3D Morphing

3D preobrazba polž-žaba

Demo

Področja uporabe

- Scientific Visualization
- Education
- Entertainment
- Computer Animation
  - gives the animator the ability to “fill” an animation between key-framed objects

Kako izvedemo preobrazbo

- To interpolate object shapes
- To interpolate object attributes including color, textures, and normal fields

Dobra preobrazba

- **Natural**
  - Keep as much as possible of the two shapes during the transformation
  - They are subjective aesthetic criteria
- **Need user control**
  - intuitive
  - not too heavy
  - can be adapted to user’s knowledge

The problem of blending two surfaces, even polyhedral ones, is not simple.

In order to blend two polyhedral models, most techniques require establishing a full correspondence between their structures

However, a correspondence alone does not guarantee a smooth transition from the source model to the designated model, and the vertices’ paths have to avoid troublesome situations such as self-intersections.

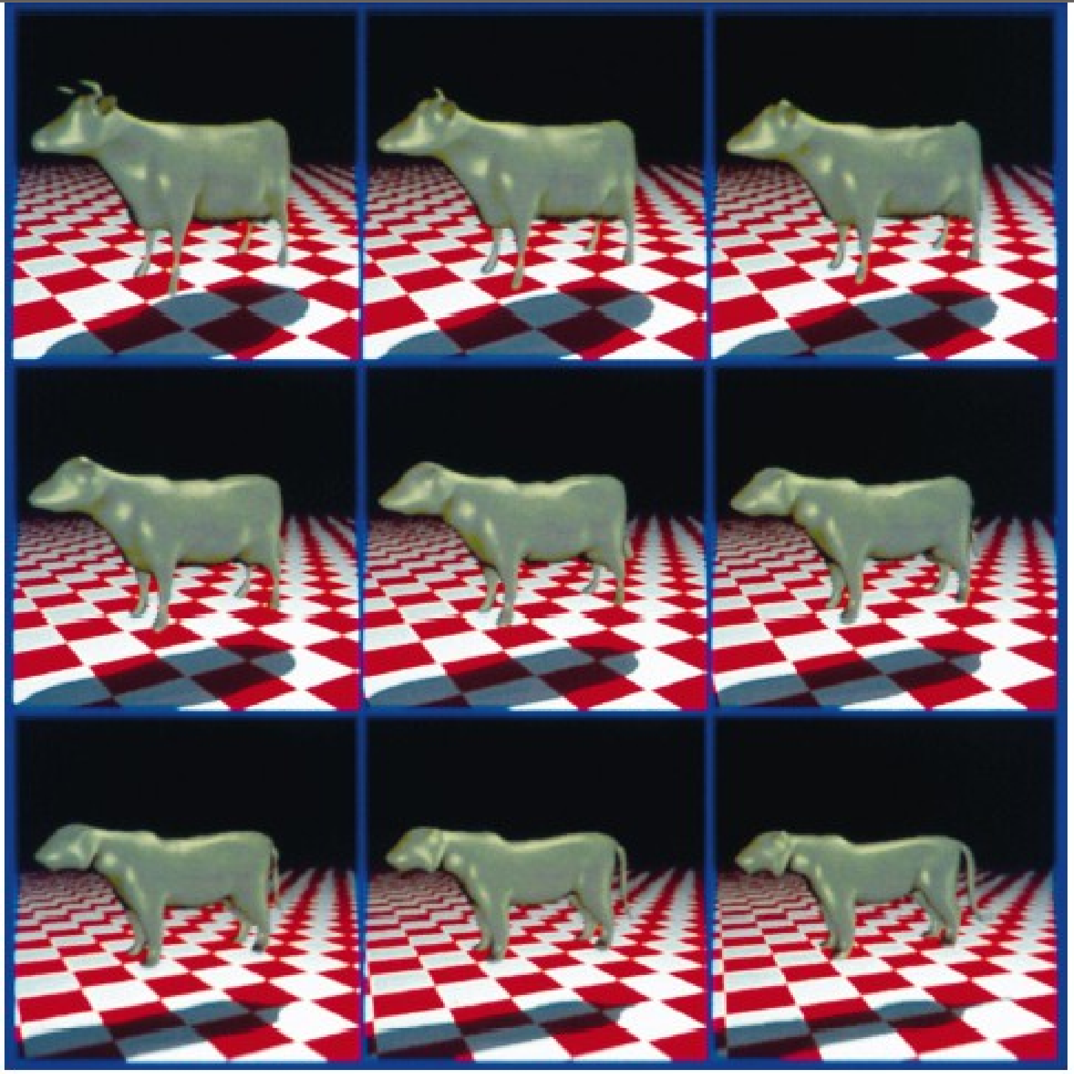
Klasifikacija metod

- Boundary representations-based approaches
- Volume-base approaches

3D preobrazba

- What is 3D morphing ?
  - A 3D model of the object is transformed from one shape into another.
- Why 3D morphing ?
  - Morphs are independent of viewing and lighting parameters.
  - View-dependent effects possible e.g., shadows, highlights, camera can be animated during the morph.
  - Traditional 2D morphs are inherently “flat” looking.
- Features of a Good 3D morphing algorithm
  - Conceptually Simple
  - Minimal topological restrictions.
  - Easy to use user-control

3D preobrazba krave v tigra



3D morphing between a cow and a tiger. Note that the camera roams during the animation and the model casts a shadow that evolves according to the shape of the 3D model. Such view-dependent effects are impossible with image-space metamorphosis.

Mehka animacija objektov

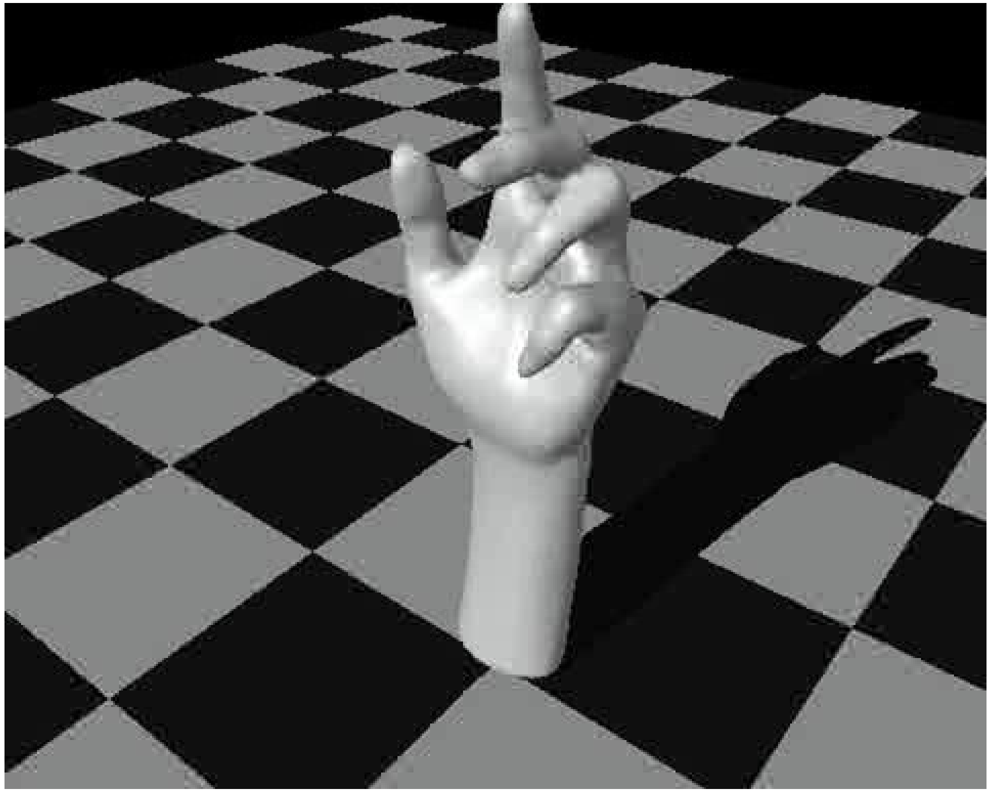
- Import the tricks from traditional animation into computer animation
  - Give characters a pseudopersonality
  - Stretch and squeeze is used to highlight dynamic action such as deceleration due to collisions
    - shape distortion

Razlika med mehko animacijo objektov in modeliranjem

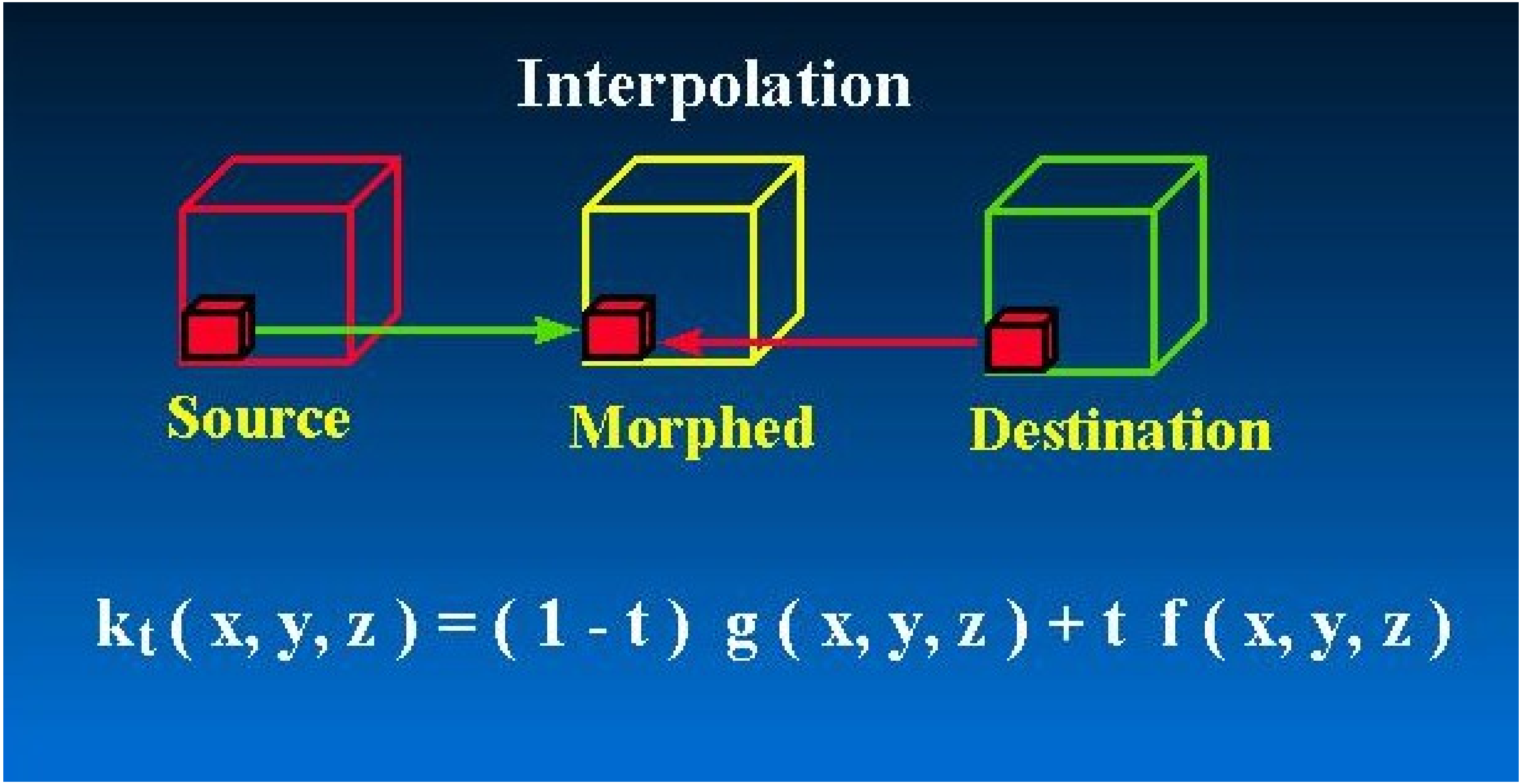
- It blurs the traditional distinction between modeling and animating
  - a different model is created for each frame
  - animate the data that represents the model

3D preobrazba

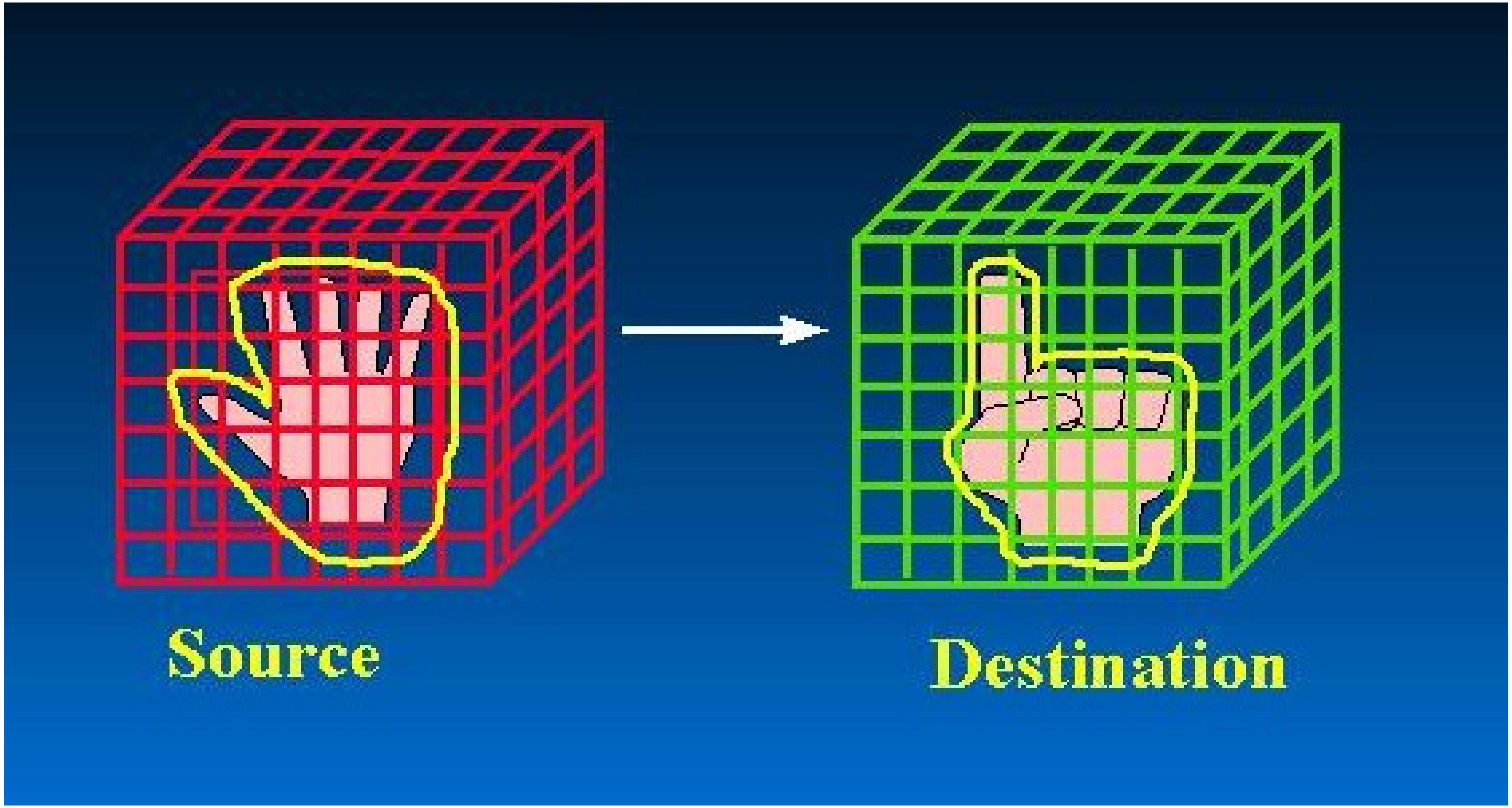
Given two objects, metamorphosis involves producing a sequence of intermediate objects that gradually evolve from one object to the other.



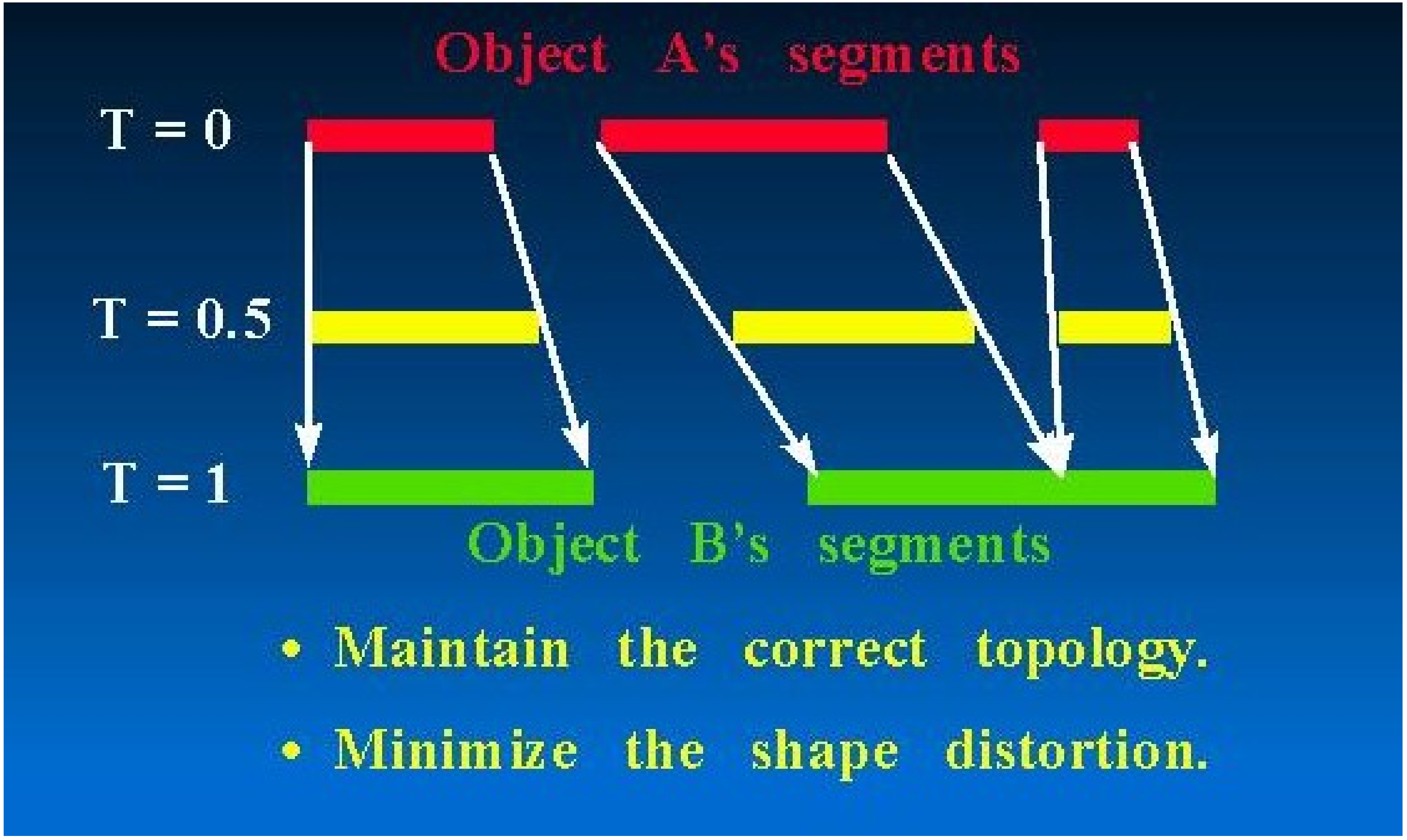
Naivna 3D preobrazba



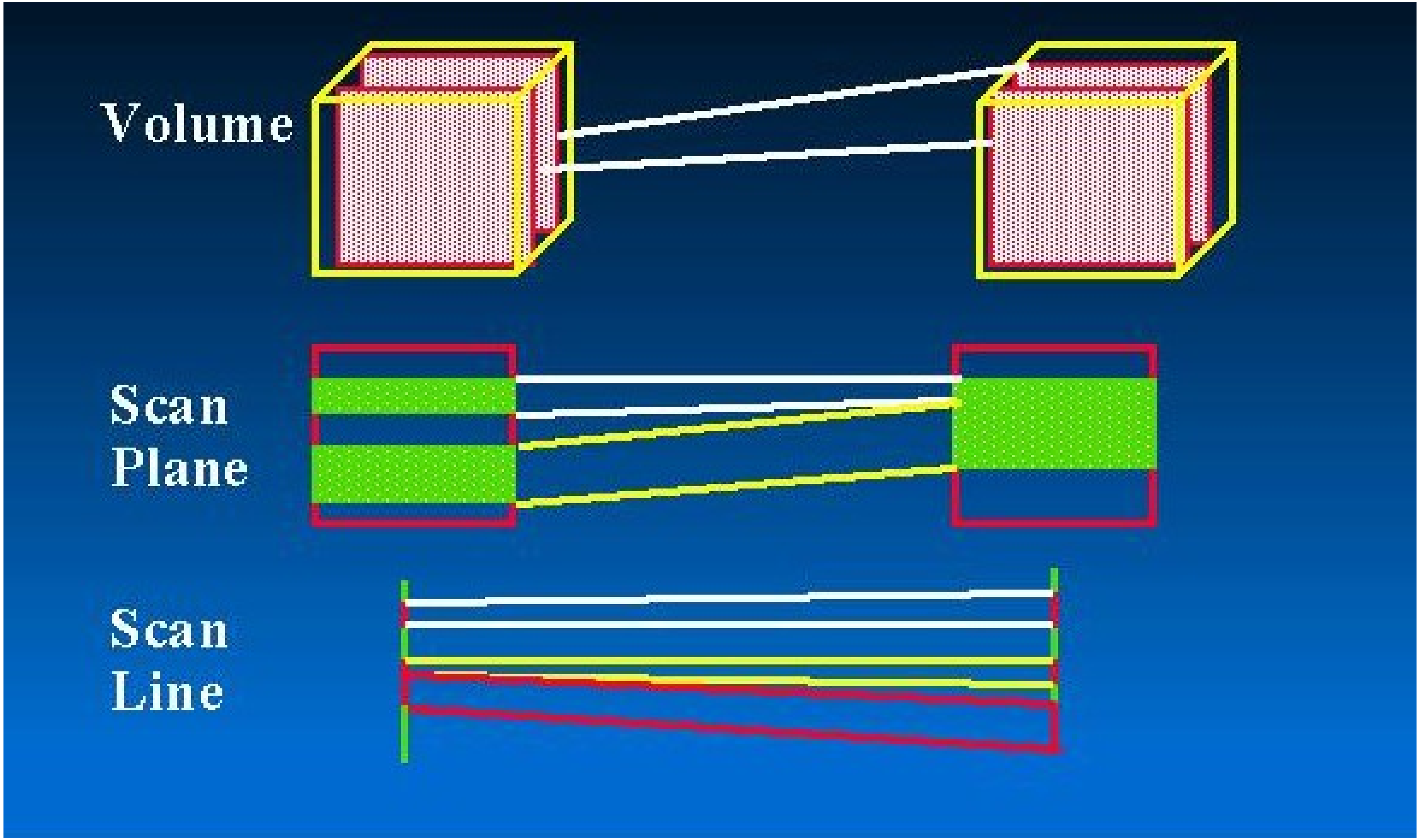
Problem korespondence



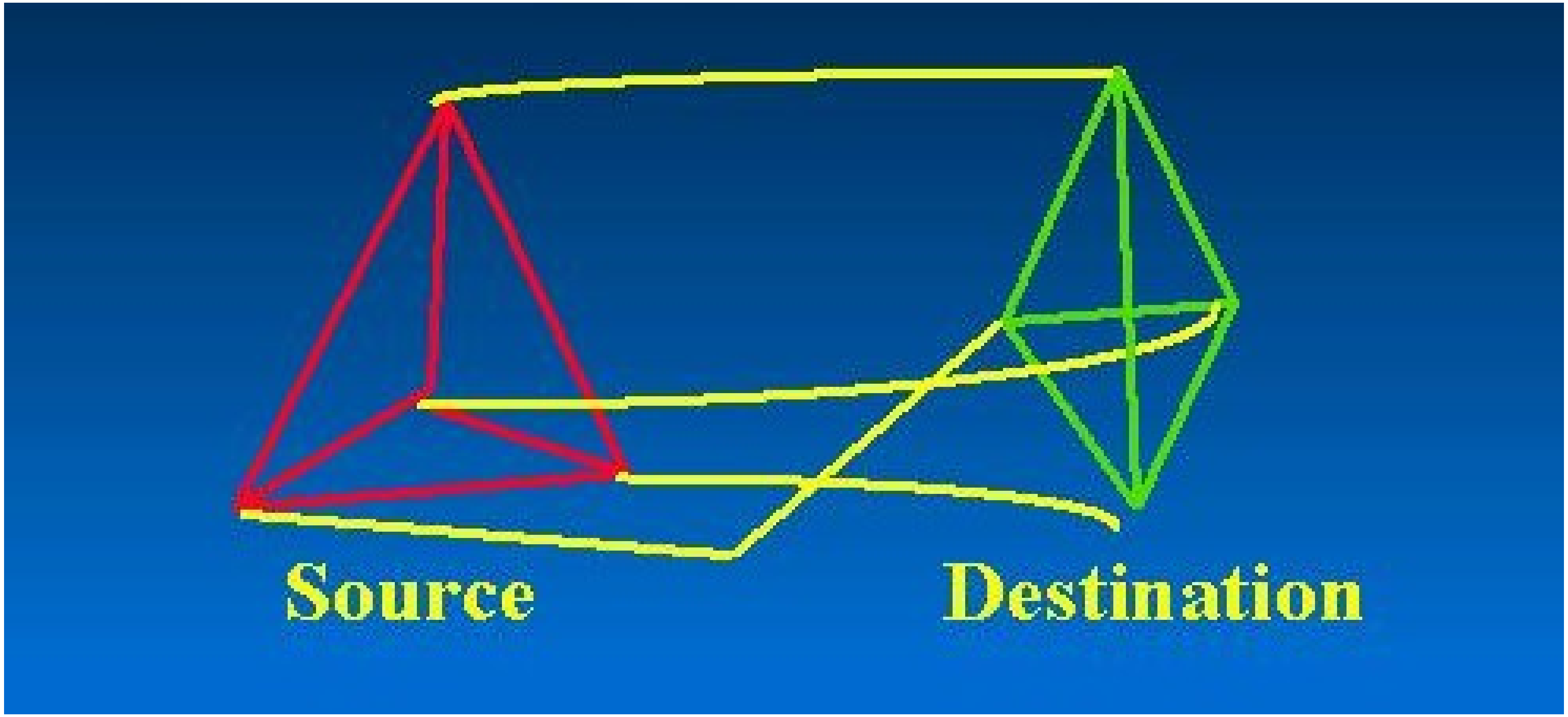
Problem korespondence v 1 dimenziji



Problem korespondence v 3 dimenzijah

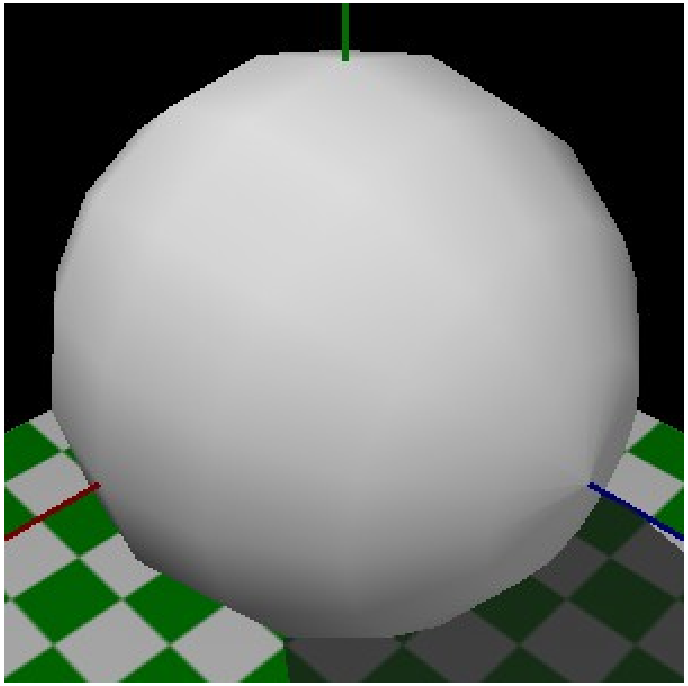


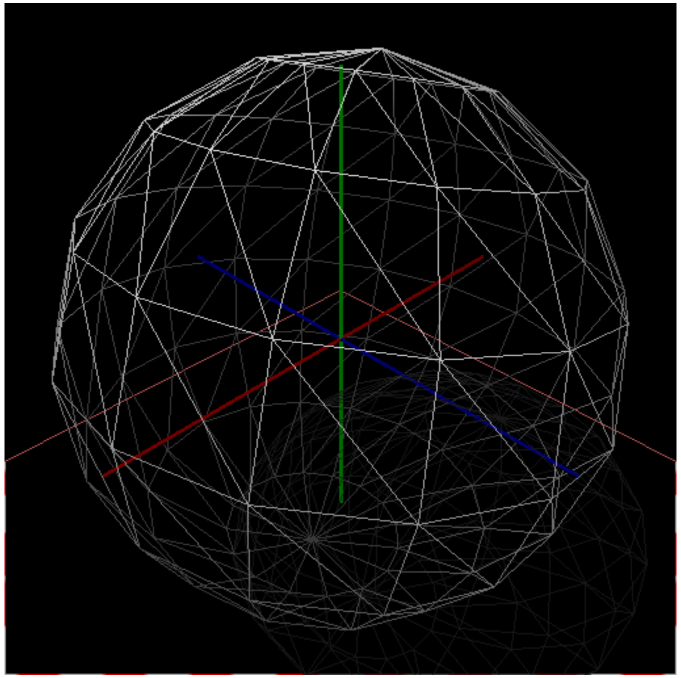
Preobrazba na osnovi poligonov

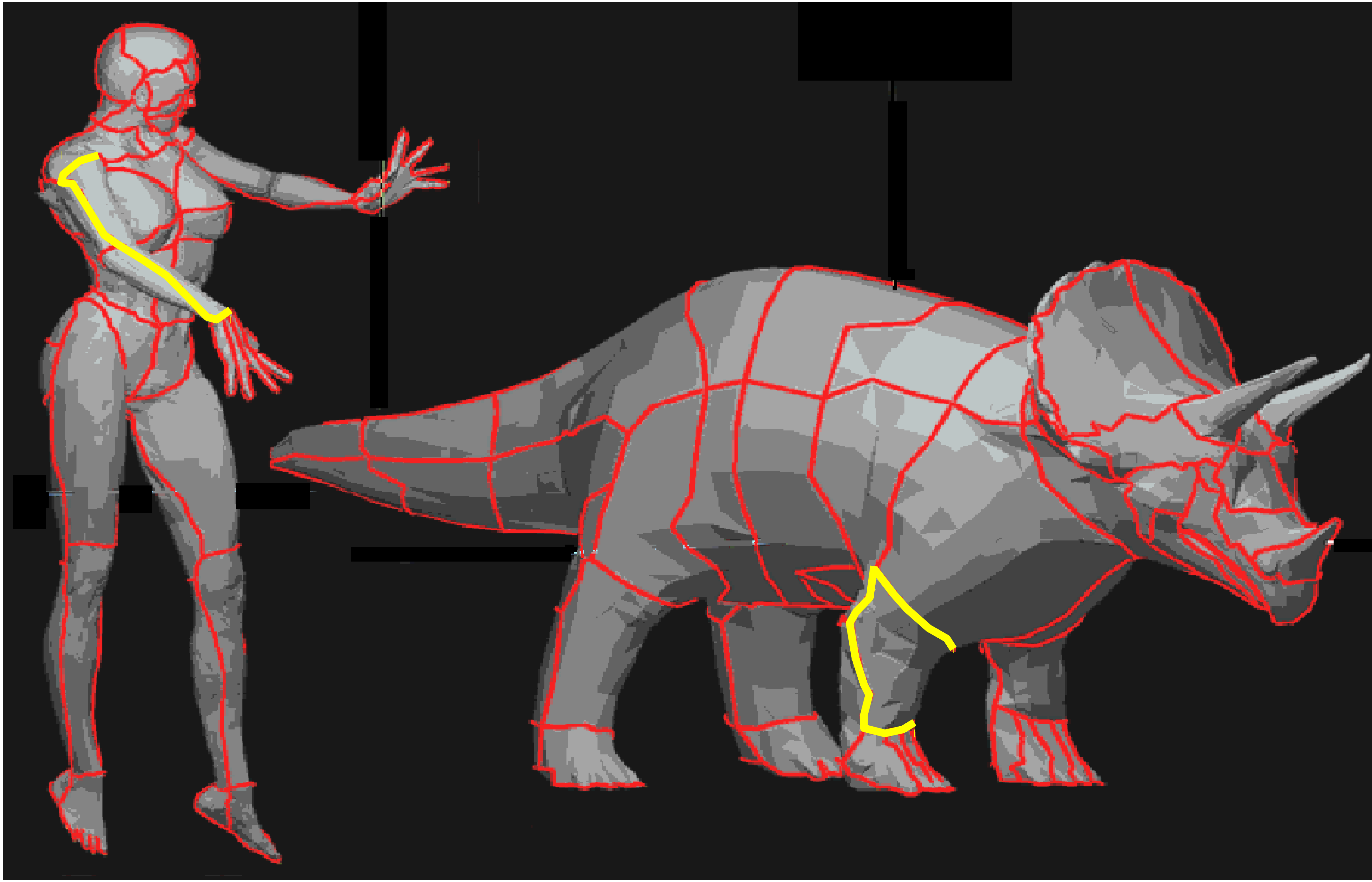


3D model

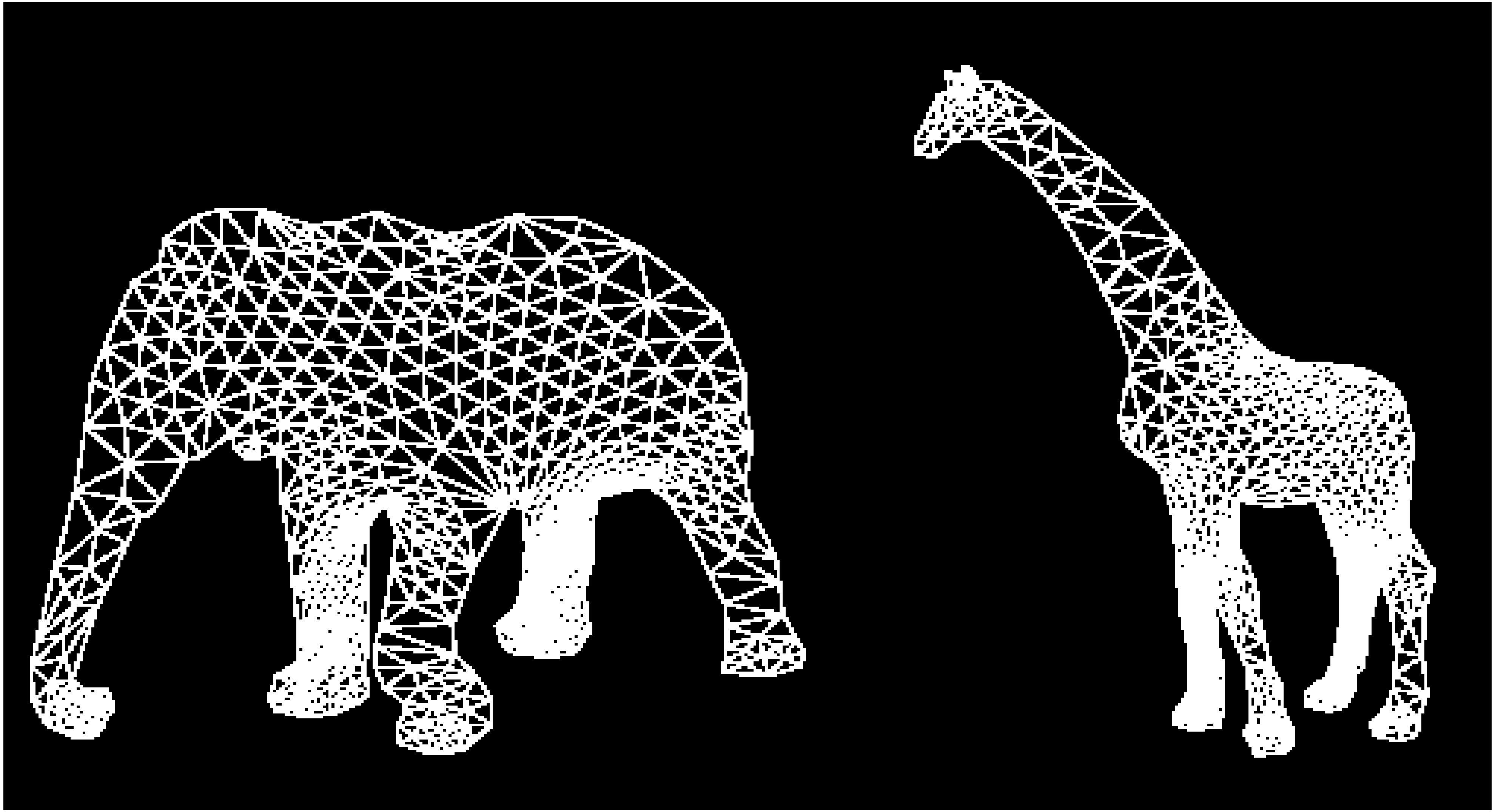
Model → Polygons (triangles) → vertices → Other parameters (normals, textures)



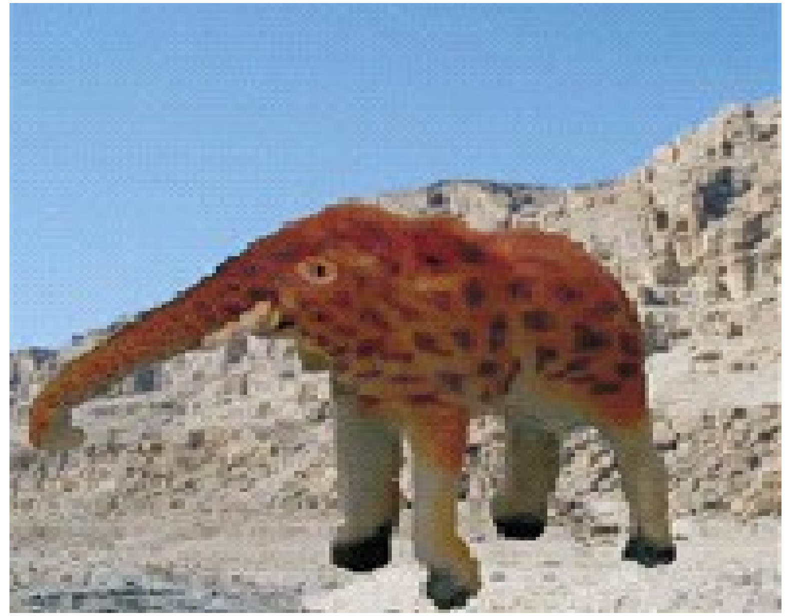


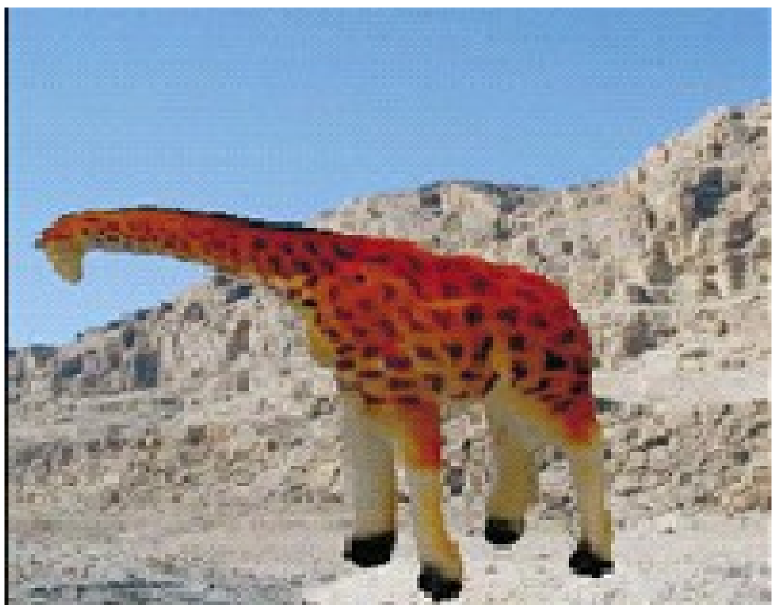


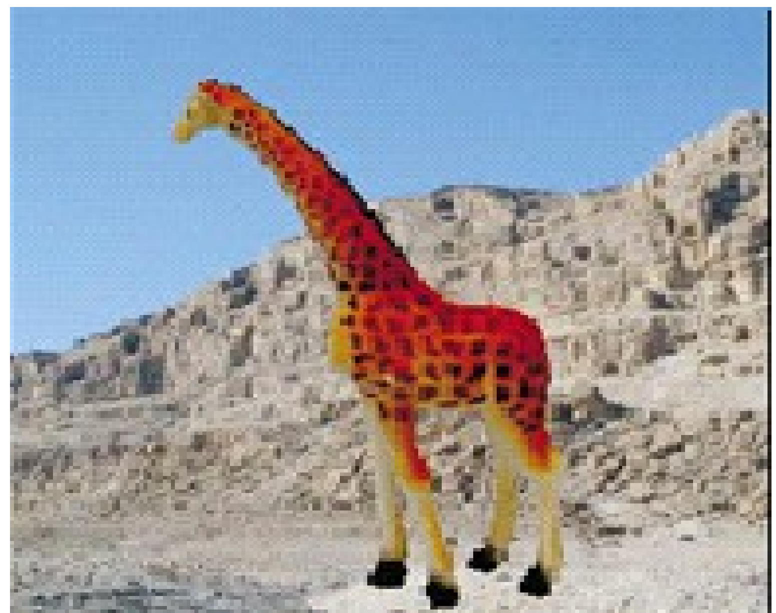
3d preobrazba slon žirafa 1



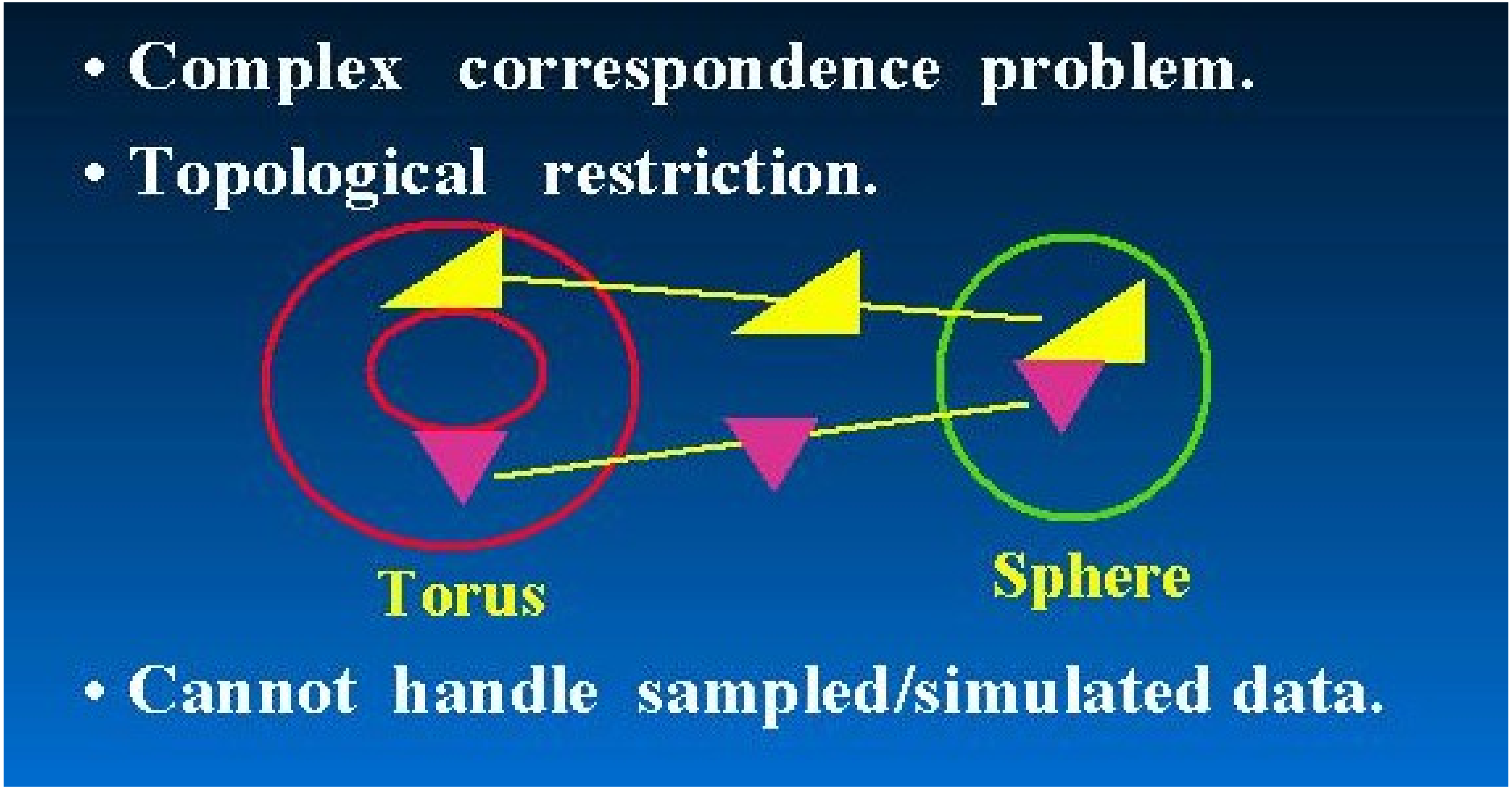
3d preobrazba slon-žirafa 2







Omejitve preobrazbe, temelječe na poligonih

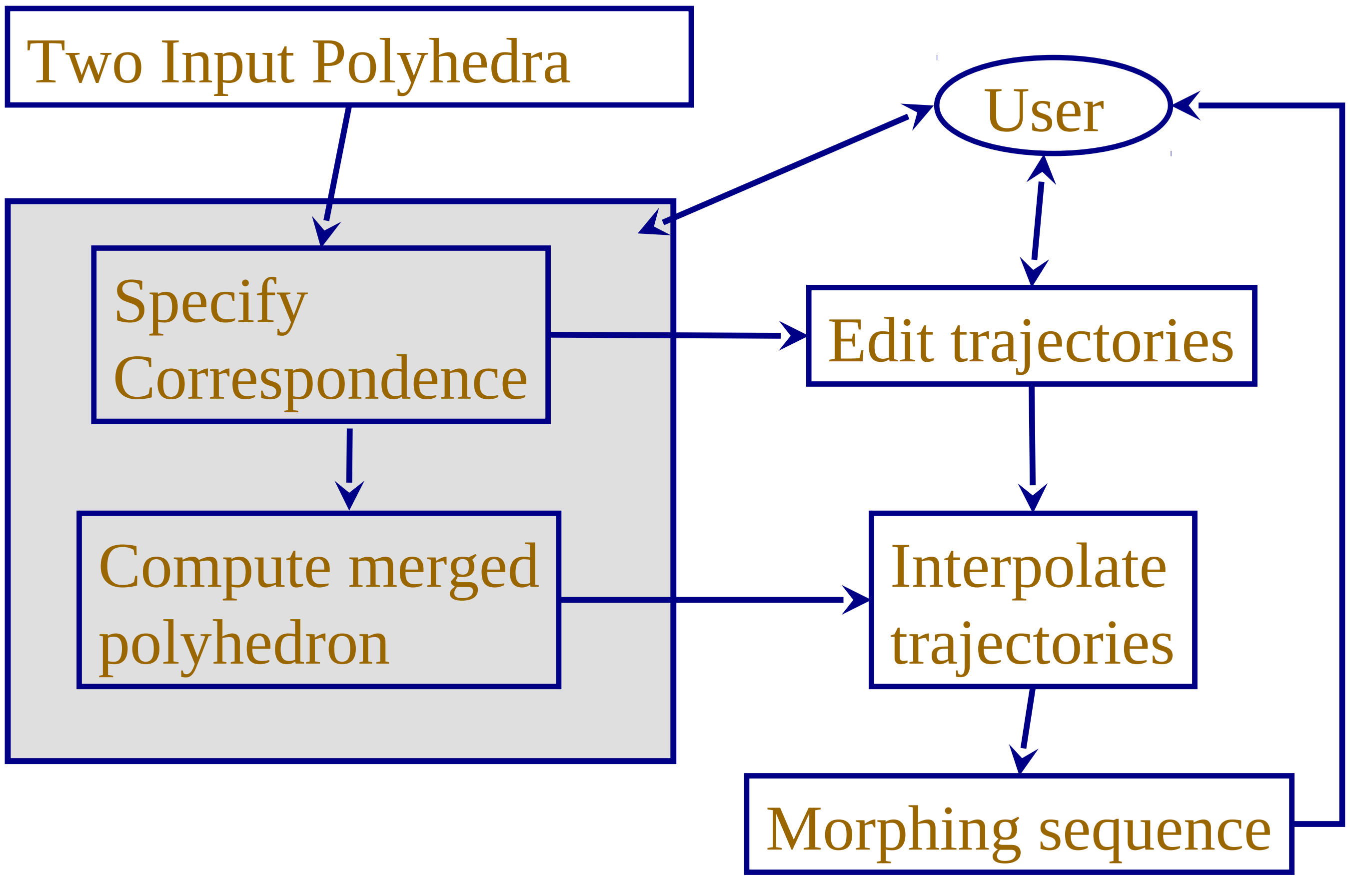


B-rep Based 3D morphing

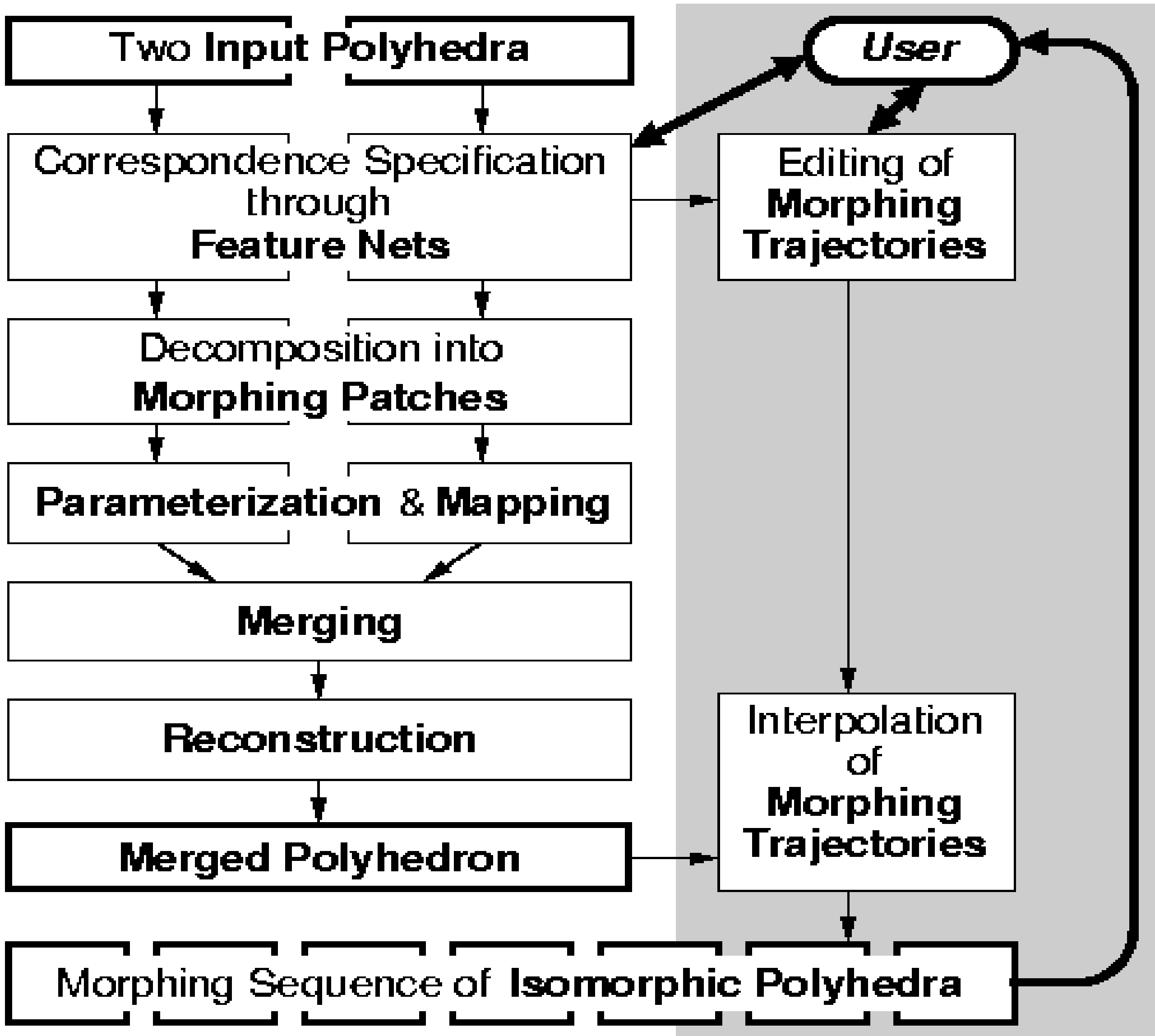
- **Polyhedral Morphing Using Feature-Based Surface Decomposition**

- A. Gregory, A. State, M. C. Lin, D. Manocha, and M. A. Livingston. Interactive surface decomposition for polyhedral morphing. The Visual Computer (1999) 15:453-470

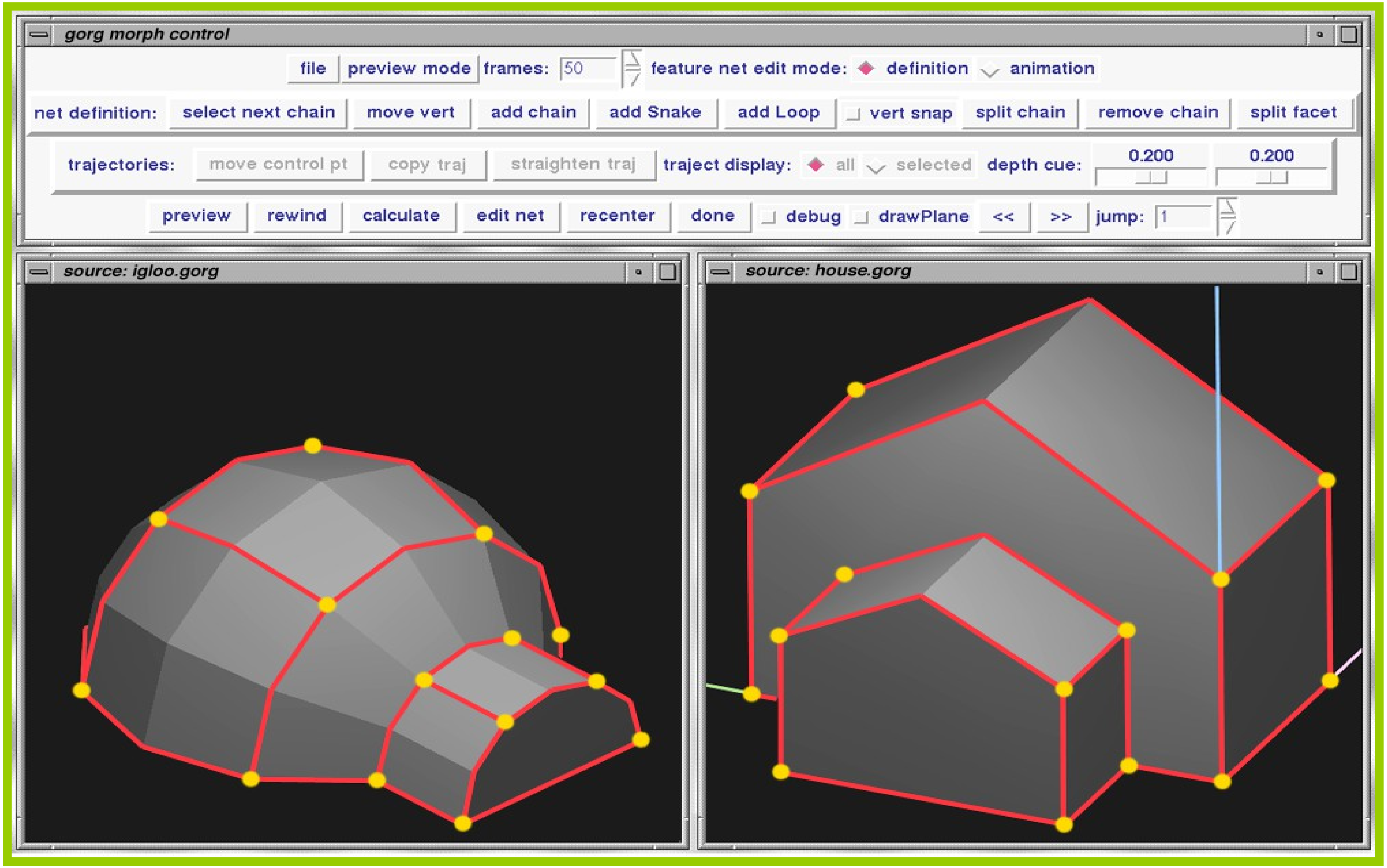
Postopek 3D preobrazbe



Arhitektura sistema



Specificiranje korespondence



Kaj mora narediti uporabnik

- The users only need to specify a few corresponding pairs of features on the two polyhedra.

- They can then specify the trajectories along which these features travel during the morph using Bezier curves, as shown below

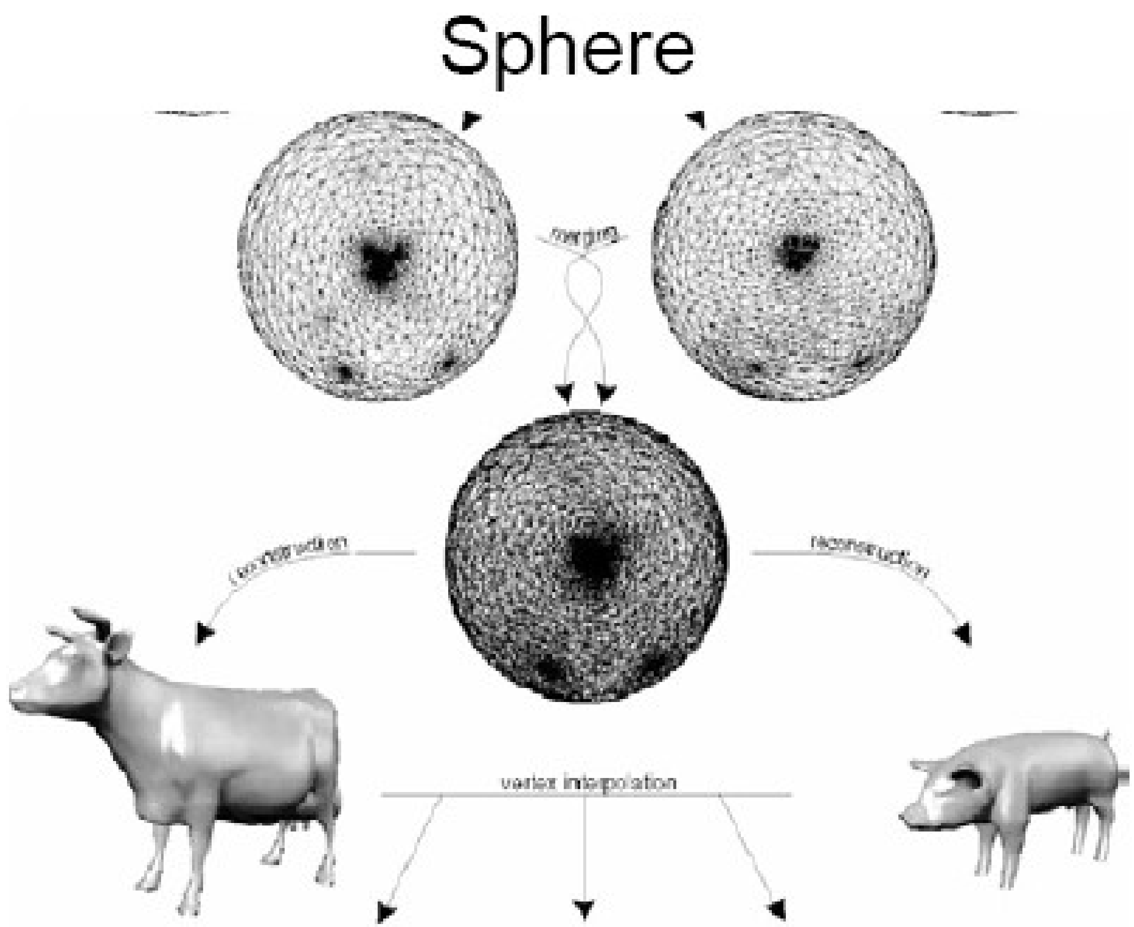
Skupna povezljivost

- Input: two models parameterized on common domain
- Output: both models remeshed with common connectivity (preserving point correspondence)
- Methods:
  - Overlay
  - Subdivision meshing

Prevleka (Overlay)

- Map both models to base domain
  - Sphere: use spherical mapping
  - Base mesh: use one pair of patches at a time
- Merge vertex-edge graphs
- Reconstruct facets

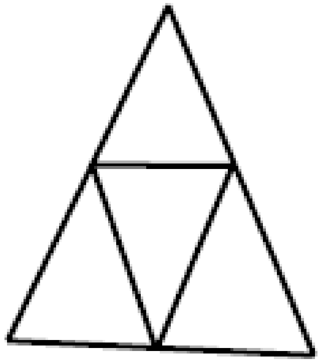
Preslikava na kroglo

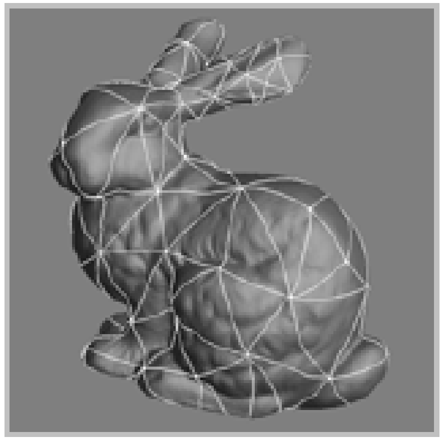


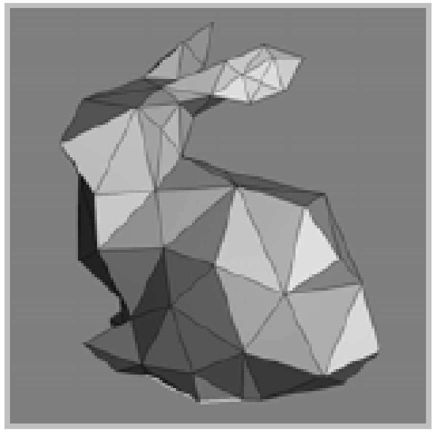
- All computations (intersections, etc..) on sphere

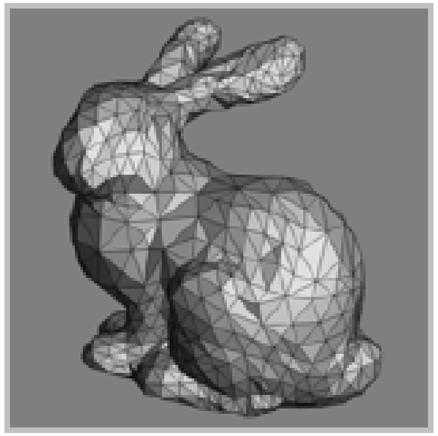
Predelava mreže z delitvijo

- Works for triangular base mesh
- Mesh each base mesh triangle to required density using subdivision pattern
- Project back to source/target meshes using parameterization









Primerjava metod

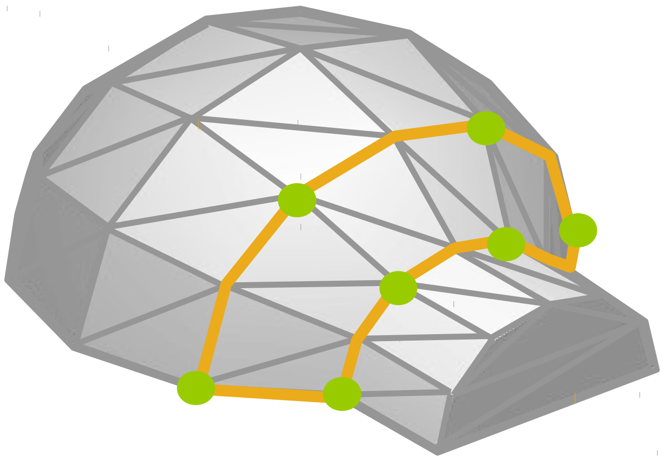
- Overlay
  - Pros:
    - Preserves source/target geometry
    - Not ‘very’ affected by parameterization distortion
  - Cons:
    - Increases mesh size by x10
    - Very labor intensive to implement
- Subdivision
  - Pros:
    - Simple
    - Nice mesh if patch layout is good
  - Cons:
    - Approximation only – depend on resolution
    - Depends very strongly on patch shape & parametric distortion

Računanje korespondence

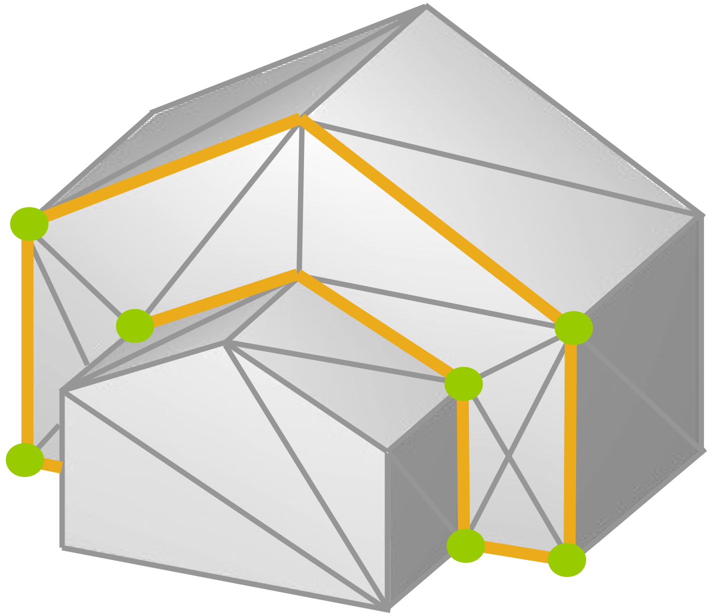
- Feature-Nets decompose input polyhedra into morphing patches
- For each corresponding Morphing Patch pair:
  - map both onto a 2D polygon
  - merge the vertex-edge graphs
  - reconstruct the facets

Računanje korespondence

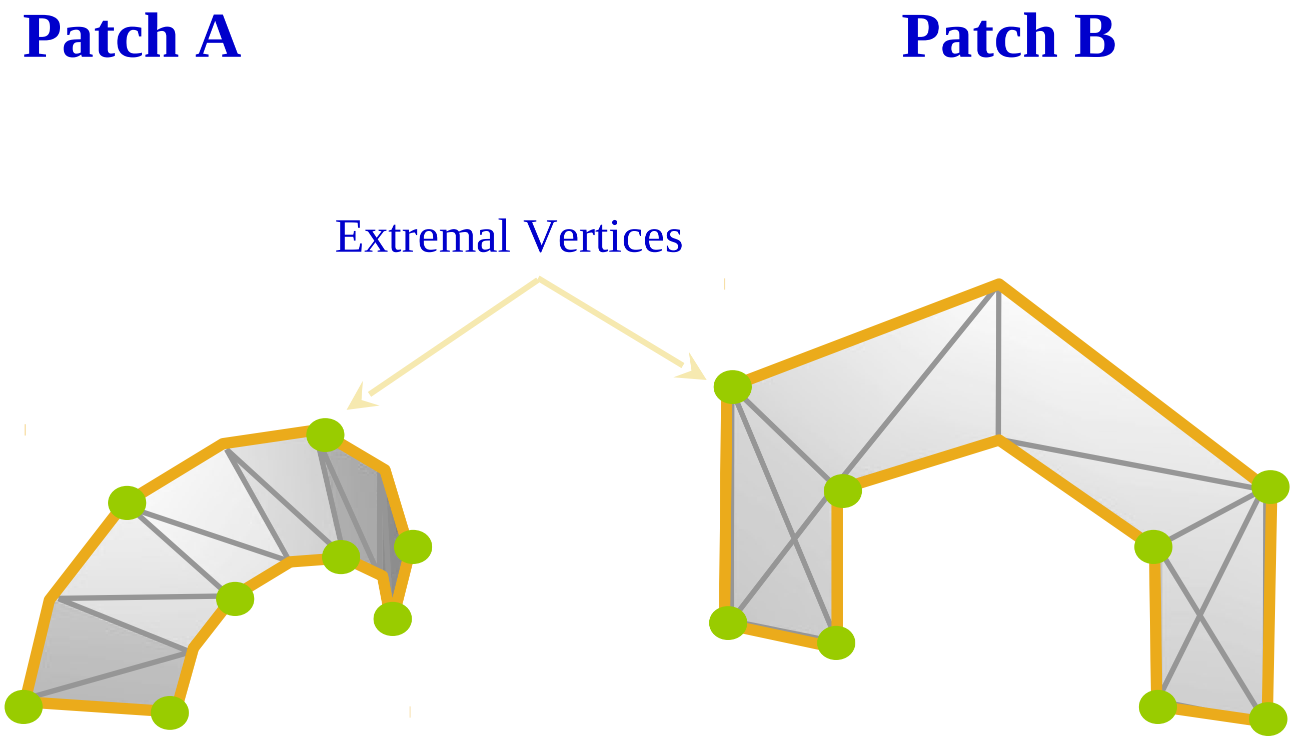
A (Igloo)



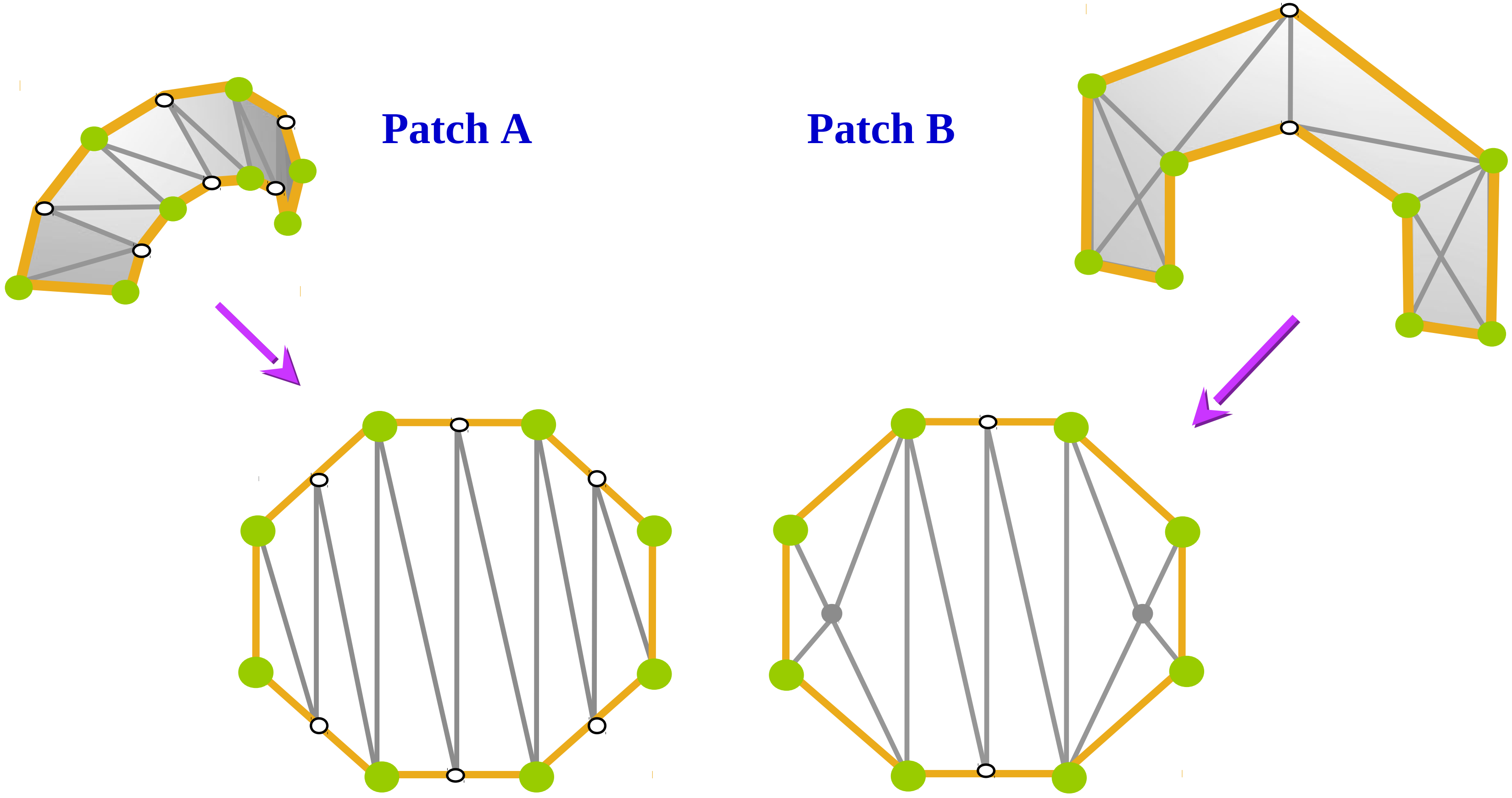
B (House)



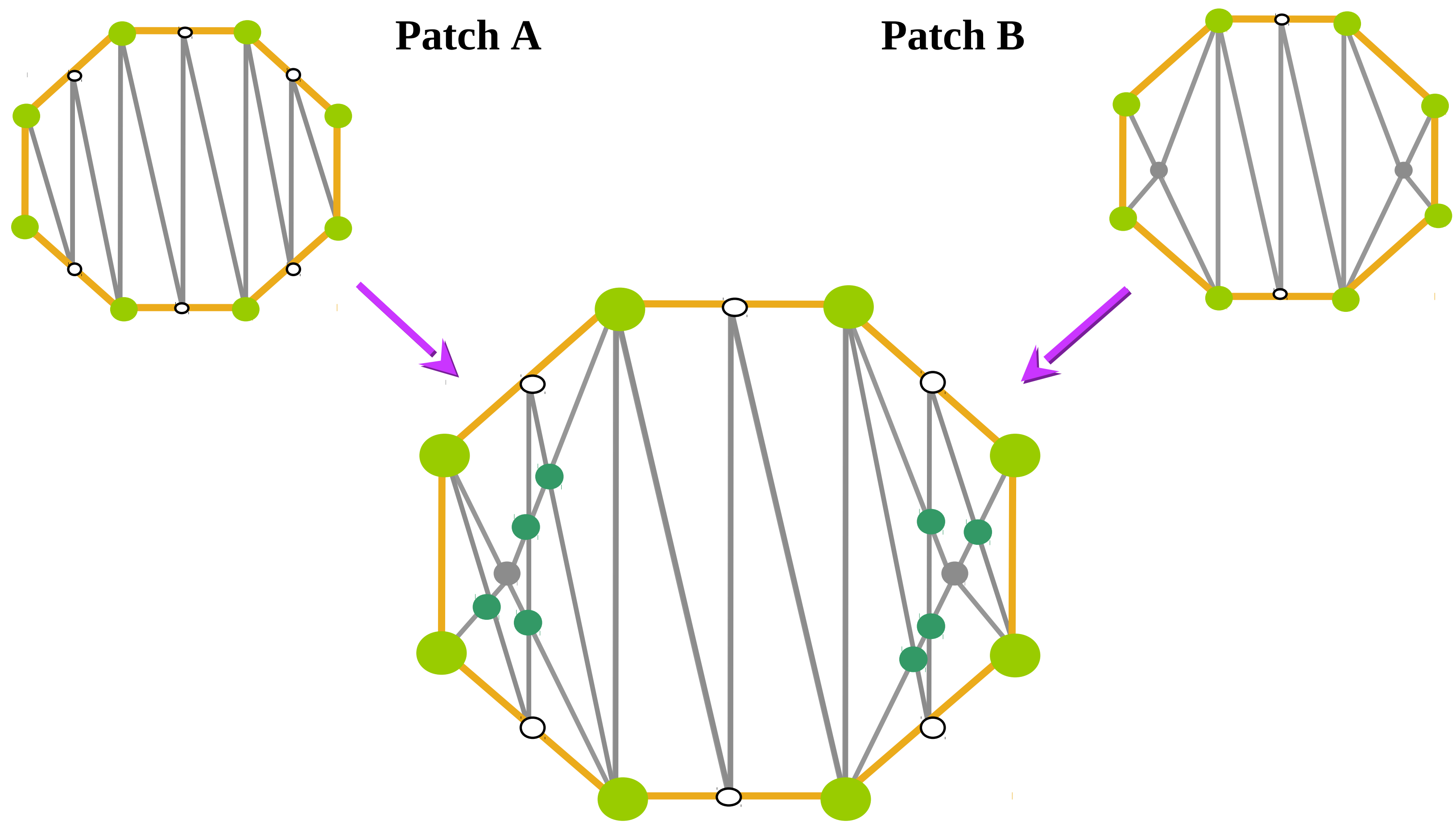
Računanje korespondence



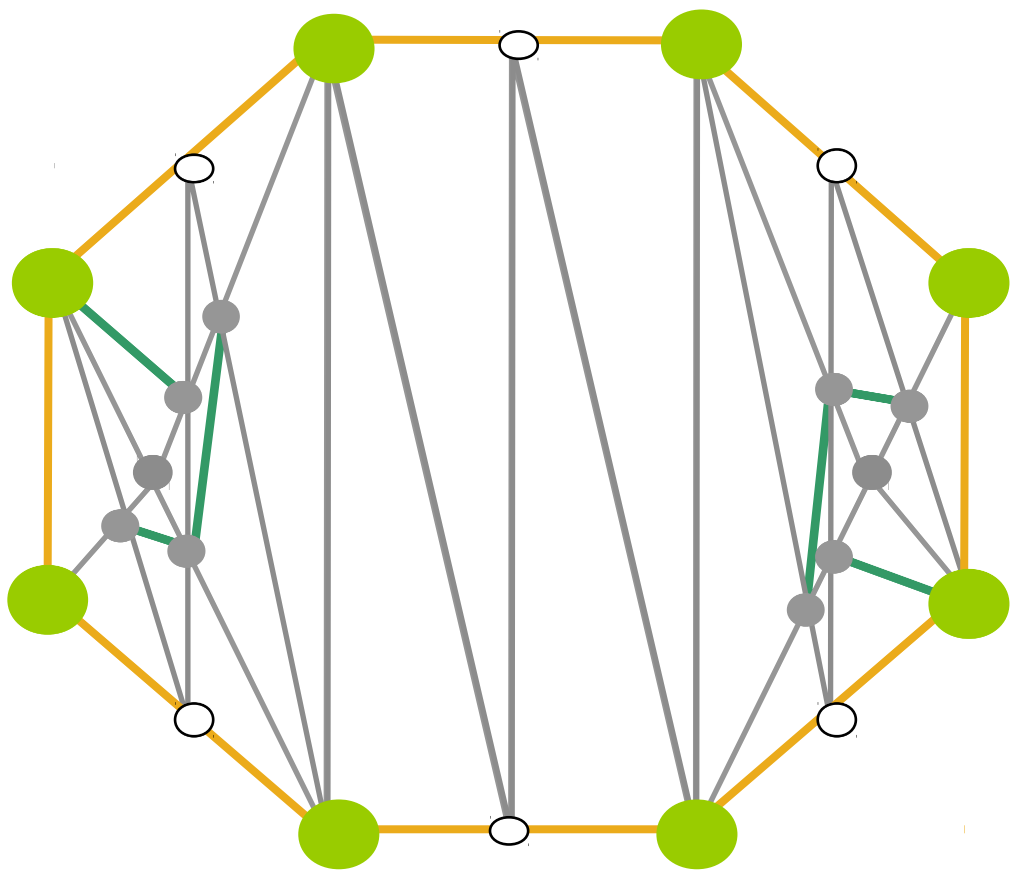
Preslikava



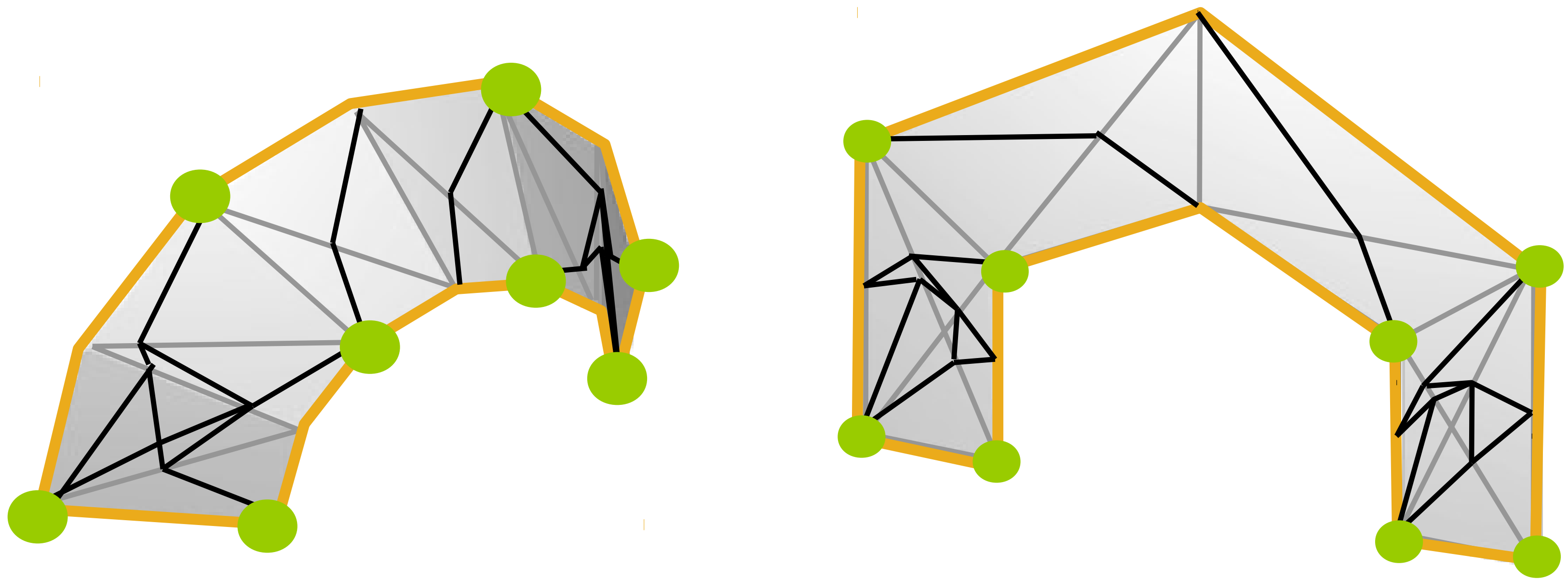
Zlivanje (Merging)



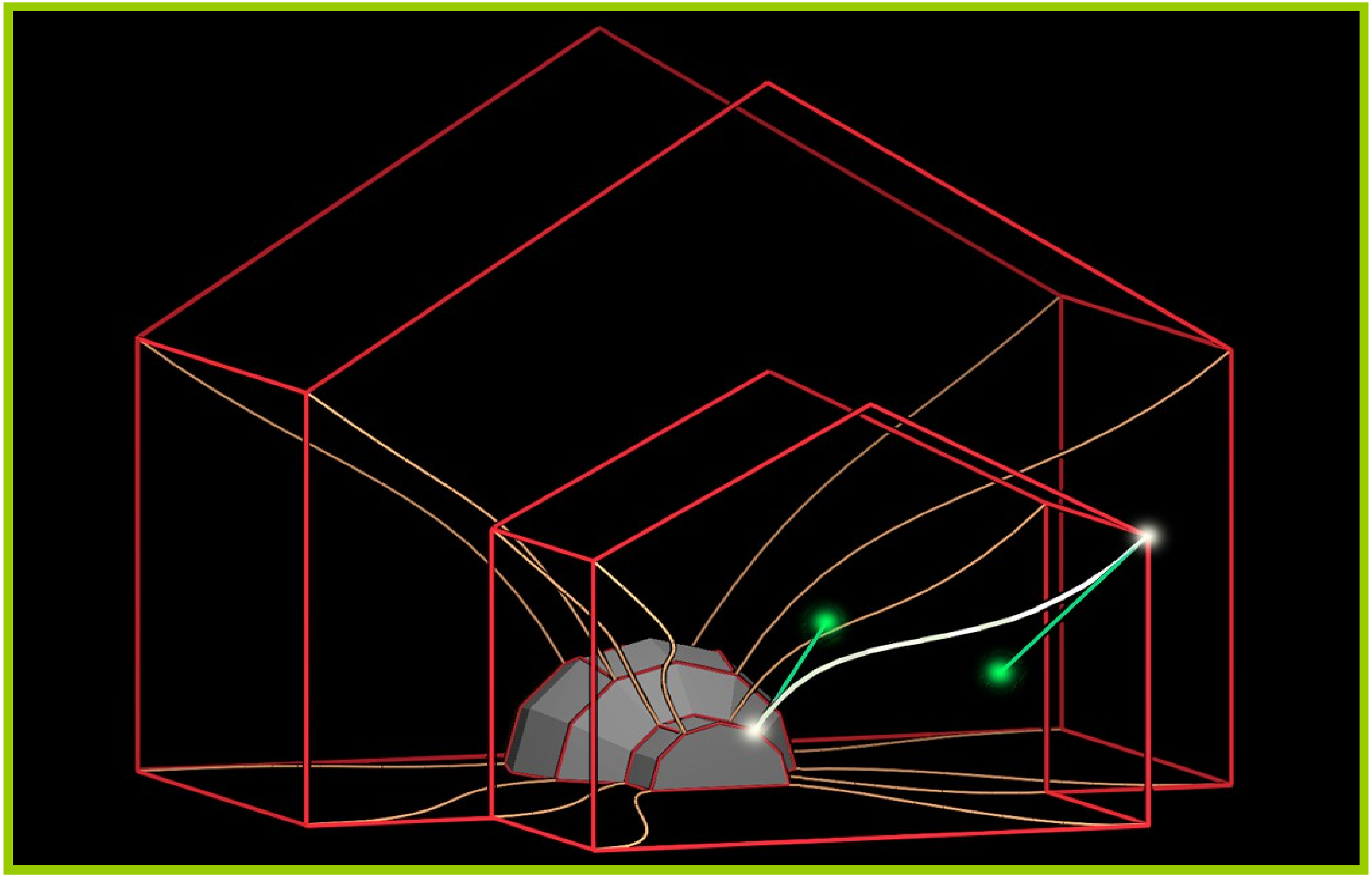
Rekonstrukcija



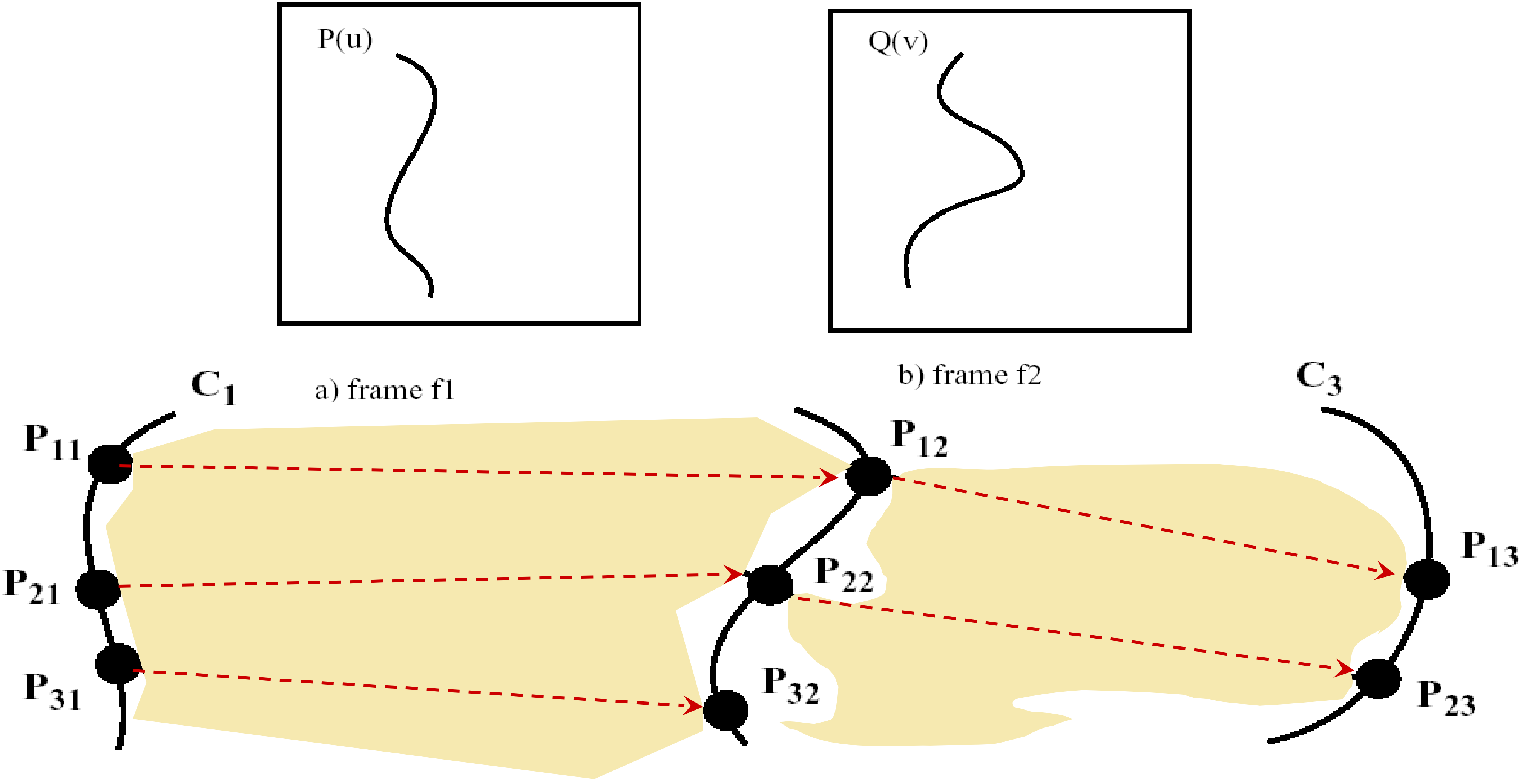
Končana korespondenca



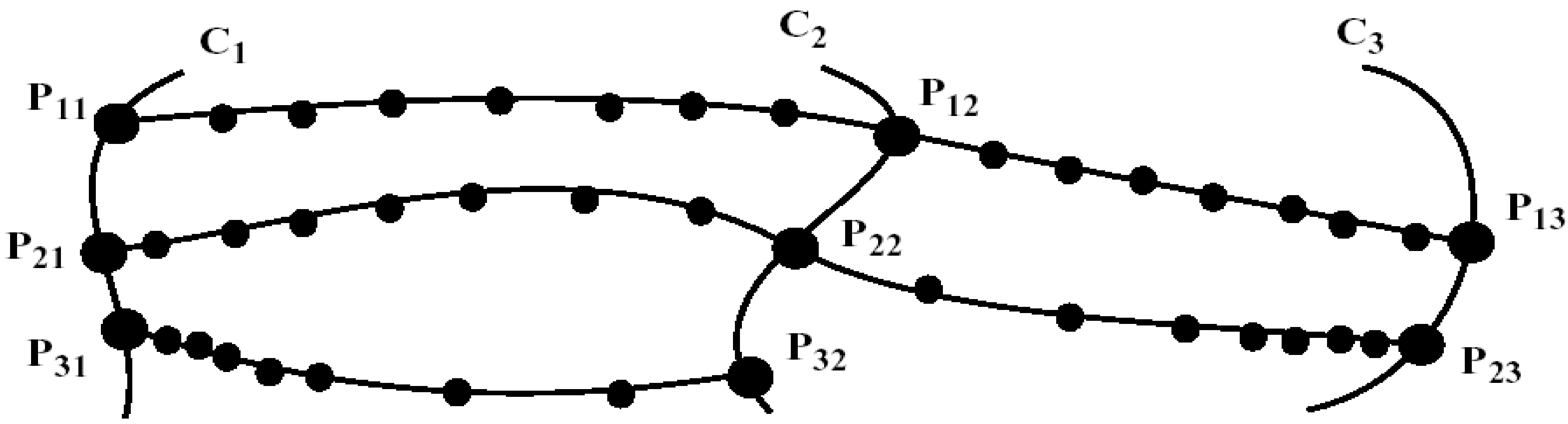
Specifikacija trajektorij preobrazbe



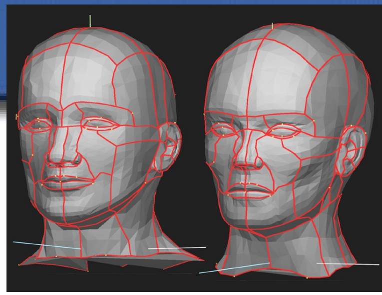
Interpolacija krivulj

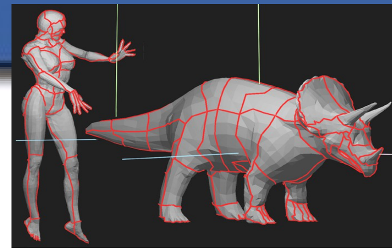


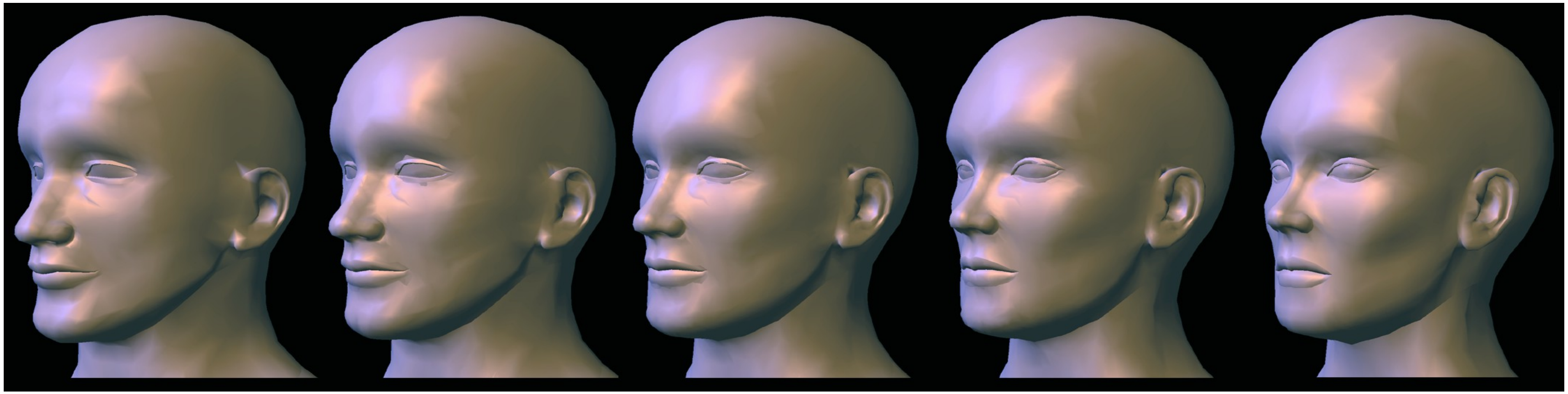
Omejitve interpolacije



Reeves, William T.
“Inbetweening for Computer Animation Utilizing Moving Point Constraints”
SIGGRAPH 81, pp.263-269







Volume-base Approaches

- D. Cohen-Or, D. Levin, A. Solomovoci. Three-dimensional distance field metamorphosis. ACM Trans. Graphics 17:116-141, 1998
- http://www.math.tau.ac.il/~levin/

Tehnike

- The objects are expressed as level sets of distance functions
- Two steps:
  - Warp: deform the 3D space in order to make the two objects to be morphed coincide as much as possible
  - Interpolation: linear interpolate distance fields deformed by the warp

Interakcija

- The user interface allows to select feature (or anchor) points in each voxelized object space and map the anchor points of the source object to the anchor points of the target object

Given two or more objects of general topology, intermediate objects are constructed by a distance field metamorphosis.

In the presented method the interpolation of the distance field is guided by a warp function controlled by a set of corresponding anchor points. Some rules for defining a smooth least-distorting warp function are given.

To reduce the distortion of the intermediate shapes, the warp function is decomposed into a rigid rotational part and an elastic part.

The distance field interpolation method is modified so that the interpolation is done in correlation with the warp function. The method provides the animator with a technique that can be used to create a set of models forming a smooth transition between pairs of a given sequence of keyframe models.

The advantage of the approach is that it is capable of morphing between objects having a different topological genus where no correspondence between the geometric primitives of the models needs to be established. The desired correspondence is defined by an animator in terms of a relatively small number of anchor points.

3D Shape Interpolation (1)

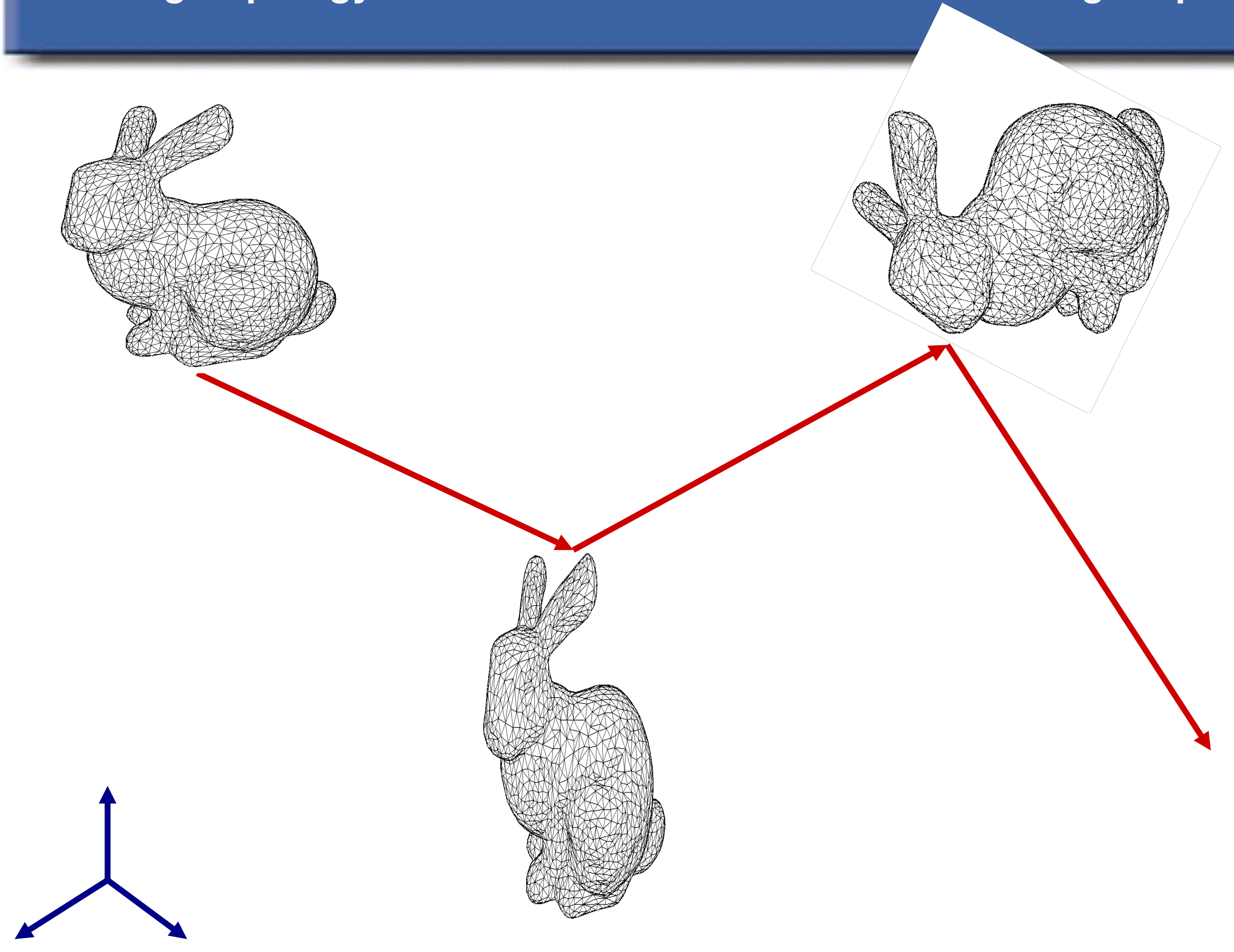
Animating Shape Change

- Per-vertex animation curves
  - beginning and end known
- Simply change parameters with time
  - Twist angle
  - Scaling constant
  - Seed vertex position
- All standard rules apply
  - Curve smoothness, motion controls, etc.

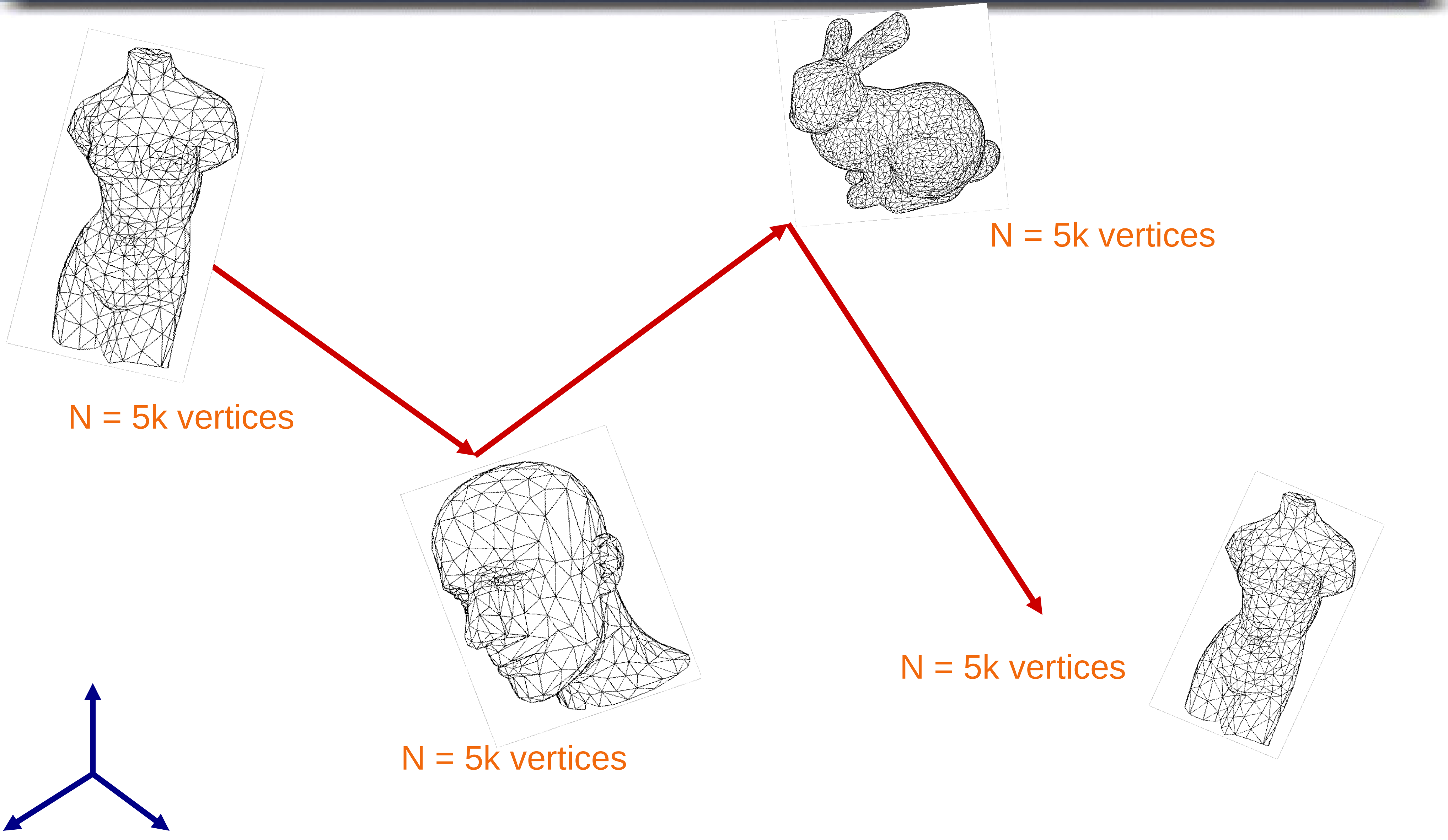
3D Shape Interpolation Approaches

- Matching topology
- Star shaped polyhedra
- Star shaped with respect to an axis
- General map to sphere
- Merging topologies)
- Recursive subdivision)

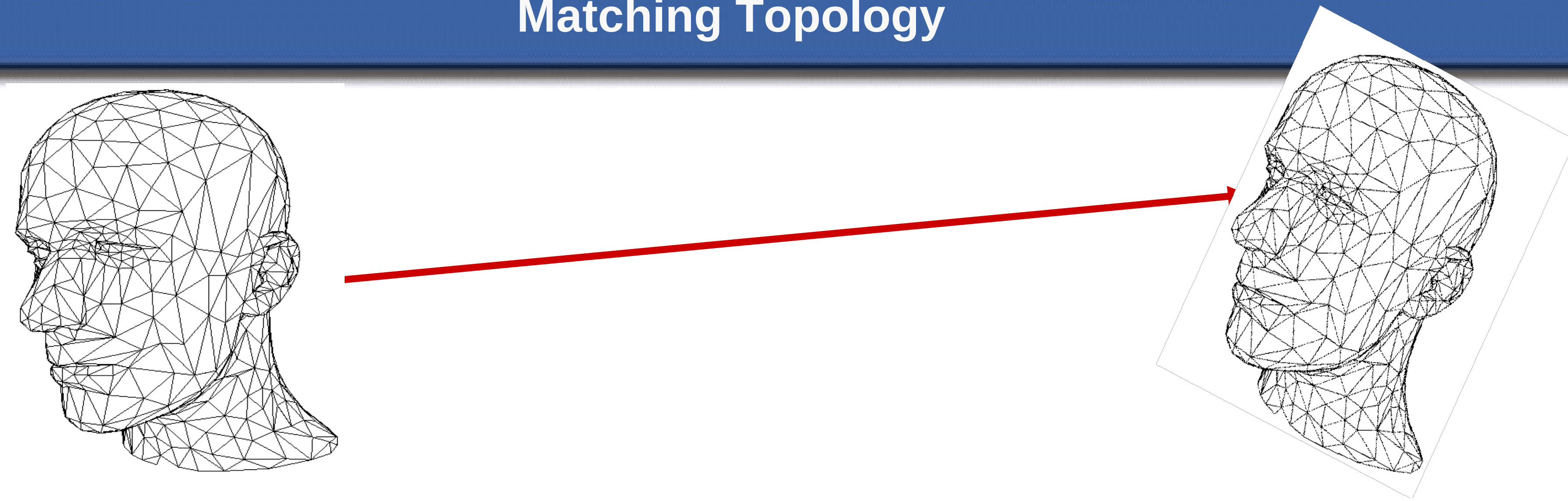
Matching Topology → same meshes with same vertex-edge topology



Matching Topology → different meshes with same vertex-edge topology

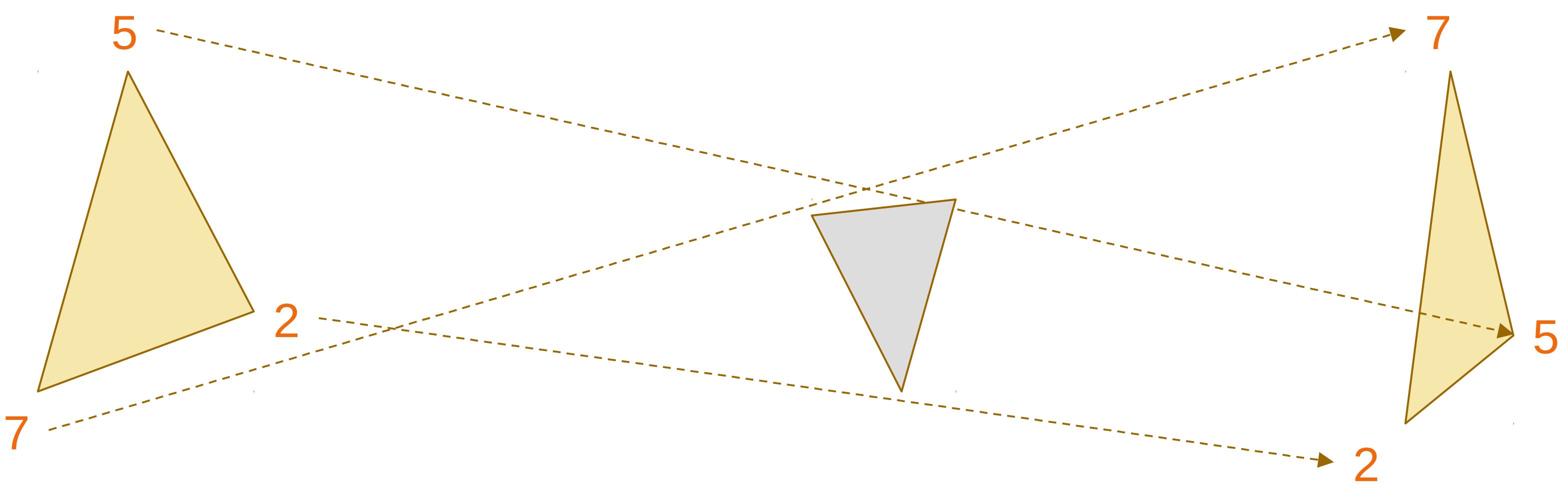


Matching Topology

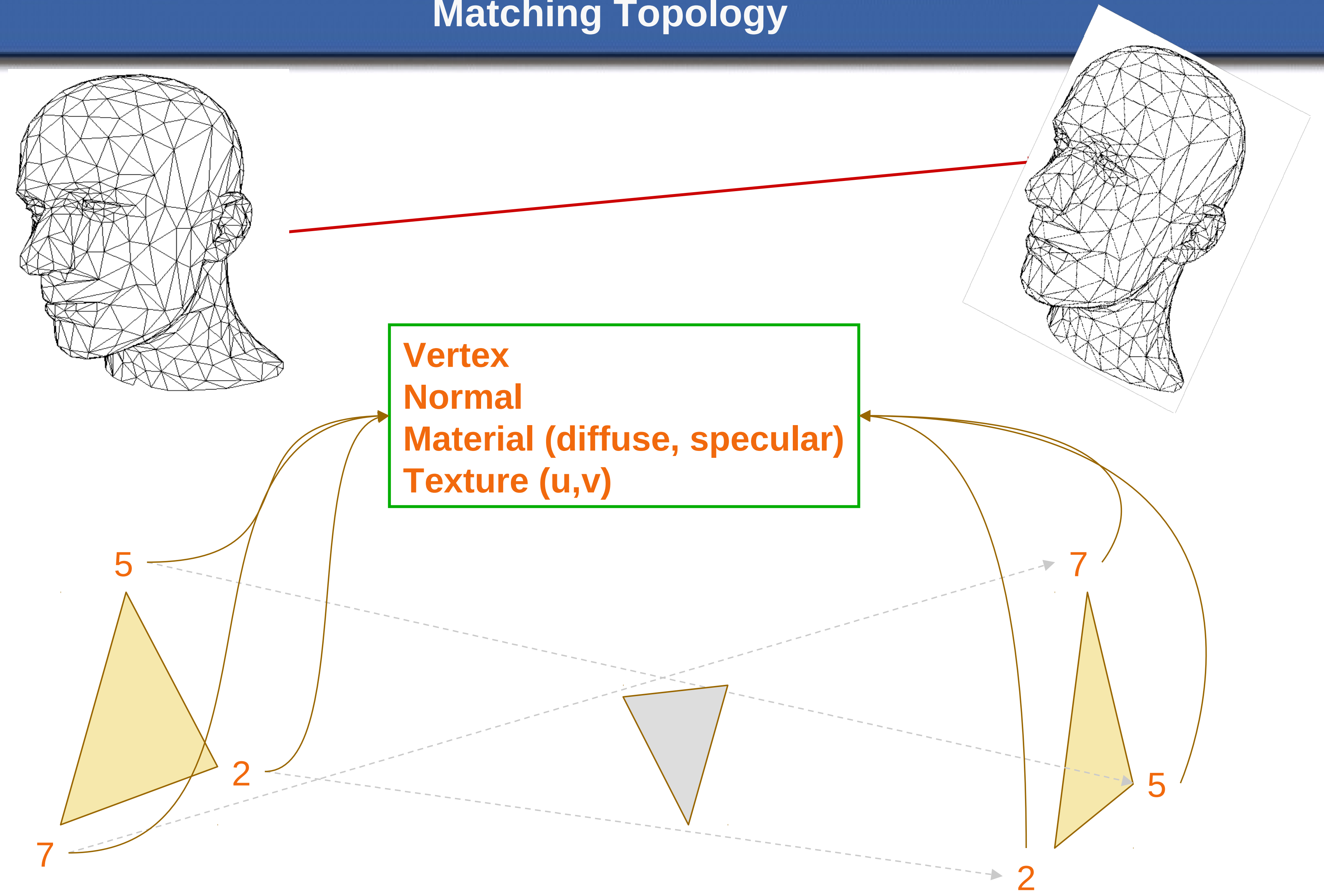


N = 5k vertices

N = 5k vertices

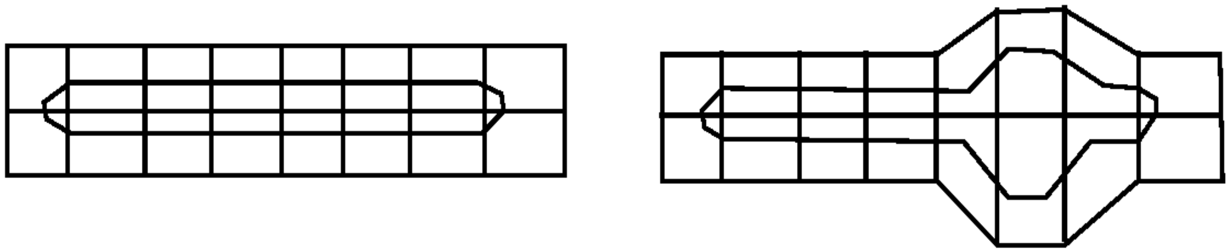


Matching Topology

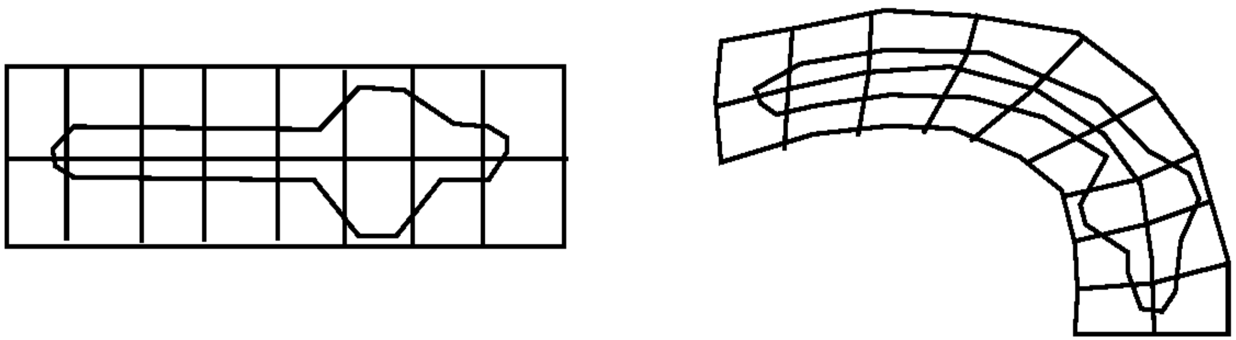


Matching Topology

Used in Free From Deformation (FFD)



a) Bulging

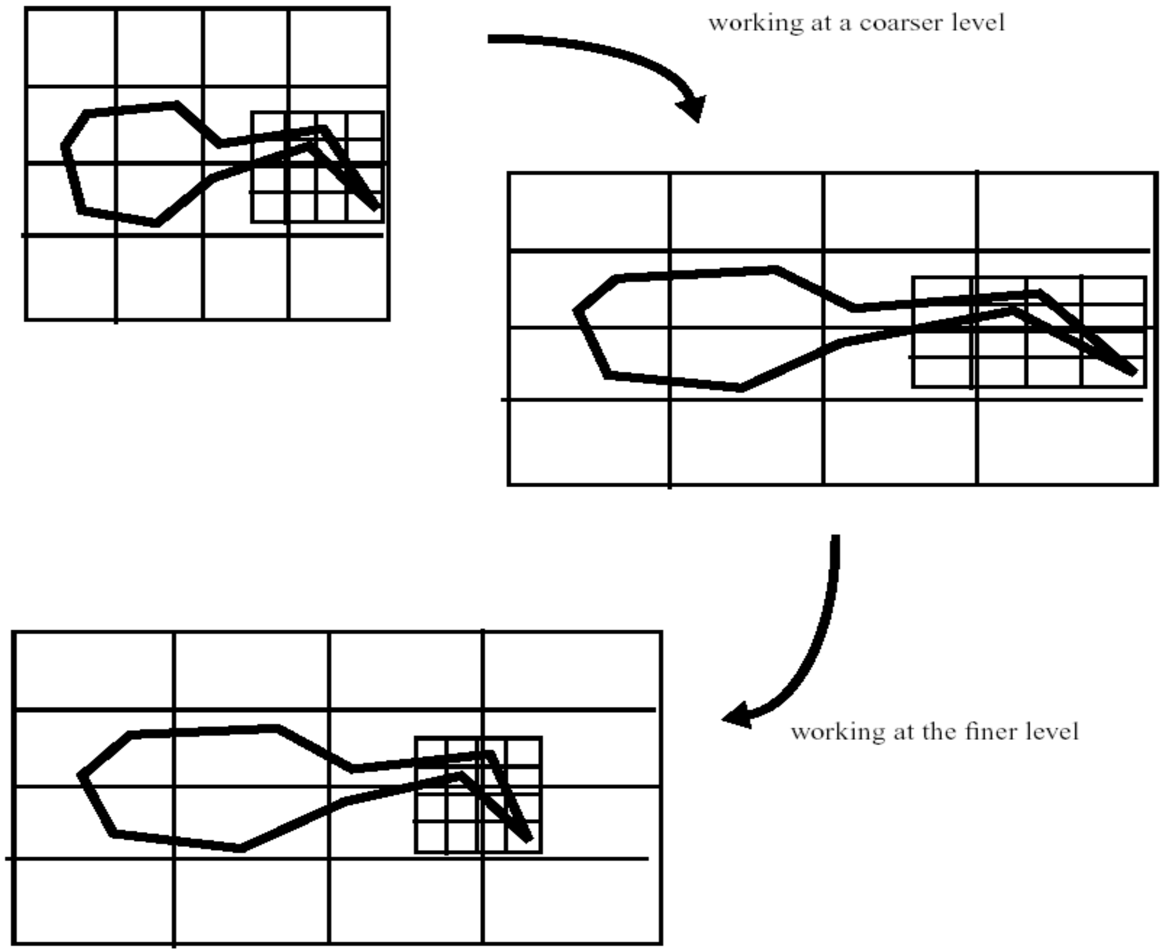


b) Bending

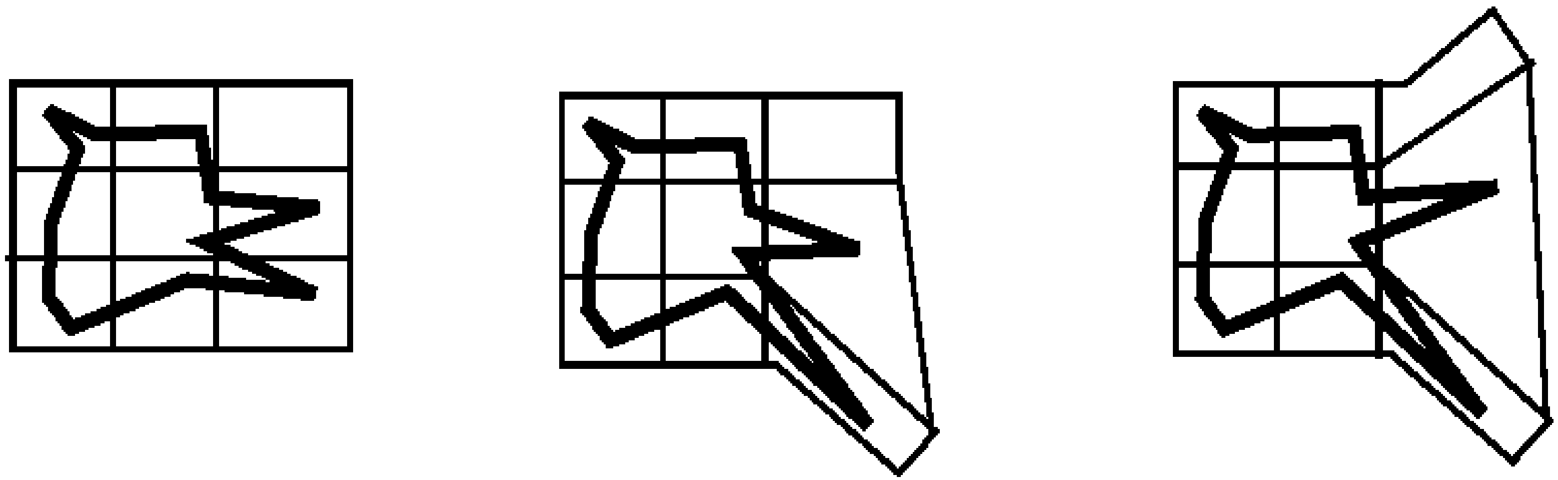
Sequential FFD

Matching Topology

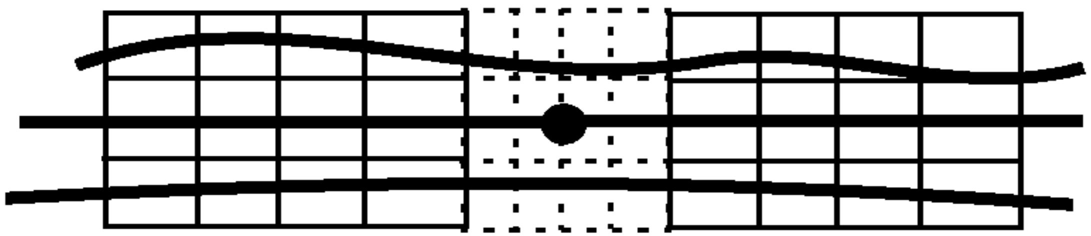
Hierarchical FFD



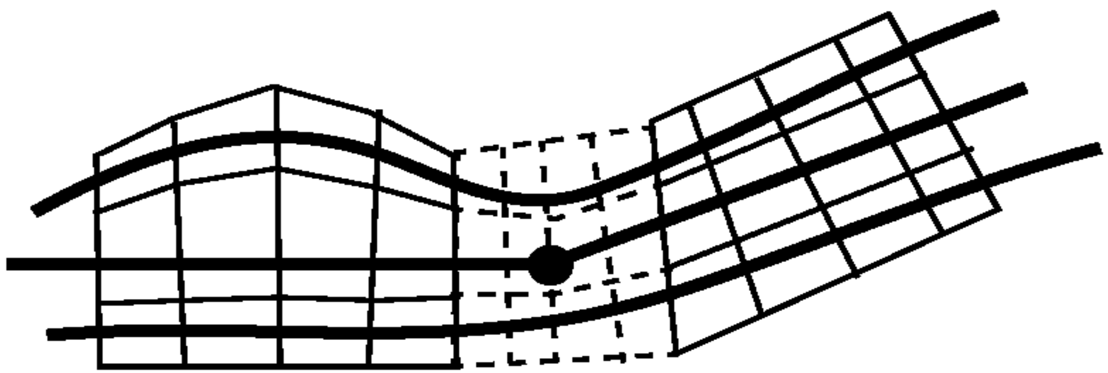
FFD and Animation



FFD and Articulated Joints



a) initial configuration



b) Surface distorted after joint articulation

Light Field Morphing

A general framework for image-based 3D morphing

- Enables morphing between image-based objects
- 3D morphing without modeling
- Suitable for objects with complex surface properties (e.g., fur, subsurface scattering, hypertexture)

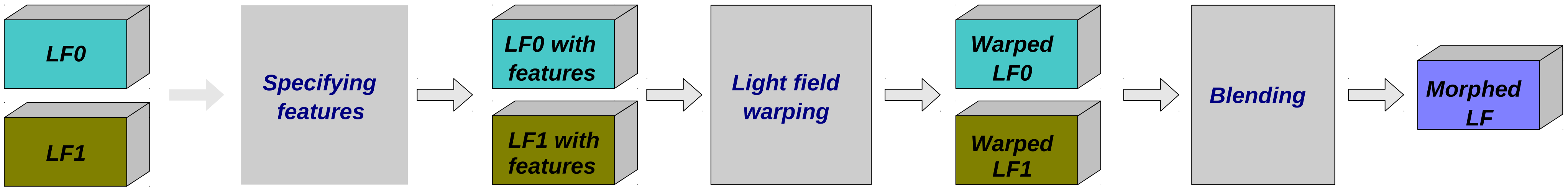
Morphing = Correspondence

- Image morphing
  = 2D pixel correspondence
- Geometry-based 3D morphing
  = 3D vertex correspondence
- Light field morphing
  = 4D ray correspondence

Contributions

- A UI for specifying features in 4D ray space
- Ray-space warping
  - Handling visibility changes due to object shape change

Pregled



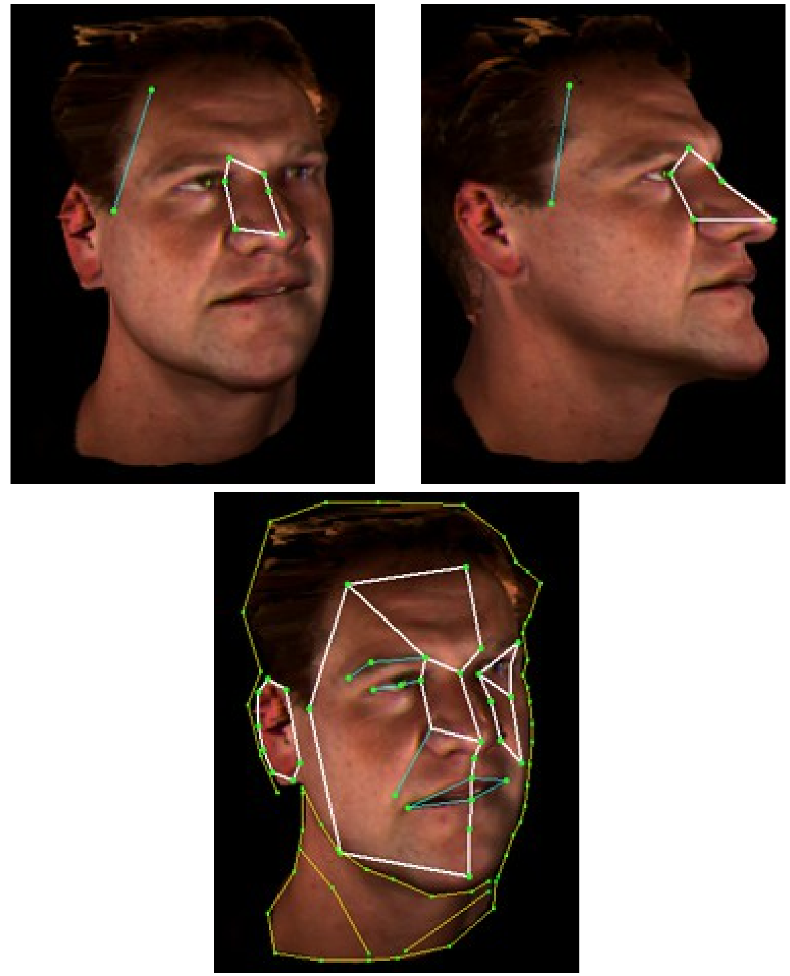
LF0
LF1
Specifying features
LF0 with features
LF1 with features
Light field warping
Warped LF0
Warped LF1
Blending
Morphed LF

Specifying Features

- Feature points
  - 3D points on object surface
  - Specified by manual correspondence guided by epipolar geometry

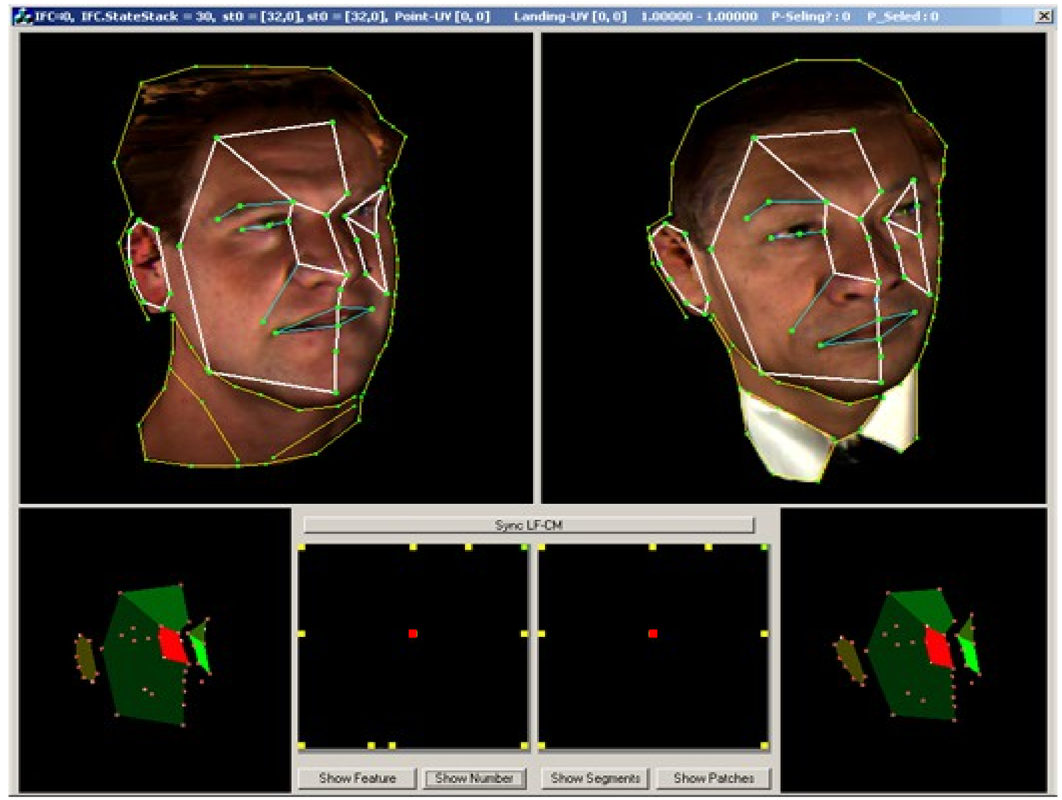
Specifying Features

- Feature lines
- Feature polygons
  - Non-planar, but relatively flat & w/o self-occlusion
  - Necessary only in areas with visibility changes

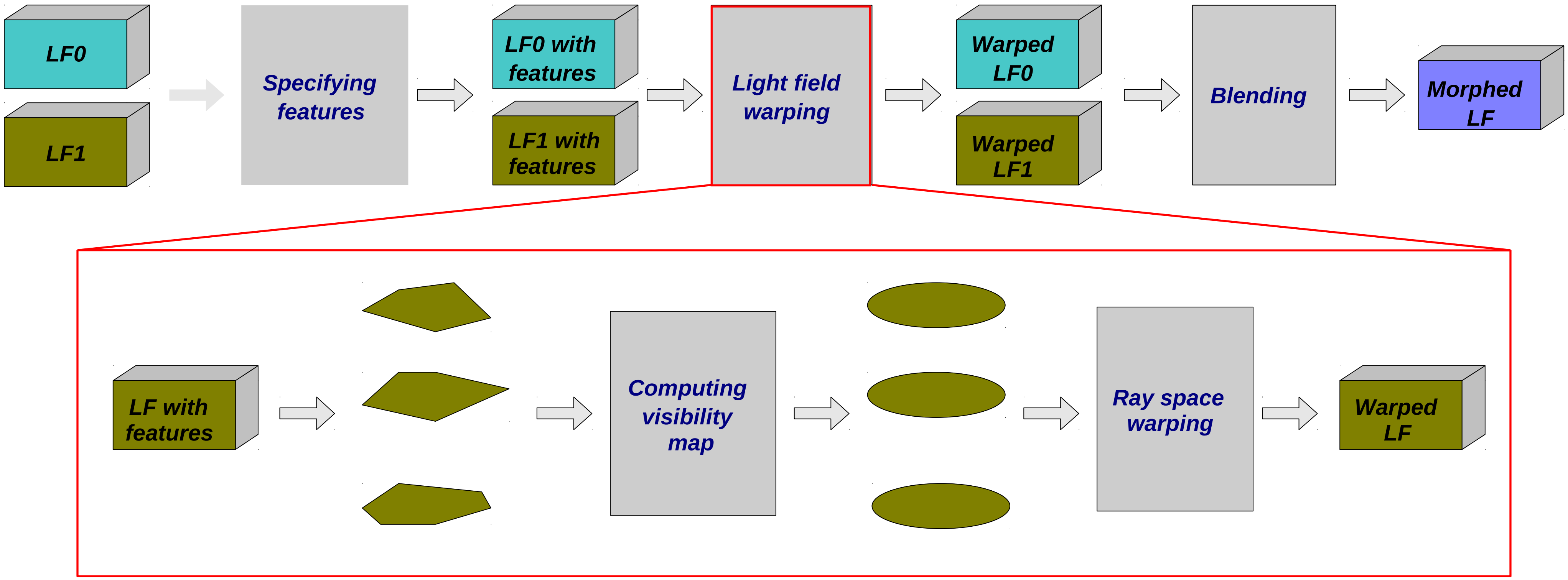


Specifying Features

- No 3D reconstruction from feature polygons
- Background pixel (ray)
  - Pixels (rays) with no visibility changes
  - Morphing controlled by background edges
- Background edges are key-framed

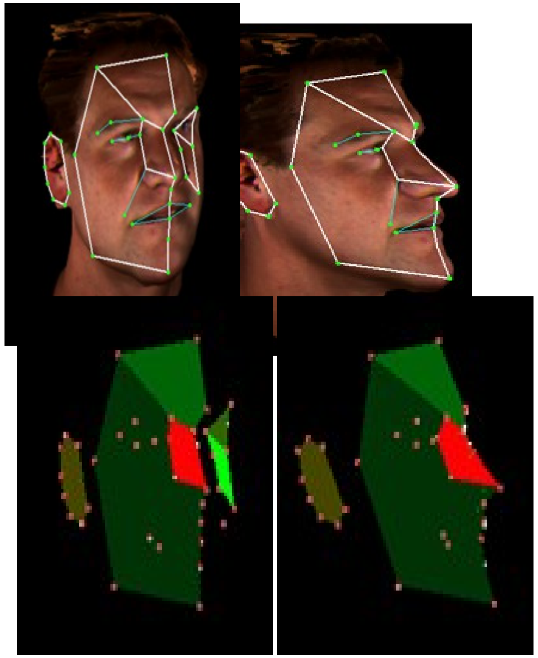


Overview



LF0
LF1
Specifying features
LF0 with features
LF1 with features
Light field warping
Warped LF0
Warped LF1
Blending
Morphed LF
LF with features
Computing visibility map
Ray space warping
Warped LF

Global Visibility Map



- GVM describes the visibility of feature polygons in each view
- Key to visibility processing
- GVM = A light field of false colors, associating each ray with a feature polygon

$$V(u,v,s,t) = \begin{cases} i & \text{if ray } L(u,v,s,t) \text{ belongs to } P_i \\ -1 & \text{otherwise} \end{cases}$$

Computing GVM

- Rendering a set of non-planar but relatively flat polygons
  - No self-occlusions
  - Two-pass OpenGL rendering with stencil buffer
- Trade off: planar vs non-planar feature polygons