CS 4732: Computer Animation

Key Frames & Shape Changes

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Key Framing

- Key frames define important poses during an animation
  - Specified by animator
  - Computer fills in ‘tweens
- How should the computer interpolate as desired by the animator?
  - For curves?
  - For shapes?

Key Framing (cont.)

- Two main problems
  - Correspondence
  - Interpolation method
- For curves
  - One could require the curves to have same number of control points
  - Interpolate control points, regenerate curve

Key Framing (cont.)

- For shapes
  - One could require the shapes to have the same topology
  - Apply physics-based simulation
  - Or use key framing for more control
- Shape animation used a lot for facial animations

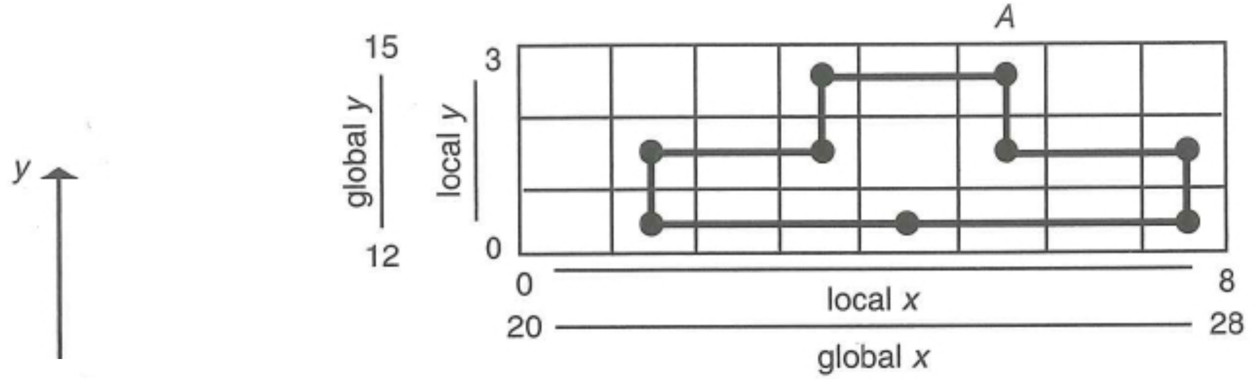
Shape Animation

- What does it mean for shapes to be different?
  - Uniform scaling?
  - Is a square the same as a rectangle?
- Pulling/pushing vertices
  - Can be tedious/time consuming
  - Can displace neighbors by some influence function

2D Shape Deformation

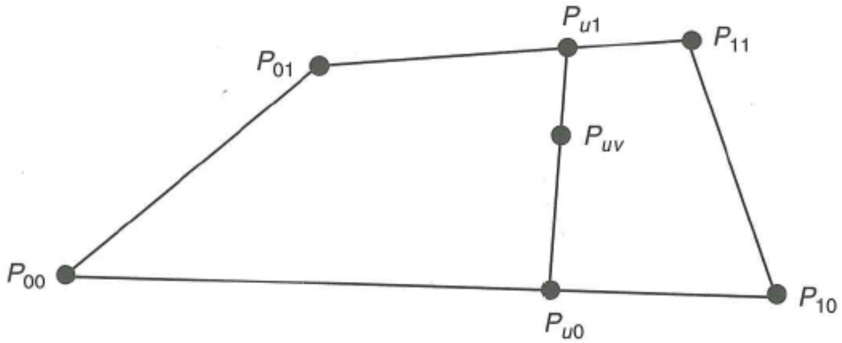
- □ One approach to deformation is to
  - Embed the vertices of the shape within a regular grid
  - Note the relative locations of the vertices to the grid intersections
  - Apply deformations to the grid
  - Recalculate the deformed vertex positions using bilinear interpolation
- □ Allows for more-efficient recalculation
- □ Makes it easier for the animator to specify deformation

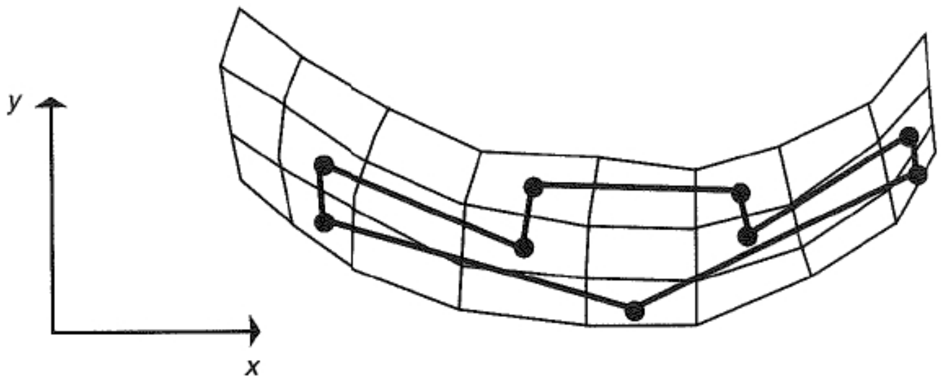
2D Shape Deformation (cont.)



(1–u)

$$P_{u0} = (1 - u)P_{00} + uP_{10}$$
$$P_{u1} = (1 - u)P_{01} + uP_{11}$$
$$P_{uv} = (1 - v)P_{u0} + vP_{u1}$$
$$= (1 - u)(1 - v)P_{00} + (1 - u)vP_{01} + u(1 - v)P_{10} + uvP_{11}$$

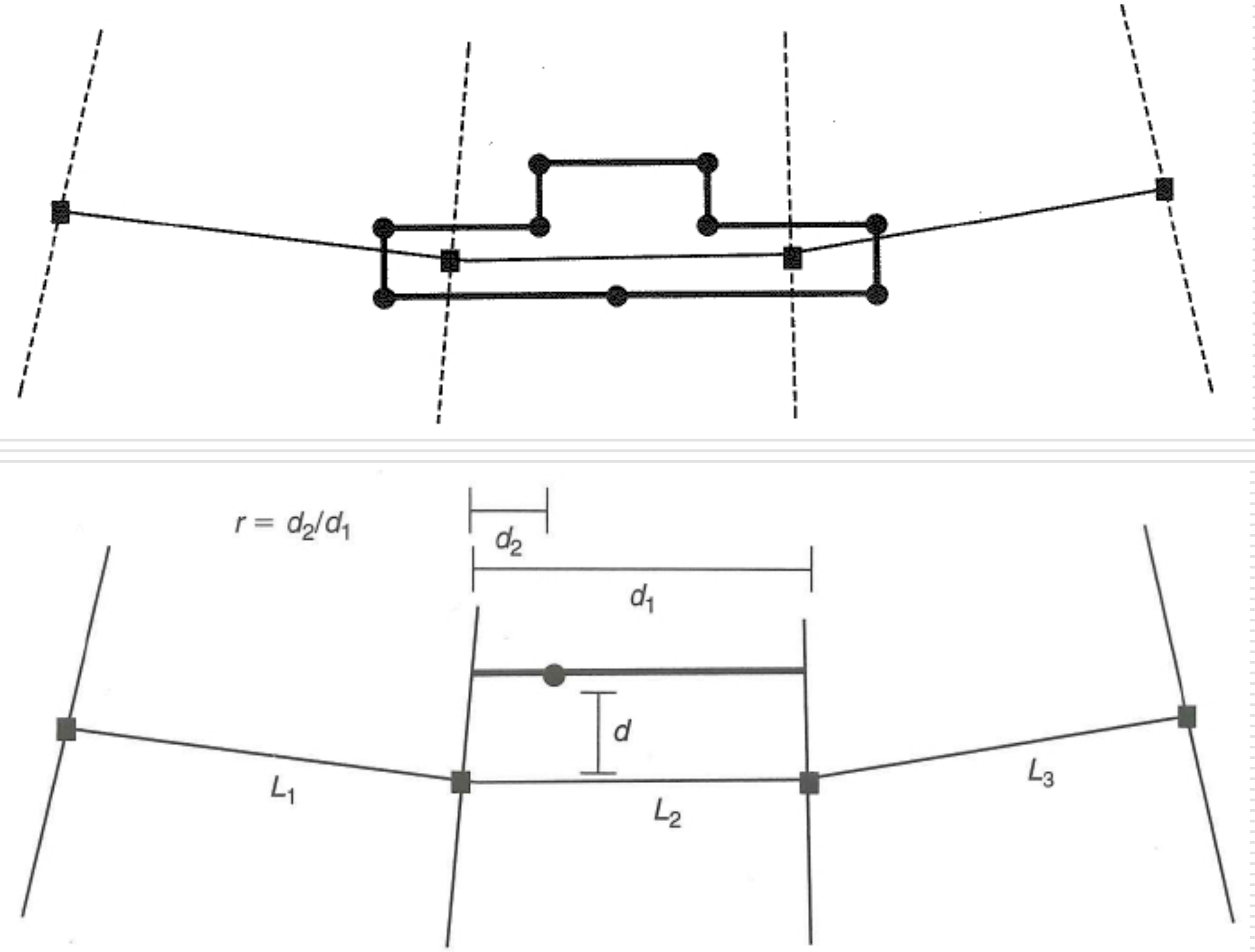




Polyline Deformation

- □ Similar to grid deformation
- □ Calculate the relative position of the vertices to a polyline
- □ Good for snakes, tentacles, etc.

Polyline Deformation (cont.)



Free Form Deformation (FFD)

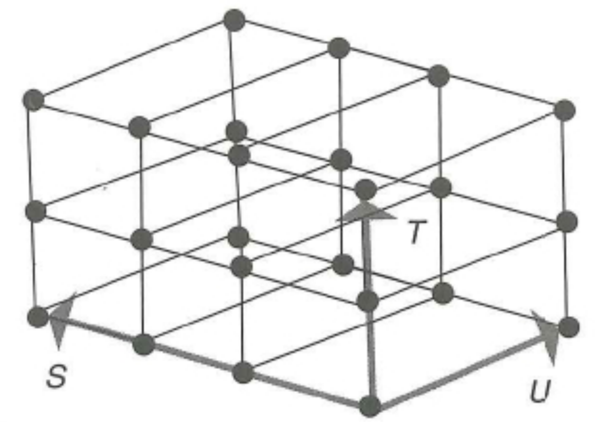
- Extend 2D technique to 3D
  - Use cubic (or other) interpolation instead of bilinear
  - Embed the shape within a grid defined by three axes
  - Record the locations of the vertices within the grid
  - Deform the grid
  - Calculate the new positions

FFD (cont.)

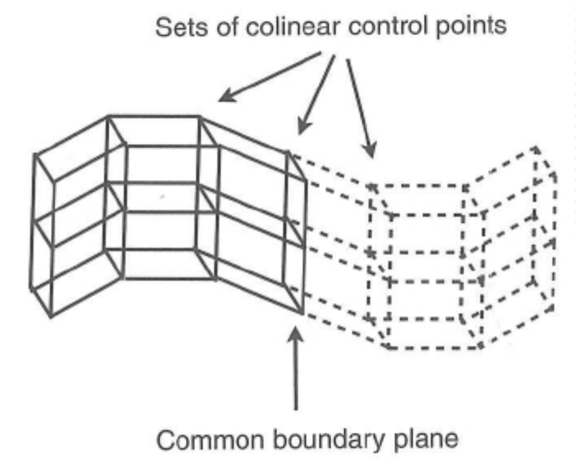
- Continuity can be insured in the same way as in 2D
- FFDs can be applied in sequence or hierarchically as well.
- Animation can be carried out by
  - Moving the control points over time
  - Moving the shape through the distorted space
  - Can define a "tool" and deform shapes with it

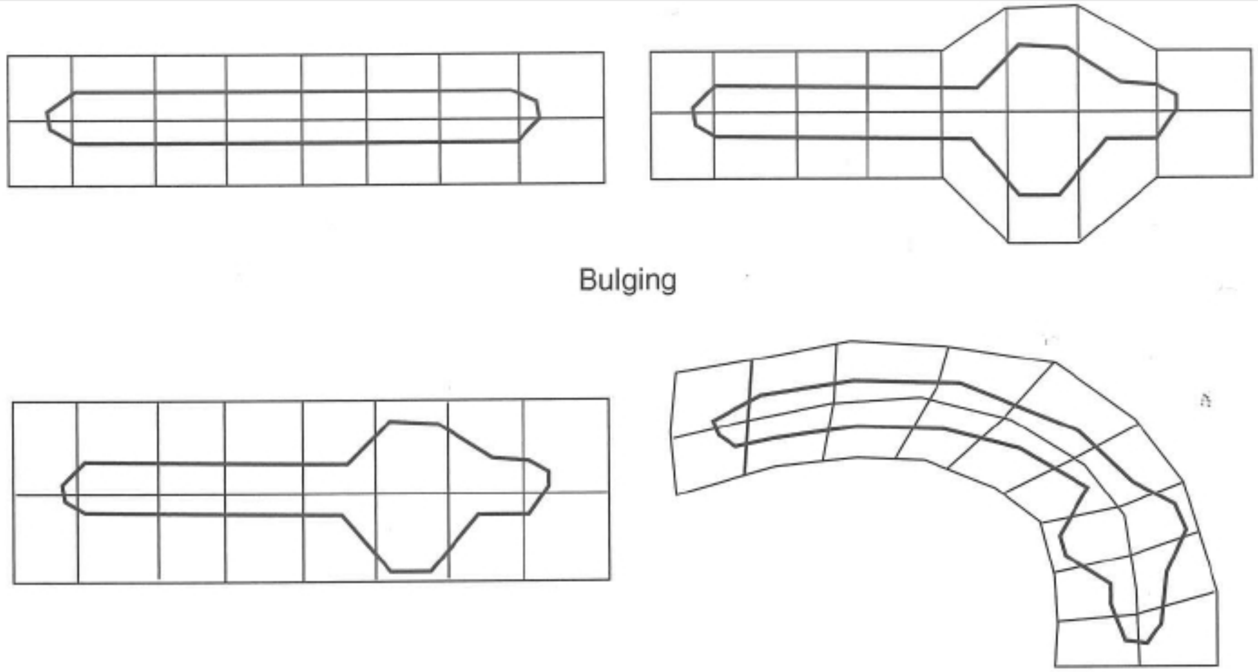
FFD Animation

- Control points can be deformed based on
  - Physical simulation, e.g., a ball hitting a sponge
  - Key framing
  - Facial simulation (e.g., bones, muscles, etc.)
  - Any function you can think of!



FFD Animation (cont.)

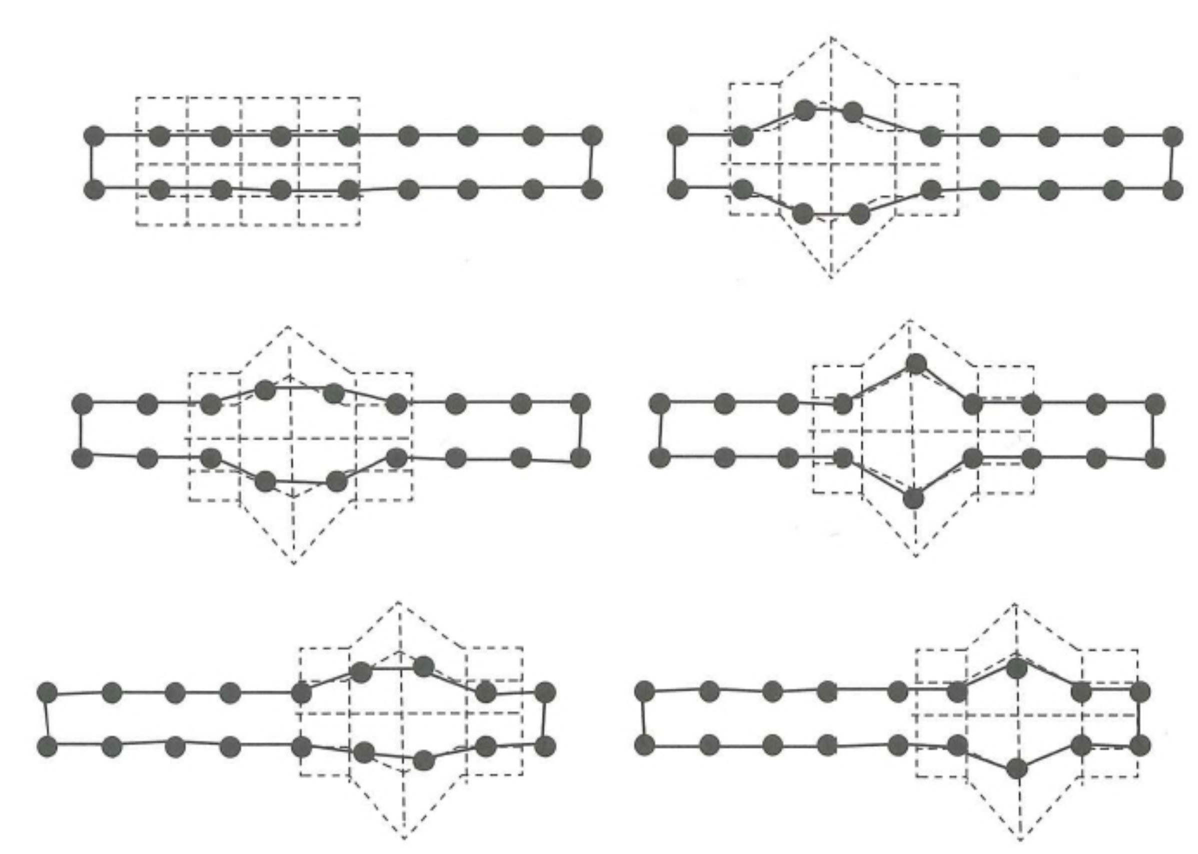



Bulging

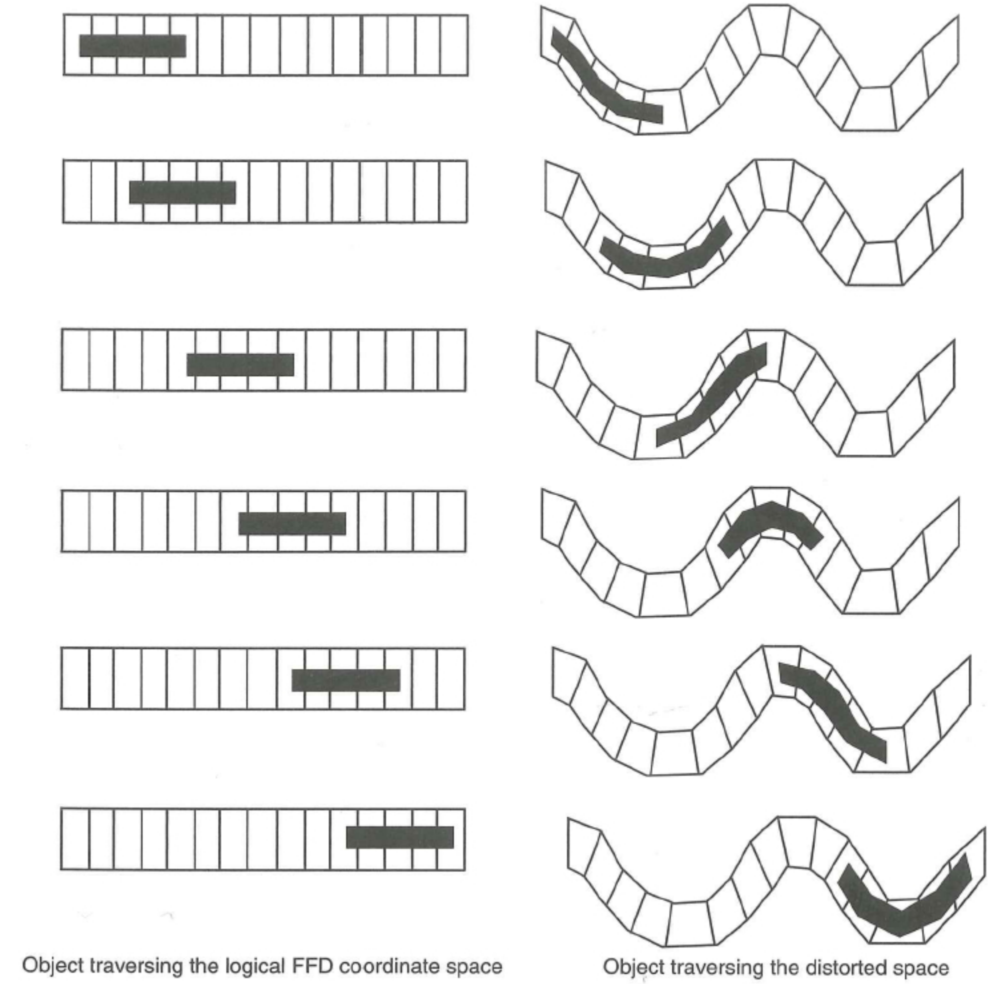
Bending

FFD Animation (cont.)

- "Tools" for distortion



FFD Animation (cont.)



Object traversing the logical FFD coordinate space

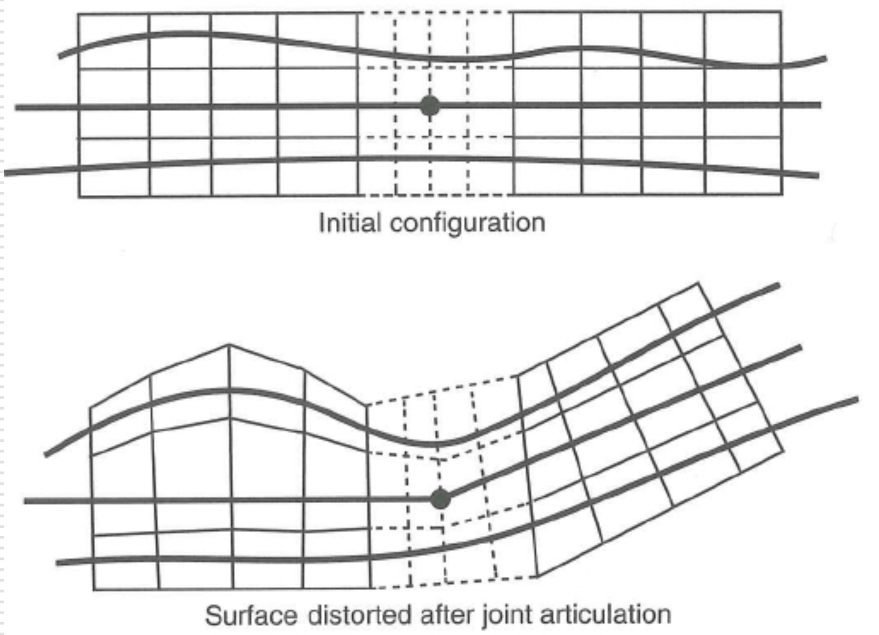
Object traversing the distorted space

Bones, Joints & Muscles

- How does all this relate to modern tools for animating figures?
- Bones as reference objects
  - Link length, joints, etc.
  - Bone movement constrained by muscles, etc.
- Skin defined in space as a spring-mass model
- Deformation is a combination of FFD & springs

Bones, Joints & Muscles (cont.)

- □ Bones move
- □ FFD lattice "anchored" to bone
- □ Spring-mass model moves FFD control points



Initial configuration

Surface distorted after joint articulation

3D Morphing

- Smoothly change one 3D shape into another
- Two main approaches
  - Volume based
  - Surface based
- Which one to use depends on properties of the shapes, and the desired effect

WPI

Volume-Based 3D Morphing

- □ Represent each shape shape as a volume
- □ Morph one volume to another
- □ Can be expensive
- □ Does not take into account properties that might be important for animation
- □ Not used as much as surface-based morphing

Terms Used in Surface-Based

- Object
  - Entity that has 3D surface geometry
- Shape
  - Set of points in object space that make up an object's surface
- Model
  - Any complete description of the shape of an object
- One 3D ***object*** may have several ***models*** that describe its ***shape***

More Terms

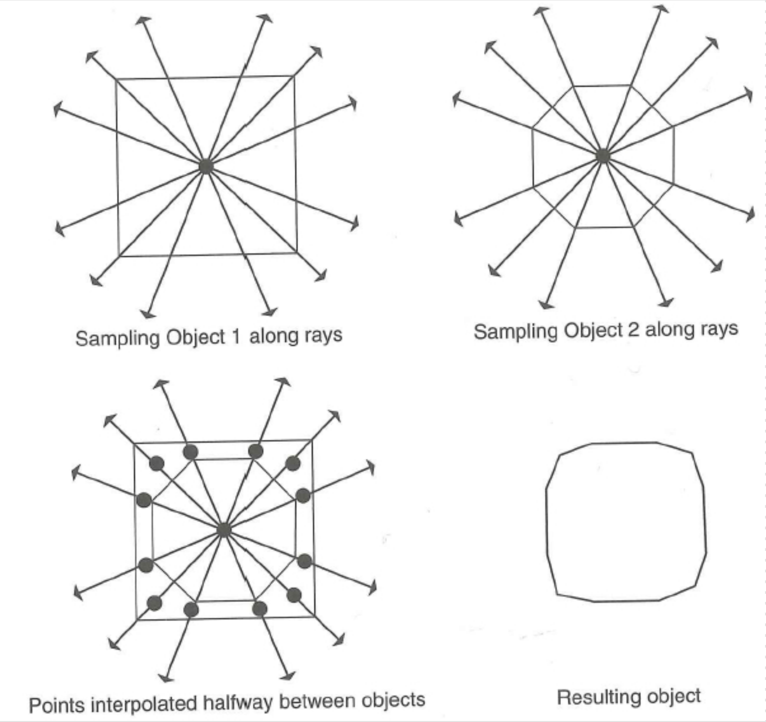
- Topology
  - The number of holes an object has, and the number of bodies in the object
  - The vertex/edge/face connectivity of a polyhedron
- Genus
  - How many holes an object has
  - Sphere is *genus 0*
  - Doughnut is *genus 1*

Surface-Based 3D Morphing

- Two main problems to solve
  - Vertex correspondence problem
    - Finding a mapping for each vertex on one shape to a vertex on the other
  - Interpolation problem
    - Creating a set of intermediate objects that move from one to the other
- Shapes typically have different surface topologies
  - Connectivity of vertices
  - Some objects may have "holes" in them

Surface-Based 3D Morphing (cont.)

- If the topologies match
  - Just interpolate 3D vertex positions over time
- If star-shaped object
  - Find distance to point in *kernel*, and interpolate


Sampling Object 1 along rays
Sampling Object 2 along rays
Points interpolated halfway between objects
Resulting object

Mapping Onto a Sphere

- Several approaches
  - Project all vertices, edges, etc. onto the surface of a sphere
  - Then take the union of the vertices/edges for both objects
  - Then project back
  - Then perform vertex-by-vertex interpolation
- Can lead to an explosion of new edges
- Does not attempt to match edges
- Other approaches (in book) try this

2D Morphing

- Usually an image-based post-process
- Transform a *source image* into a *destination image*
- Main task
  - Identify corresponding features of the two images.
- Two main approaches
  - User-defined coordinate grid
  - Feature lines

User-defined Coordinate Grid

- Image-based approach
- User defines a curvilinear grid, where main features lie within corresponding grid squares
- Intermediate images are generated by
  - Interpolating the grid points
    - Linear, or higher-order using adjacent key frames
  - Stretching/compressing pixels from the source to the intermediate, and from the destination to the intermediate
- The two images are cross dissolved

User-defined Coordinate Grid (cont.)

- □ Grids

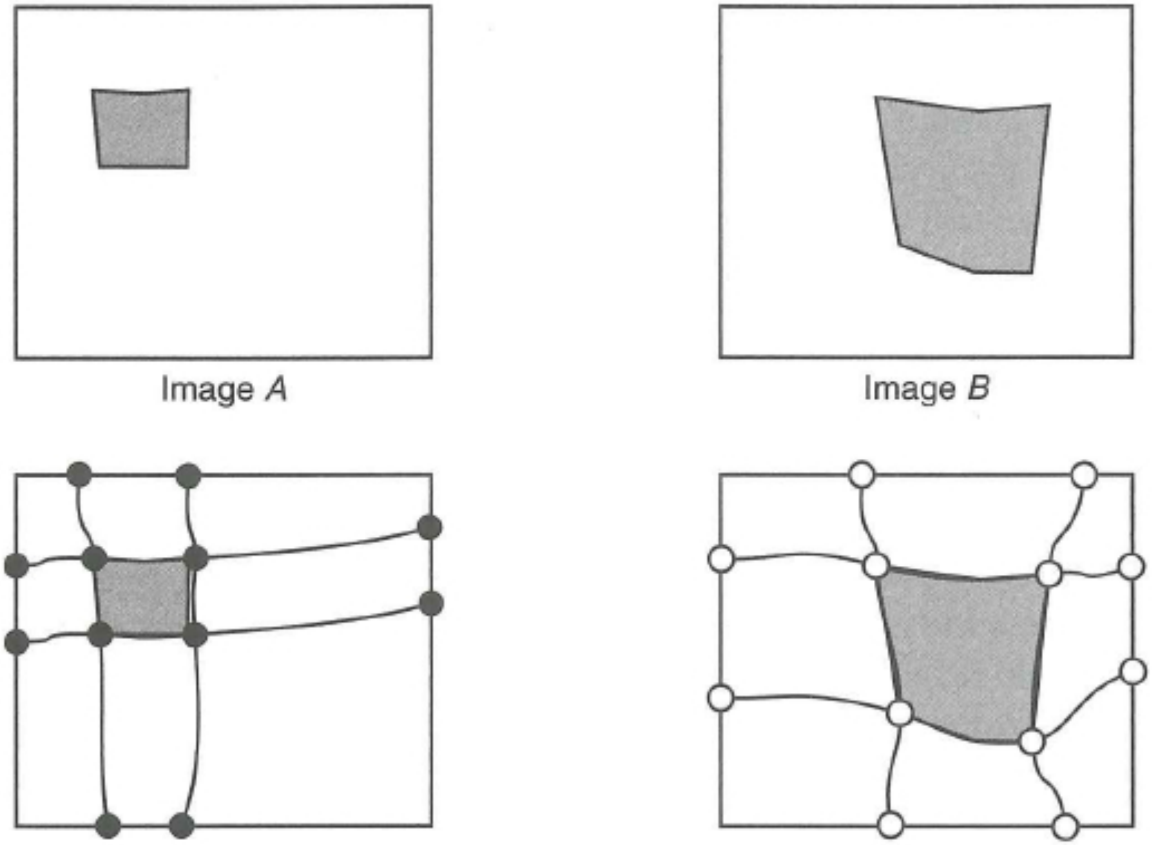


Image *A*

Image *B*

Image *A* with grid points and curves defined

Image *B* with grid points and curves defined

Feature-based Morphing

- User specifies pairs of lines on source and destination images
  - Lines should cover some features
- A mapping for each pixel to each feature line in each image is established
- Intermediate line locations are then determined using interpolation
  - Either endpoints, or center+orientation
- A weighted average is used to generate the intermediate images
- Cross-dissolve is again used

Some Examples

- http://davis.wpi.edu/~matt/courses/morph/
- http://morph.cs.st-andrews.ac.uk/fof/index.html
- http://www.fantamorph.com/index.html