CS 523: Computer Graphics, Spring 2011

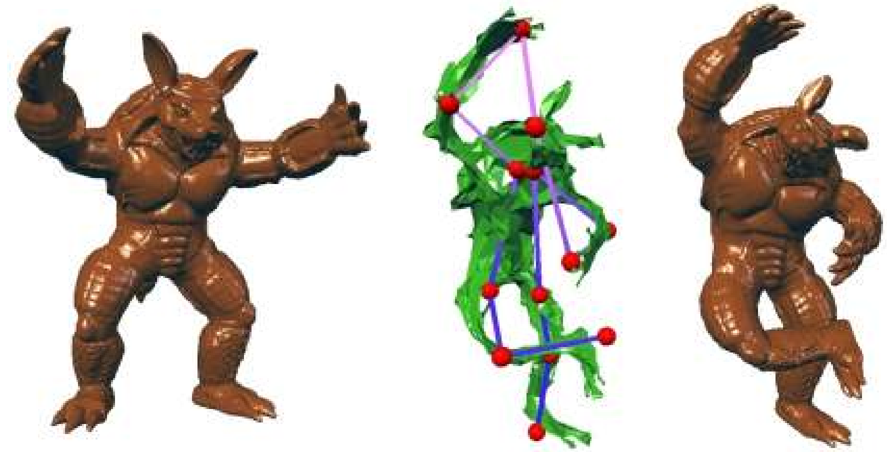
Shape Modeling

Shape deformation intro

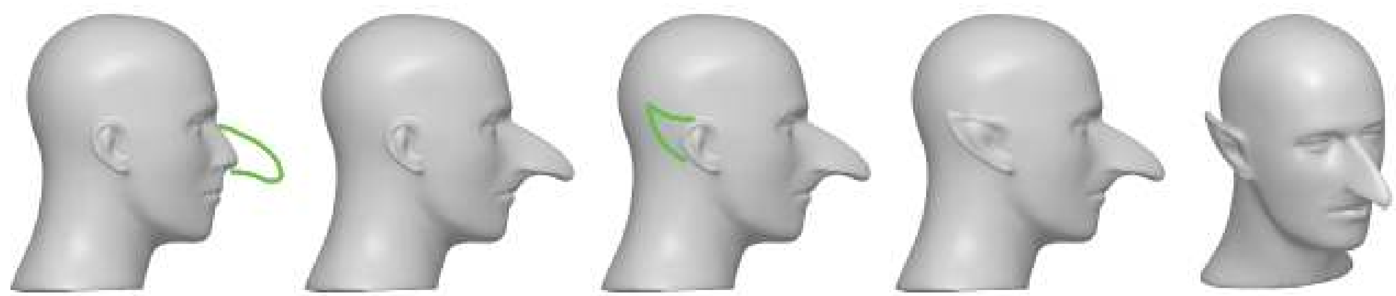
Surface vs. space deformations

Why shape deformation?

- Animation



- Editing

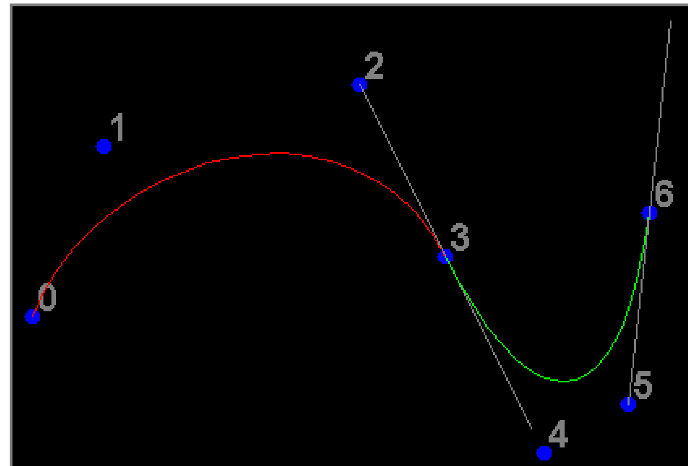


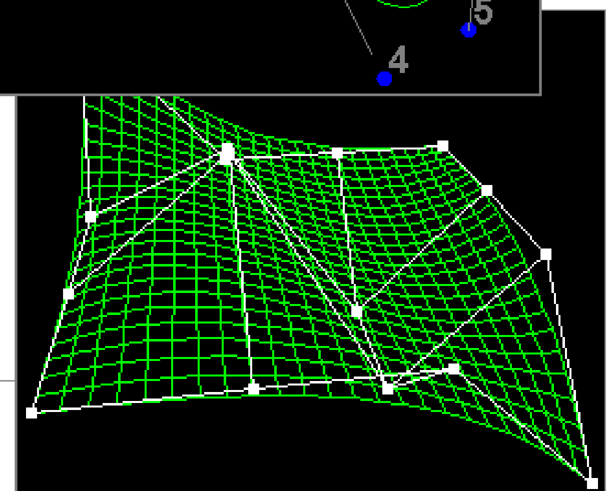
- Simulation

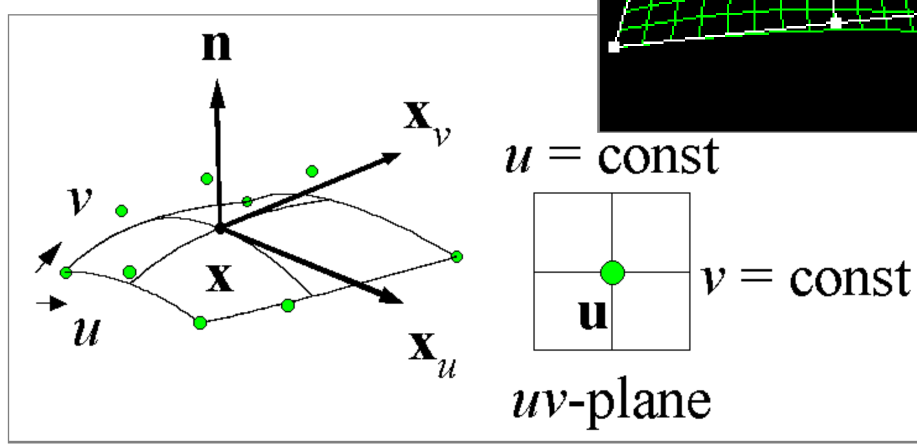
Parametric curves and surfaces

Deformation by control point manipulation

- Some online demos
  - **`http://www.cs.princeton.edu/~min/cs426/jar/bezier.html`**
  - **`http://www.nbb.cornell.edu/neurobio/land/OldStudentProjects/cs490-96to97/anson/BezierPatchApplet/`**
  - **`http://wwwvis.informatik.uni-stuttgart.de/~kraus/LiveGraphics3D/cagd/`**







Mesh/shape deformation

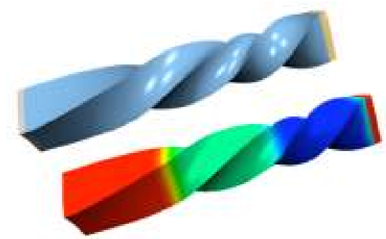
Basic idea

- Naïve method: dragging single vertices
  - One by one, or Rigid/affine (linear) transformation of vertex groups
- Smarter:
  - Create a small set of control parameters (reminder: *face* spaces)
  - Introduce a small set of deformation handles
    - Makes deformation editing easier
    - Introduces a trade-off between degrees of freedom and simplicity of the deformation task

Mesh/shape deformation

Commonly used paradigms

- **Surface based deformation**
  - Laplacian surface editing and other surface-based energy minimization approaches
  - Physically motivated:
    Laplacian preservation ≈ bending resistance

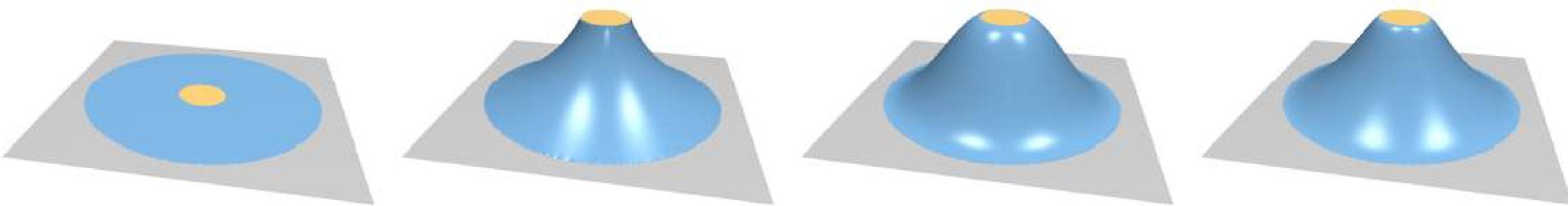


- **Space deformation**
  - Deforms some 2D/3D space using a *cage*
  - Deformation propagation to all points in the space
  - Independent of shape representation

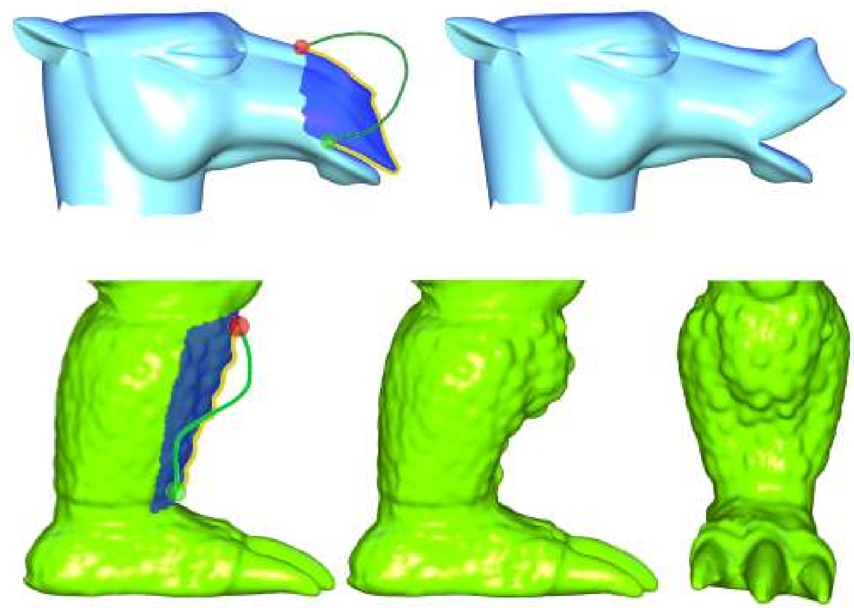
Surface-based deformations

Examples

- Region of interest (ROI) + affine deformation handle with variable boundary continuity



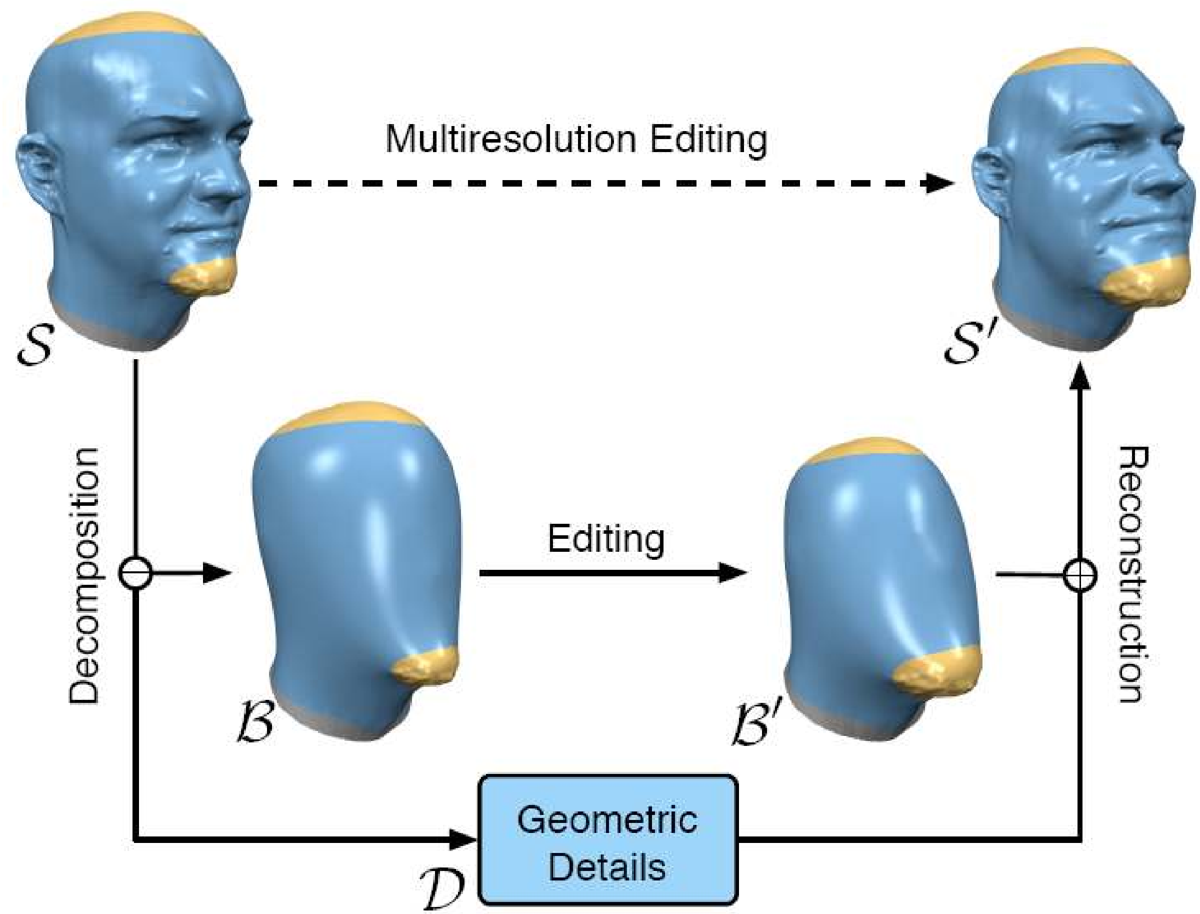
- Intuitive sketch-based deformation interfaces



Surface-based deformations

Examples

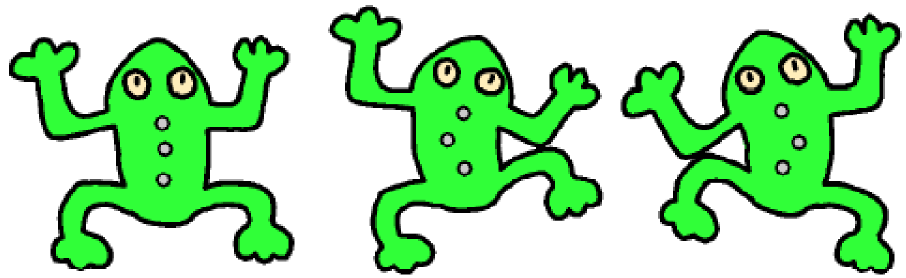
- Multi-resolution mesh editing



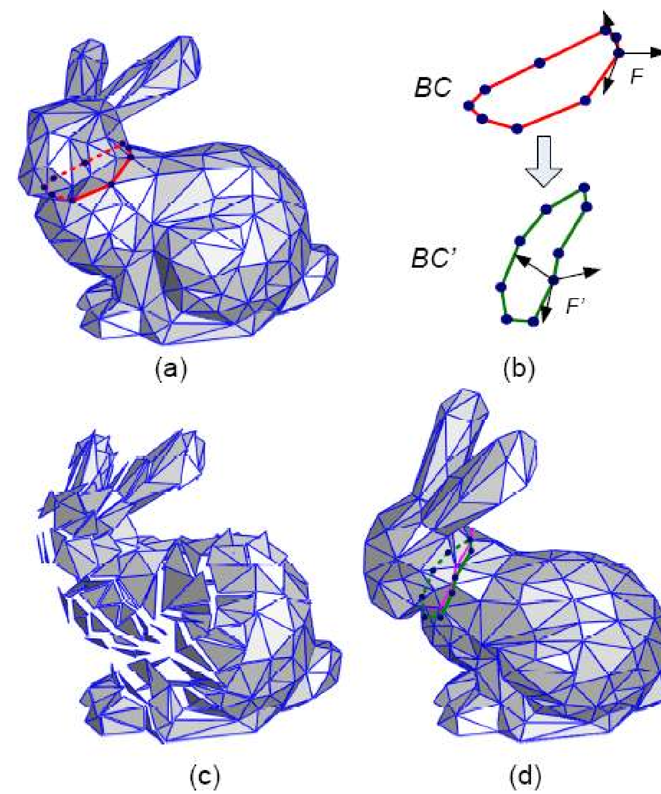
Surface-based deformations

Linear methods

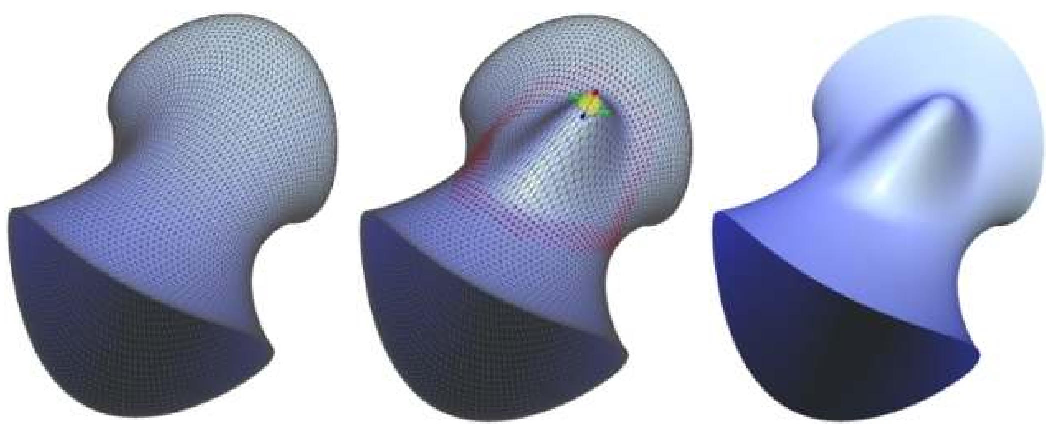
- (2D) As rigid as possible shape manipulation



- Triangle gradient methods



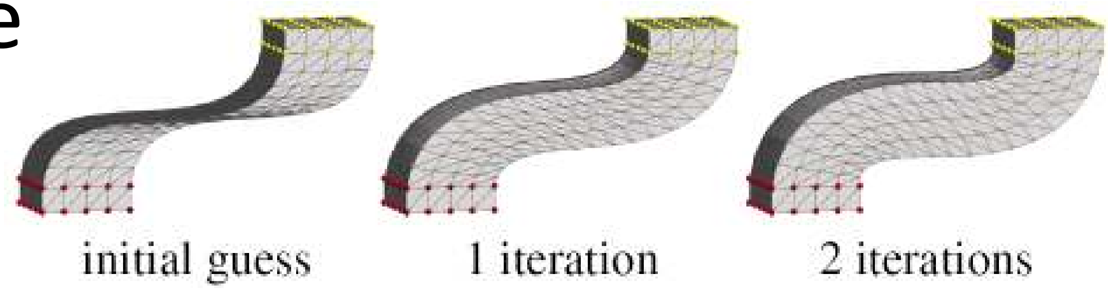
- Laplacian surface editing



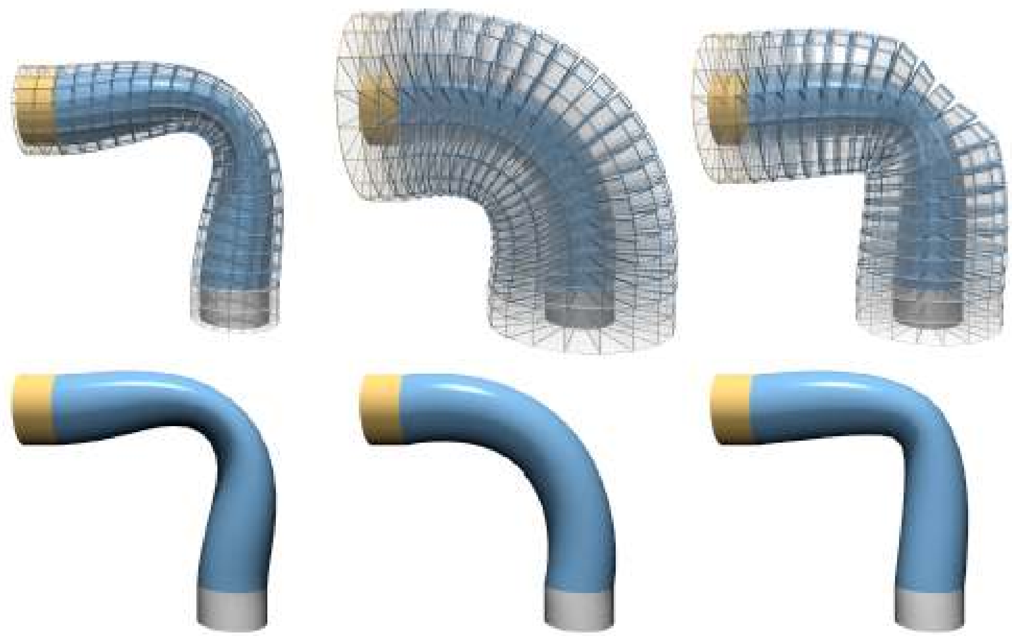
Surface-based deformations

Nonlinear methods

- As rigid as possible surface modeling



- PriMo

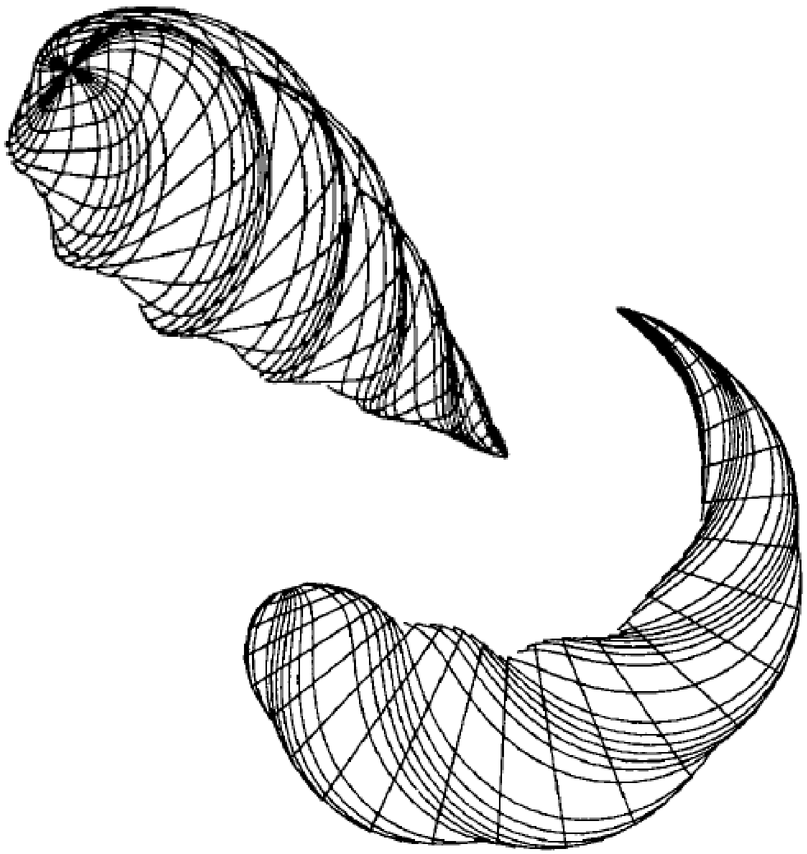


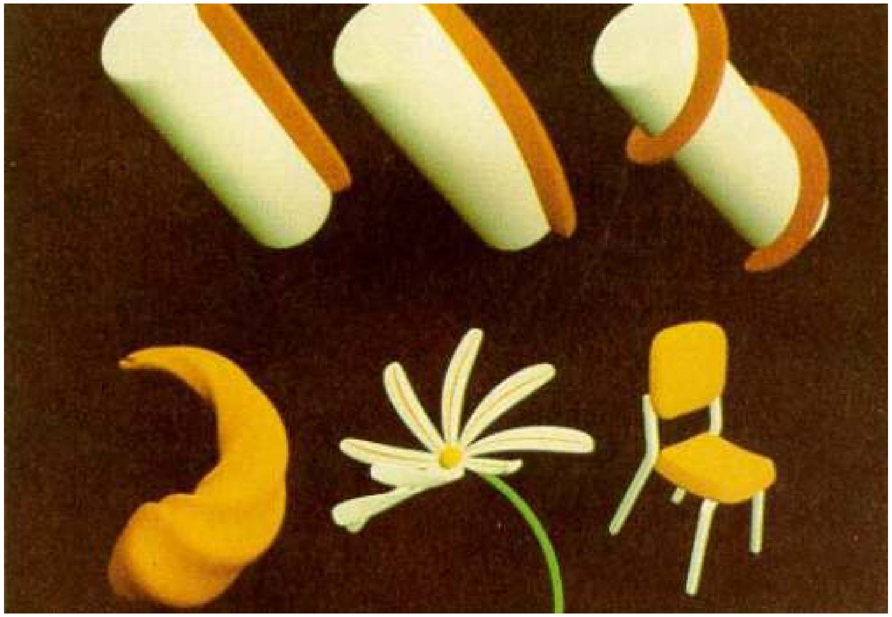
- Mesh Puppetry

Space deformations

Early seminal work in computer graphics

- Global and local deformation of solids [Barr 1984]

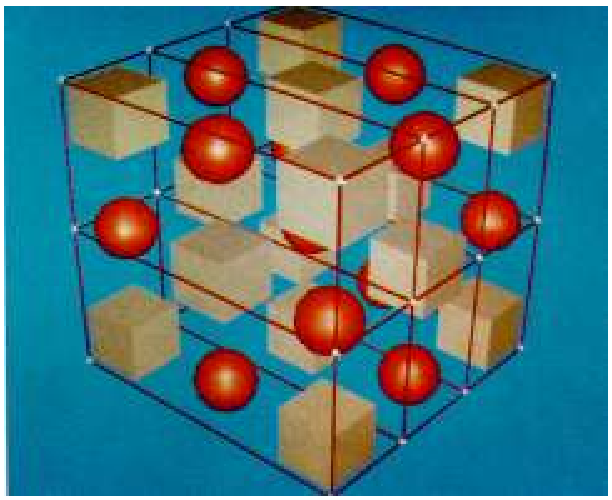




Space deformations

Early seminal work in computer graphics

- Free form deformations [Sederberg and Parry 1986]
  - Uses trivariate tensor product polynomial basis



  - Can be designed to be volume preserving

$$\mathbf{F}(x,y,z) = (F(x,y,z), G(x,y,z), H(x,y,z))$$

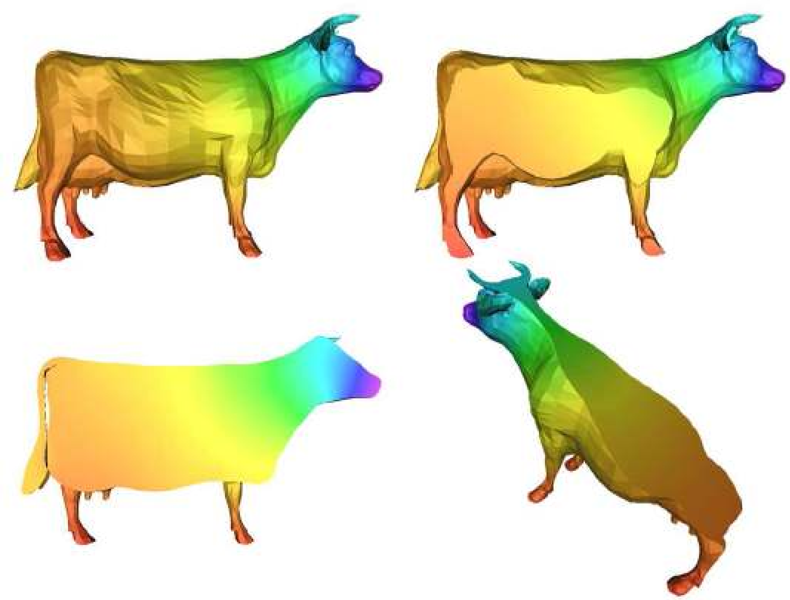
then the Jacobian is the determinant

$$Jac(\mathbf{F}) = \begin{vmatrix} \frac{\partial F}{\partial x} & \frac{\partial F}{\partial y} & \frac{\partial F}{\partial z} \\ \frac{\partial G}{\partial x} & \frac{\partial G}{\partial y} & \frac{\partial G}{\partial z} \\ \frac{\partial H}{\partial x} & \frac{\partial H}{\partial y} & \frac{\partial H}{\partial z} \end{vmatrix}$$

Space deformations

Basic idea

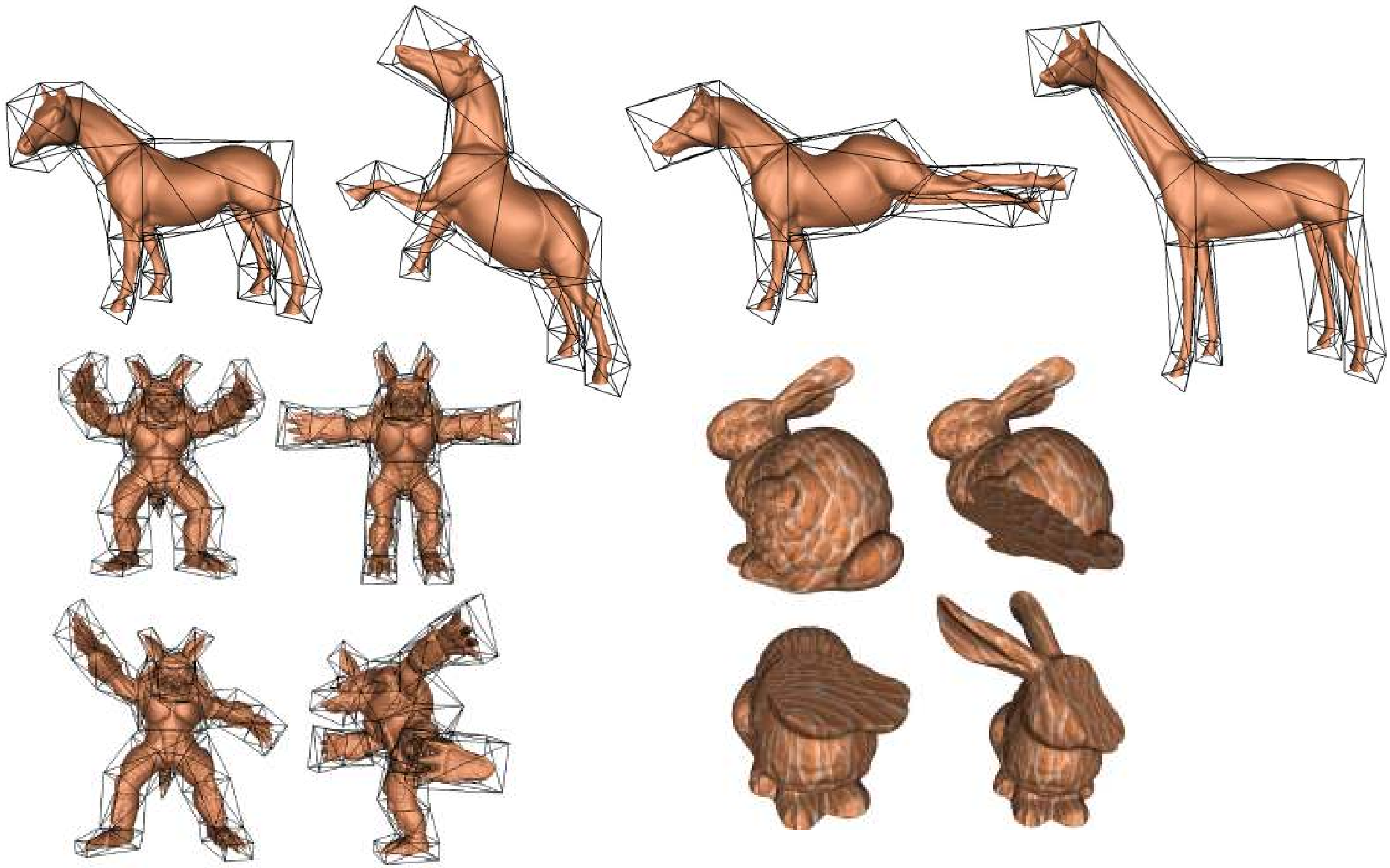
- Design a set of coordinates for all points in $\mathbb{R}^n$ w.r.t. the cage vertices
  - Each point $\mathbf{x}$ can be represented as a weighted and normalized sum of cage points
  - The coordinates are smoothly varying and guarantee continuity inside the volume



Space deformations

Examples

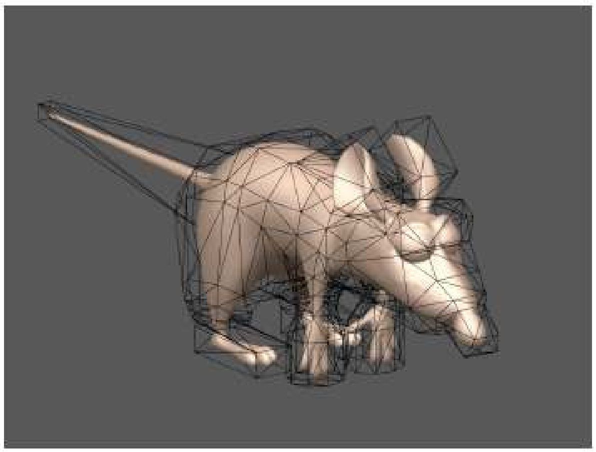
- Mean value coordinates for closed tri meshes

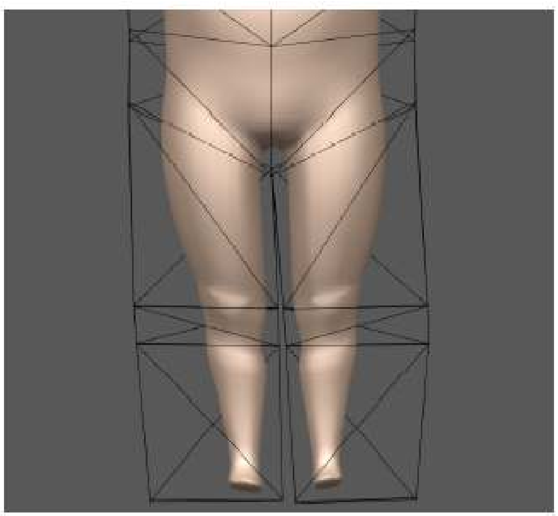
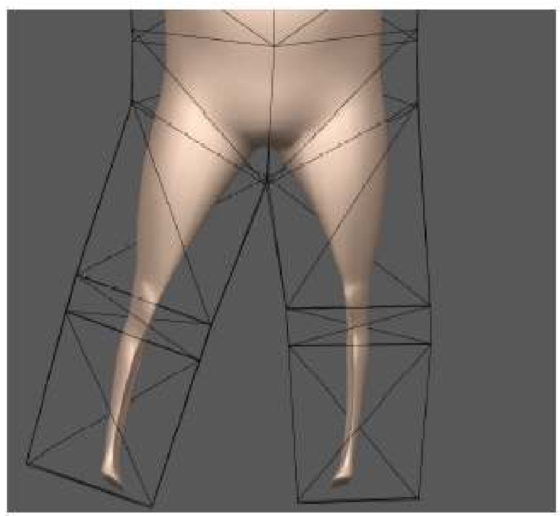
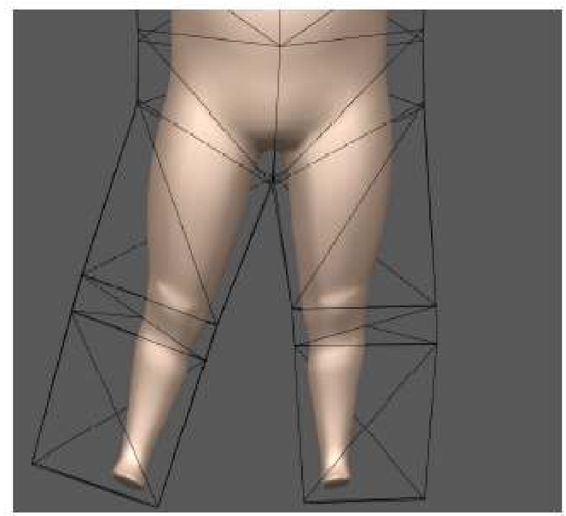


Space deformations

Examples

- Harmonic coordinates



Space deformations

Examples

- Green coordinates