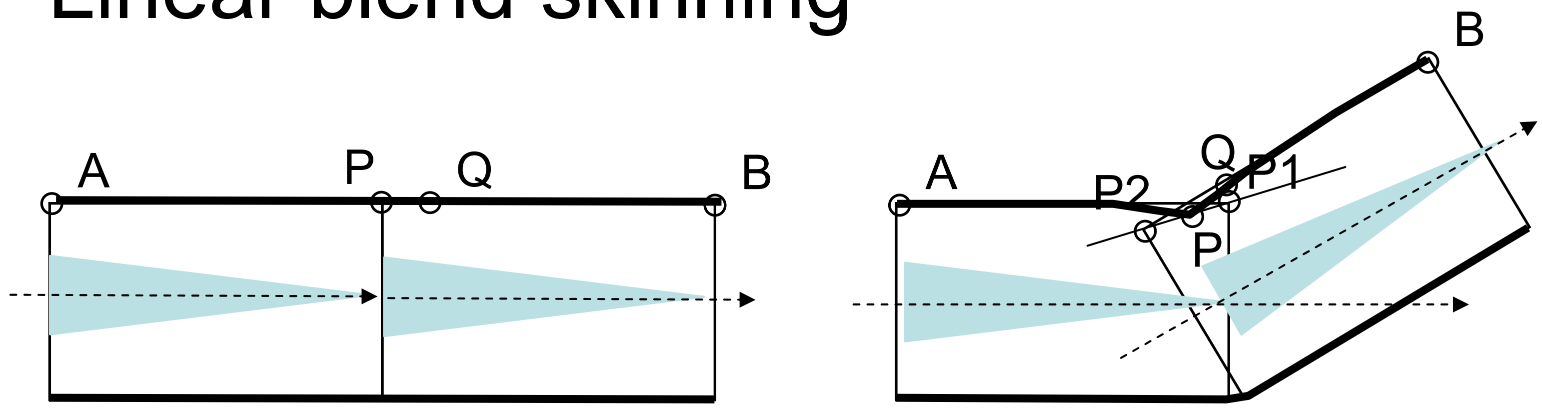
- Linear blend skinning



P = w1***P1** + w2***P2**

Skinning

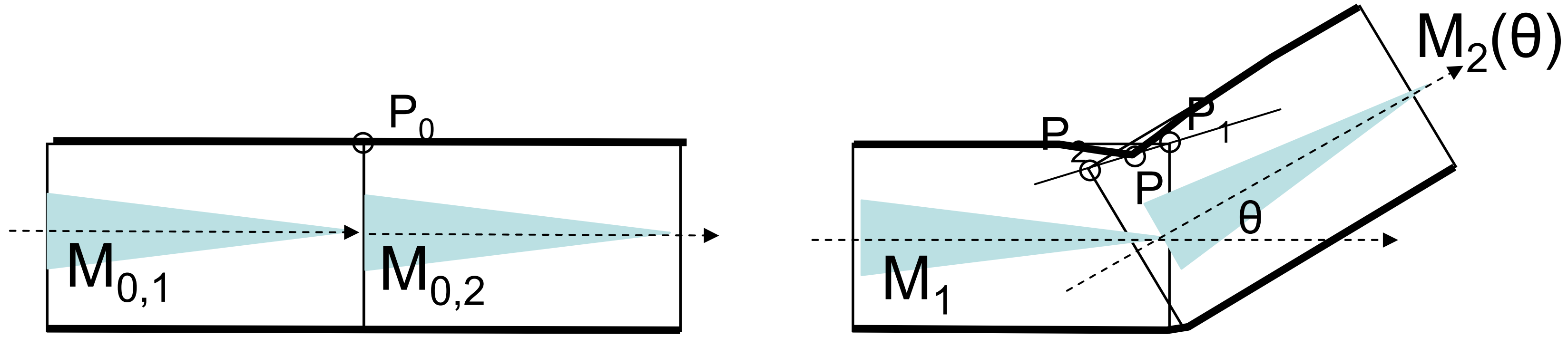
- Linear blend skinning



$\mathbf{P} = w_1 * \mathbf{P1} + w_2 * \mathbf{P2}$
w_i : [0..1], skin weights

Skinning

- Linear blend skinning



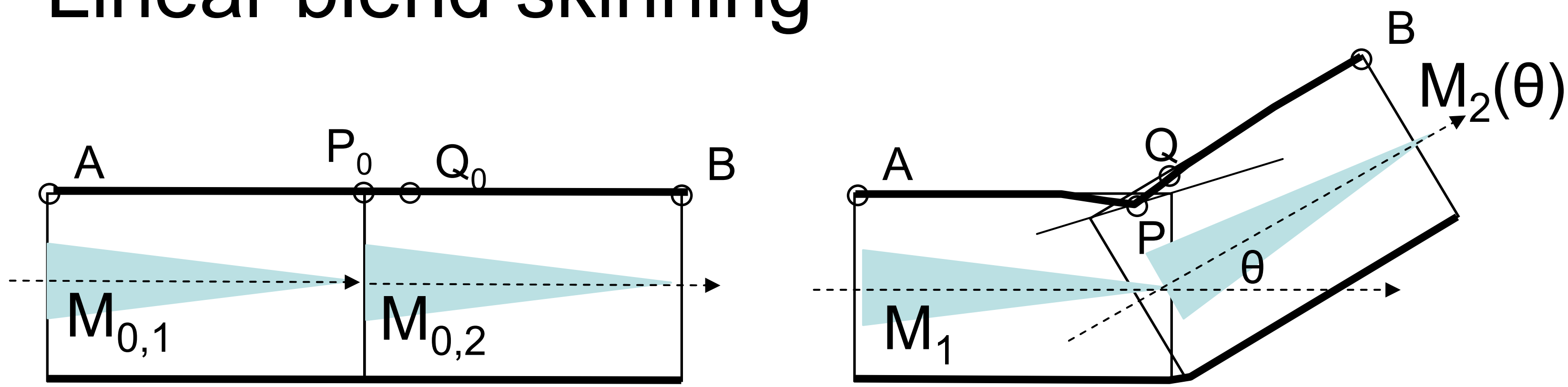
M = R T

$$\mathbf{P} = w_1 * \mathbf{P}_1 + w_2 * \mathbf{P}_2$$

with $\mathbf{P_i} = M_i \, M^{-1}_{0,i} \, \mathbf{P_0}$

Skinning

- Linear blend skinning



$$\mathbf{P} = \Sigma_i\, w_i * M_i\, M^{-1}_{0,i}\, \mathbf{P_0}$$

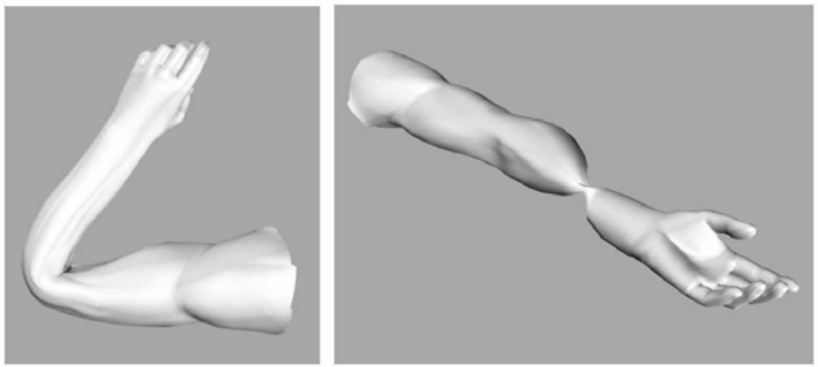
Implemented as “Skin>Smooth bind” in Maya

Skinning

- Limitations

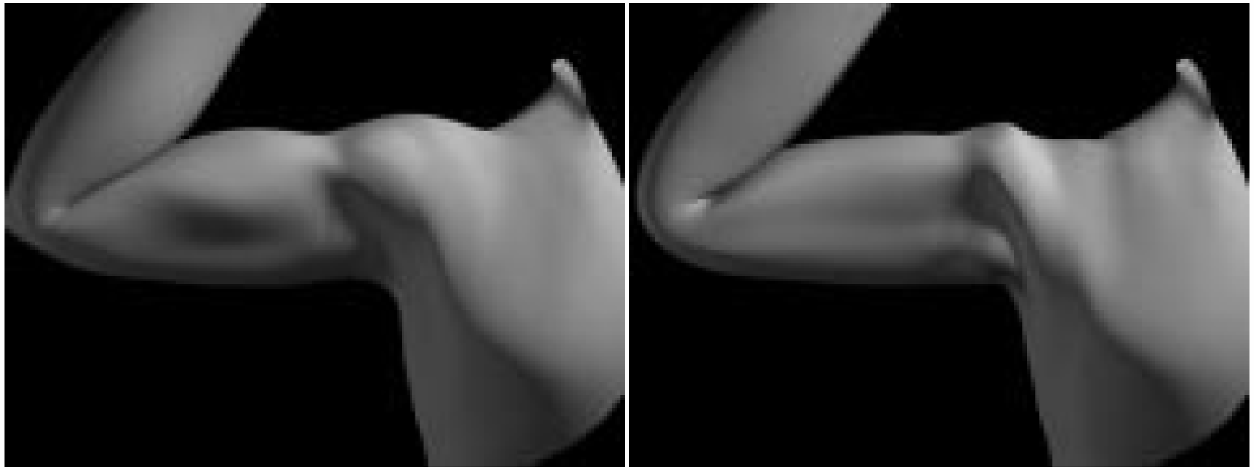
$$\mathbf{P} = \sum_i w_i * M_i \, M^{-1}_{0,i} \, \mathbf{P_0}$$
$$= \left(\sum_i w_i * M_i \, M^{-1}_{0,i} \right) \mathbf{P_0}$$

Non-rigid transformation



Skinning

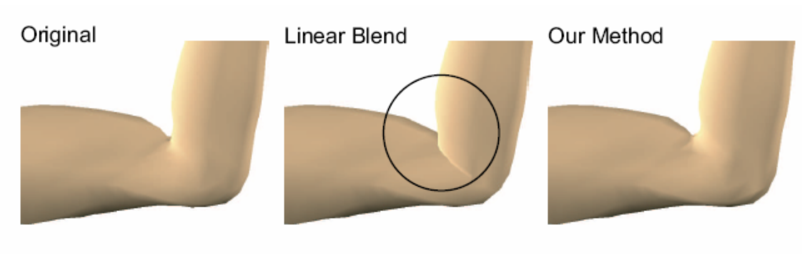
- Improvements
  - Skinning as a prediction function from joint configuration to 3D shapes

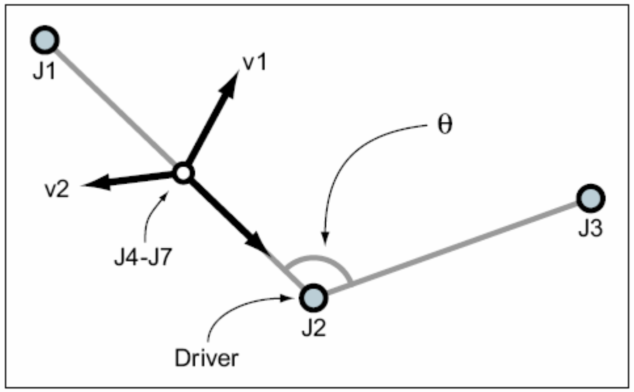


[Lewis et al., 2000]

Skinning

- Improvements
  - Incorporate user-defined examples of shapes and automatically add some joints and weights in LBS





[Mohr et Gleicher, 2003]

Skinning

- Improvements
  - Compute the matrix interpolation while maintaining correct rotations, using dual quaternions

$$\mathbf{P} = \Sigma_i\, w_i{*}M_i\, M^{-1}_{0,i}\, \mathbf{P_0}$$
$$= (\, \Sigma_i\, w_i{*}M_i\, M^{-1}_{0,i}\,)\, \mathbf{P_0}$$

[Kavan et al., 2007]

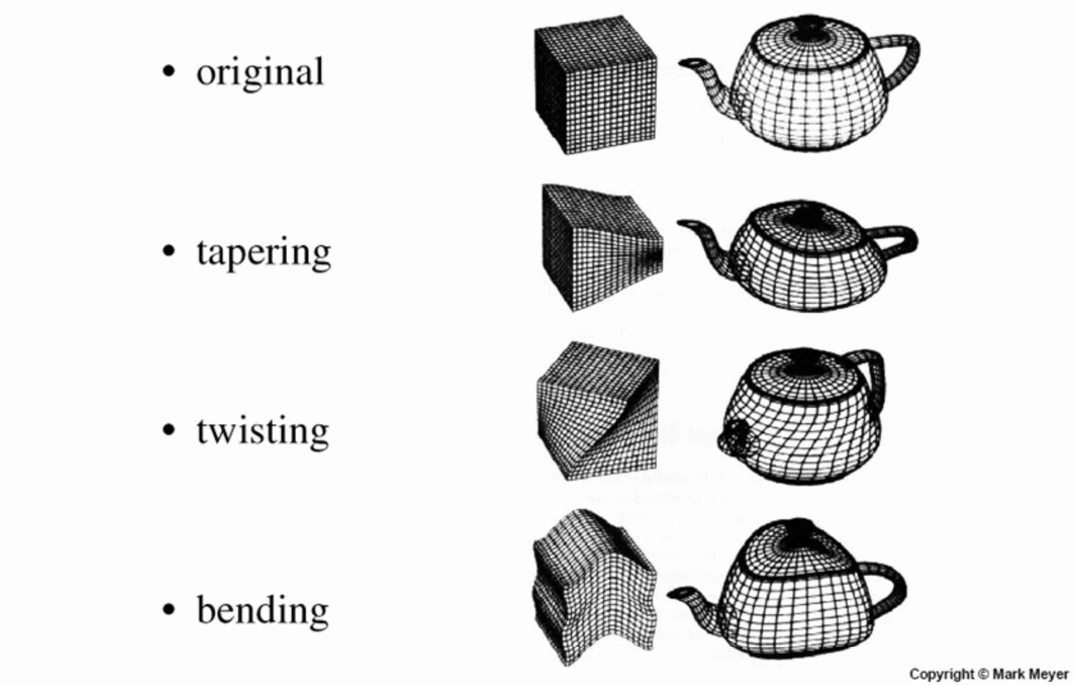
Overview

- “Skinning”
- **Non-linear deformers**
- Shape morphing
- Laplacian mesh edition

Non-linear deformers

- Global modification of 3D shapes

  the transformation matrix is a function of R^3 point

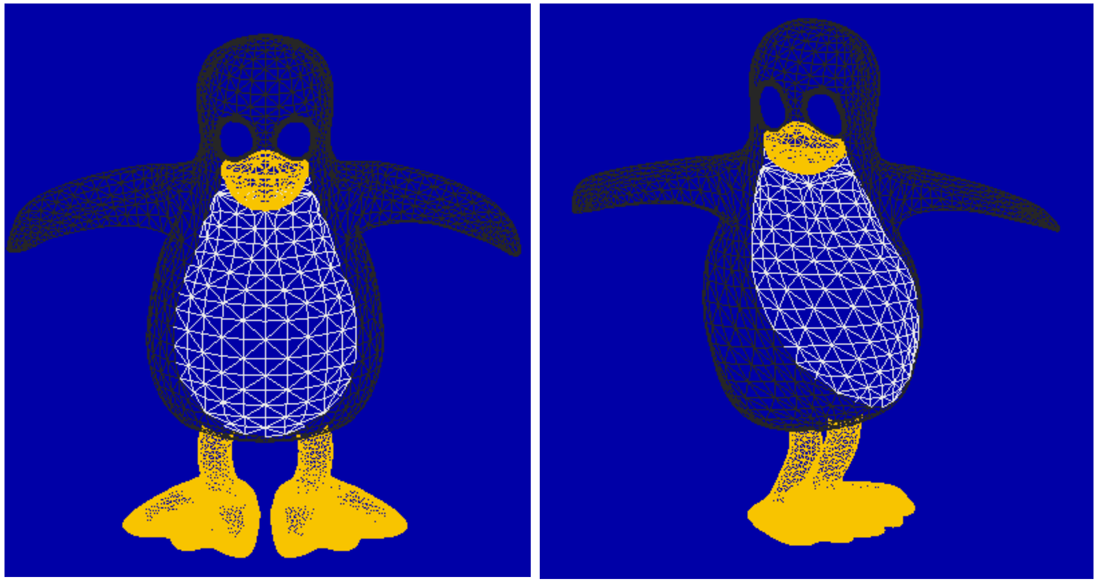


Non-linear deformers

- Non-uniform rotation (twisting)

$$r(z) = \begin{cases} 0 & z \le z_0 \\ \dfrac{z - z_0}{z_1 - z_0}\theta_{\max} & z_0 \le z \le z_1 \\ \theta_{\max} & z_1 \le z_0 \end{cases}$$

$$P' = \begin{bmatrix} \cos(r(p_z)) & -\sin(r(p_z)) & 0 \\ \sin(r(p_z)) & \cos(r(p_z)) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix}$$



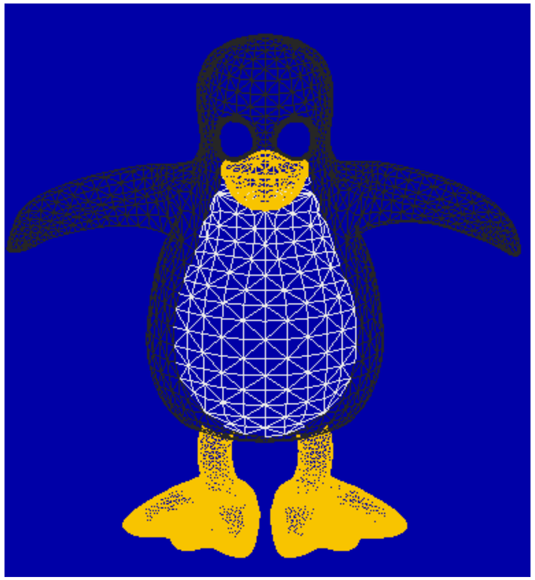
Non-linear deformers

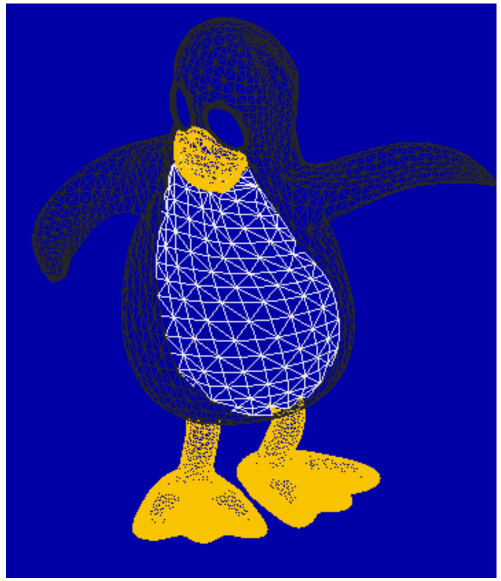
- Vortex

$$r(z) = \begin{cases} 0 & z \le z_0 \\ \dfrac{z - z_0}{z_1 - z_0}\theta_{\max} & z_0 \le z \le z_1 \\ \theta_{\max} & z_1 \le z_0 \end{cases}$$

$$\alpha(P) = r(p_z)e^{-(p_x{}^2 + p_y{}^2)}$$

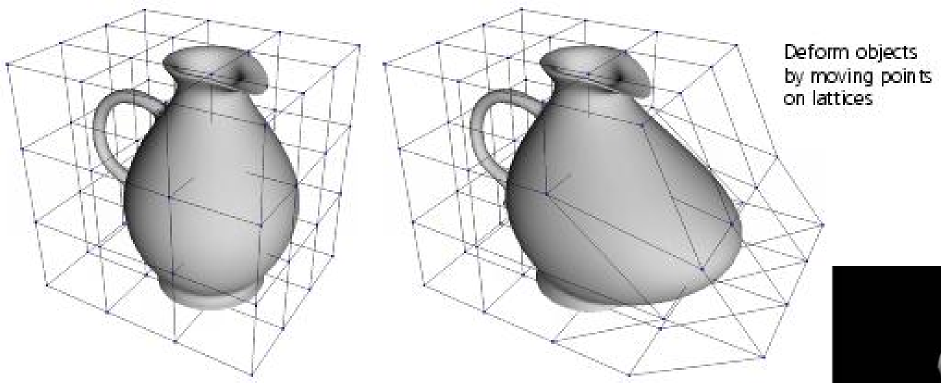
$$P' = \begin{bmatrix} \cos(\alpha(P)) & -\sin(\alpha(P)) & 0 \\ \sin(\alpha(P)) & \cos(\alpha(P)) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} p_x \\ p_y \\ p_z \end{bmatrix}$$

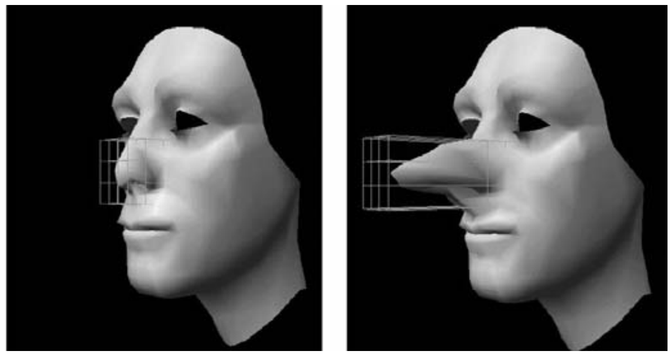




Non-linear deformers

- Free-Form Deformation (FFD)





Object embedded in “3D rubber”

Non-linear deformers

- FFD : Space interpolation

$$s = \frac{\mathbf{T} \times \mathbf{U} \cdot (M - M_0)}{\mathbf{T} \times \mathbf{U} \cdot \mathbf{S}}$$

$$t = \frac{\mathbf{S} \times \mathbf{U} \cdot (M - M_0)}{\mathbf{S} \times \mathbf{U} \cdot \mathbf{T}}$$

$$u = \frac{\mathbf{S} \times \mathbf{T} \cdot (M - M_0)}{\mathbf{S} \times \mathbf{T} \cdot \mathbf{U}}$$

$$P_{ijk} = M_0 + \frac{i}{i_{\max}} \mathbf{S} + \frac{j}{j_{\max}} \mathbf{T} + \frac{k}{k_{\max}} \mathbf{U}$$

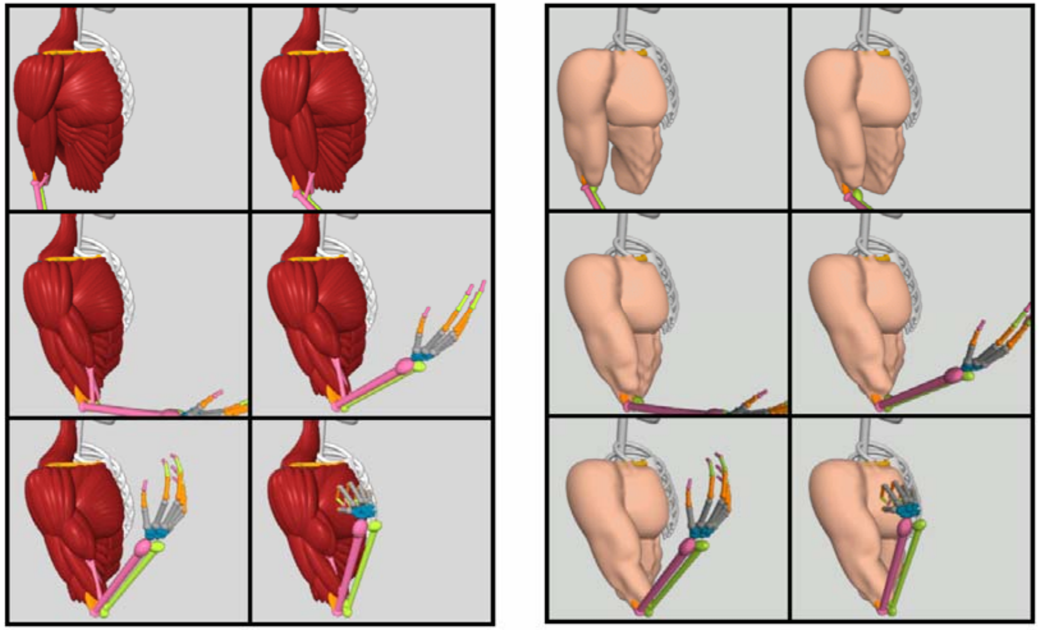
$$M_{FFD} = \sum_{i=0}^{i_{\max}} \sum_{j=0}^{j_{\max}} \sum_{k=0}^{k_{\max}} B_i^{i_{\max}}(s) B_j^{j_{\max}}(t) B_k^{k_{\max}}(u) P_{ijk}$$

Non-linear deformers

- FFD
  - applications to non-characters objects

Non-linear deformers

- Preserving volume



$V = 4/3 \pi abc$

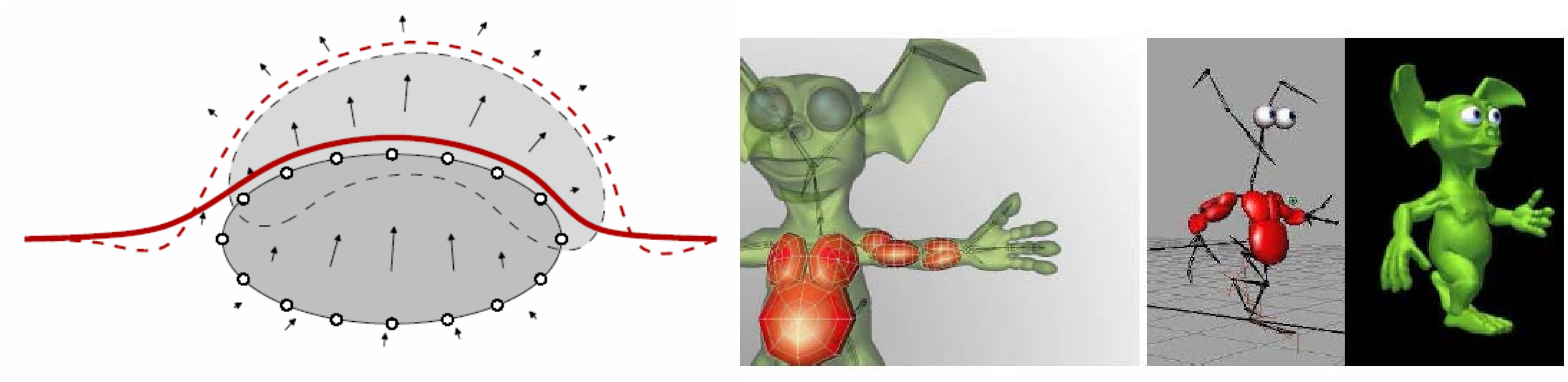
$b = \frac{3}{4} V / (\pi ac)$

[Scheepers et al., 97]

Influence object combined with skinning

Non-linear deformers

- Preserving volume



Motion of “Muscles” induces a displacement field

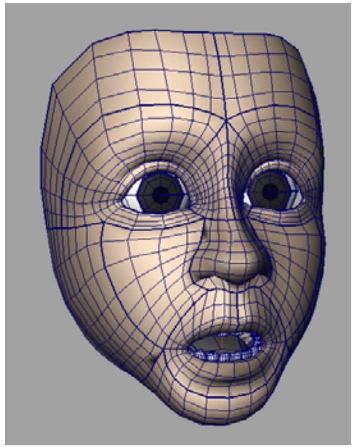
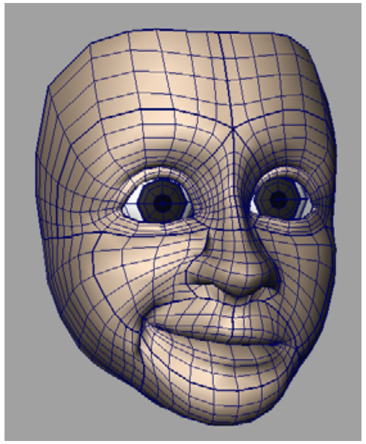
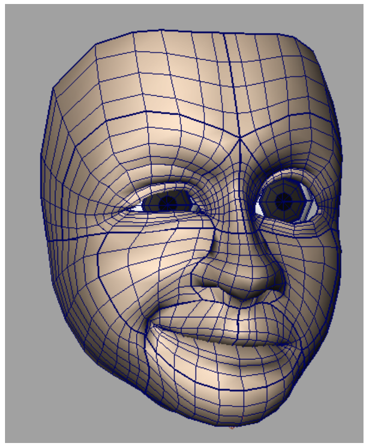
[Angelidis et Singh, 2007]

Overview

- “Skinning”
- Non-linear deformers
- **Shape morphing**
- Laplacian mesh edition

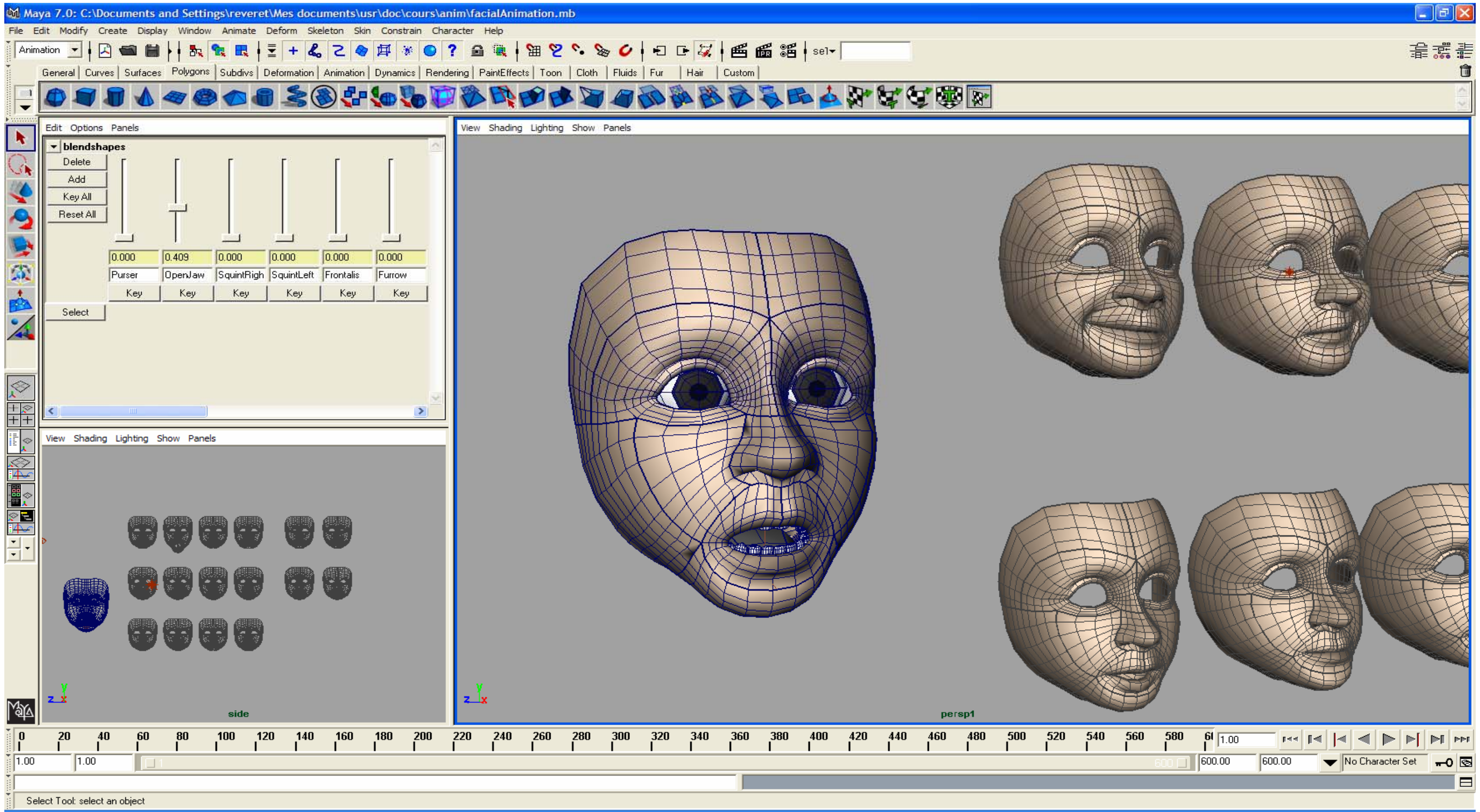
Shape morphing

- a 3D shape is a linear combination of reference shapes
  - a linear interpolation for each vertex
  - animation is controlled by blend coefficient
  - typical application is facial animation

Shape morphing

- Blend Shapes



Shape morphing

- Problem of shapes interferences
  - balance local *vs* global effect of a blend shape
  - blend shapes could be antagonist

[Lewis et al., 2005]

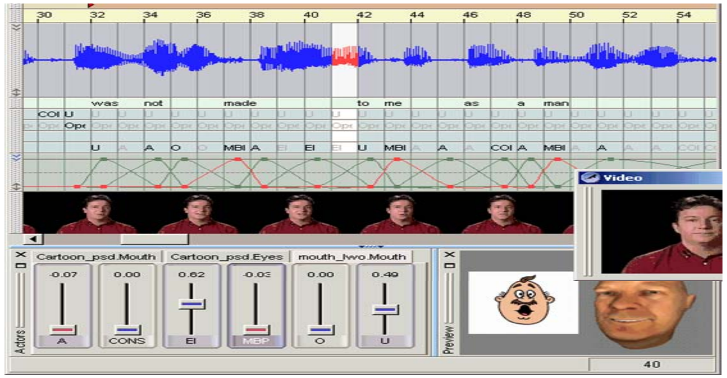
Shape morphing

- Facial animation : two main domains
  - Emotion
    - any expression is combination of basic expression: fear, disgust, joy, surprise, anger [Ekman, 75]
  - Talking
    - visual perception of speech production

Lip-synching

- Difficult task
  - how to post-synchronized video onto audio track
  - one common solution :
    - a phoneme = a 3D shape
    - several visually equivalent phonemes as a “viseme”

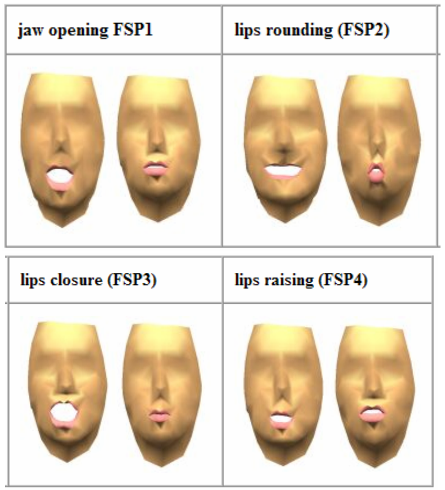
      [p,b,m], [f,v], etc.

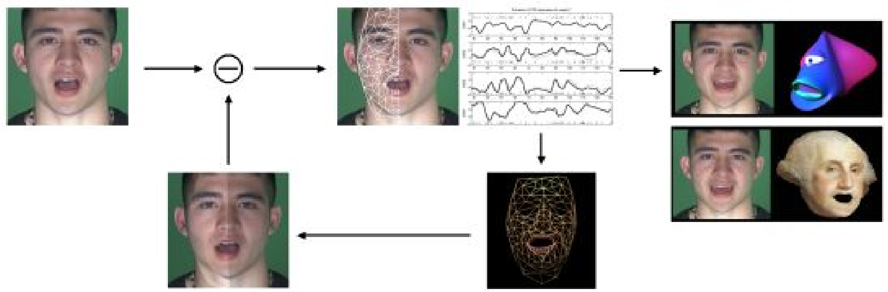


[Magpie Pro, ©Third Wish Software and Animation]

Lip-synching

- Problem of the co-articulation effect
  - audio-visual speech signal is continuous
  - audio and visual are not synchronized by nature (anticipation and latency)
  - gesture *vs* shape





[Reveret et Essa, 2001]

Overview

- “Skinning”
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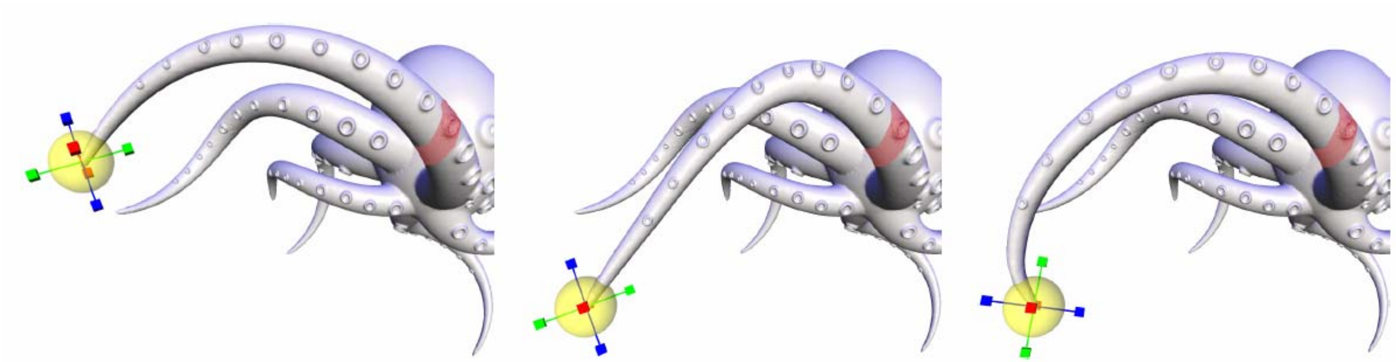
- **Laplacian mesh edition**

Laplacian mesh edition

- Character animation without a skeleton
- Group of vertices are locally deformed while preserving surface details
- Based on discrete differential geometry



[Sorkine et al., 2004]

Laplacian mesh edition

- Each vertex coordinate is replaced by the difference to the average of its neighbors

  D = L V

- Deformation by adding constrains

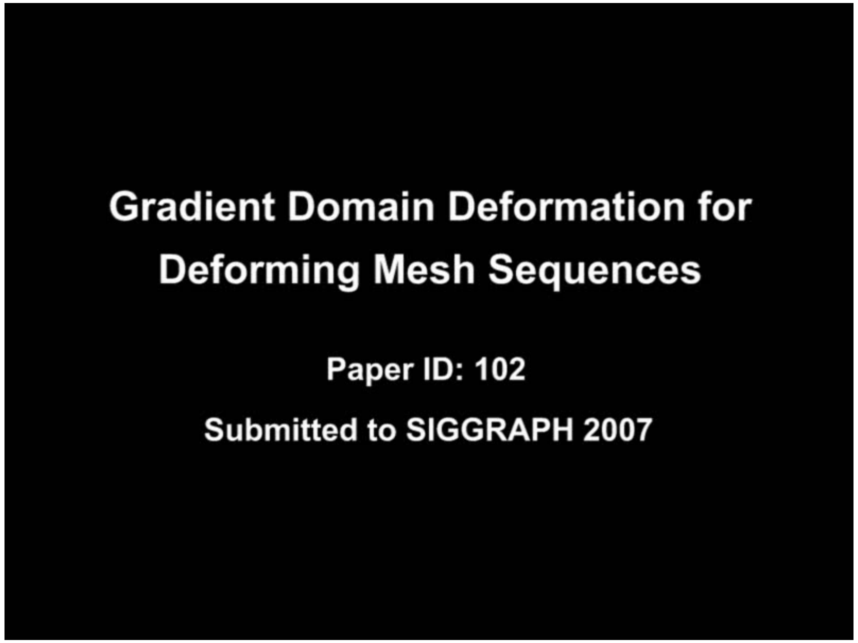
  add some rows to L => L’ and D => D’

- Reconstruction of V by approximation

  V’ = argmin(|| L’V – D’ ||)

Laplacian mesh edition

- Application to key-frame animation



[Xu et al., 2006]

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