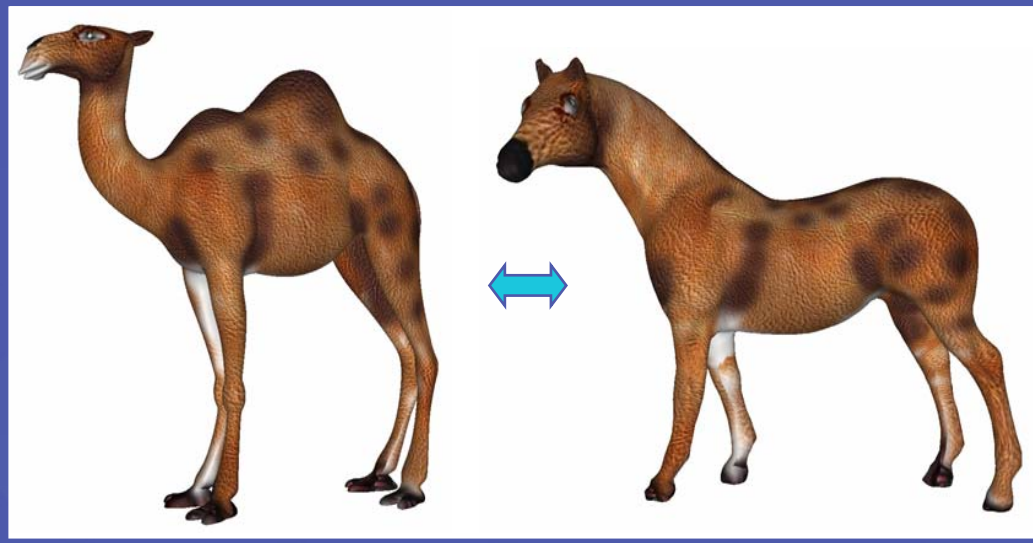
SIGGRAPH2004

Cross-Parameterization and Compatible Remeshing of 3D Models

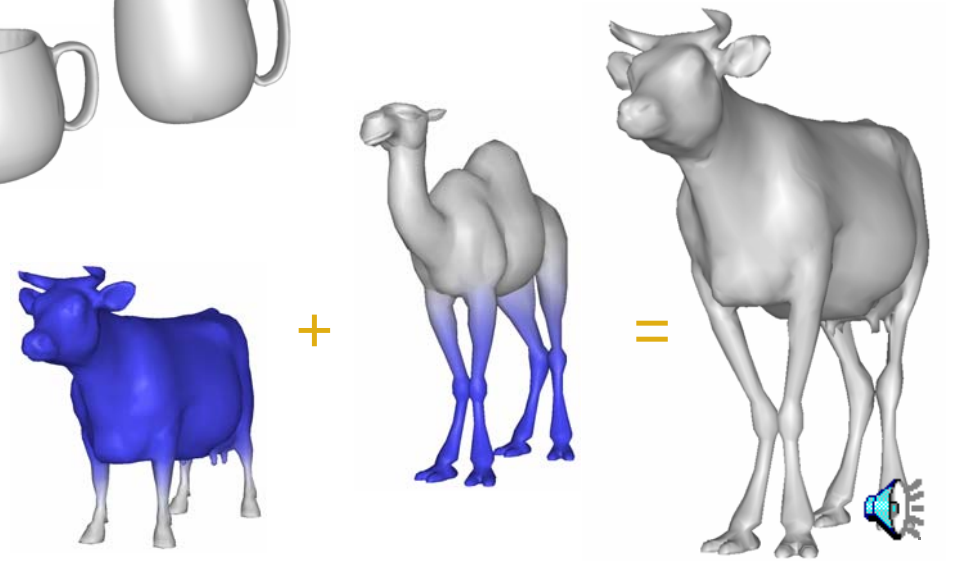
Vladislav Kraevoy Alla Sheffer
Department of Computer Science
University of British Columbia

X-Parameterization

- X-Parameterization: mapping between surface models (meshes)
- Applications:
  - Properties transfer
  - Morphing

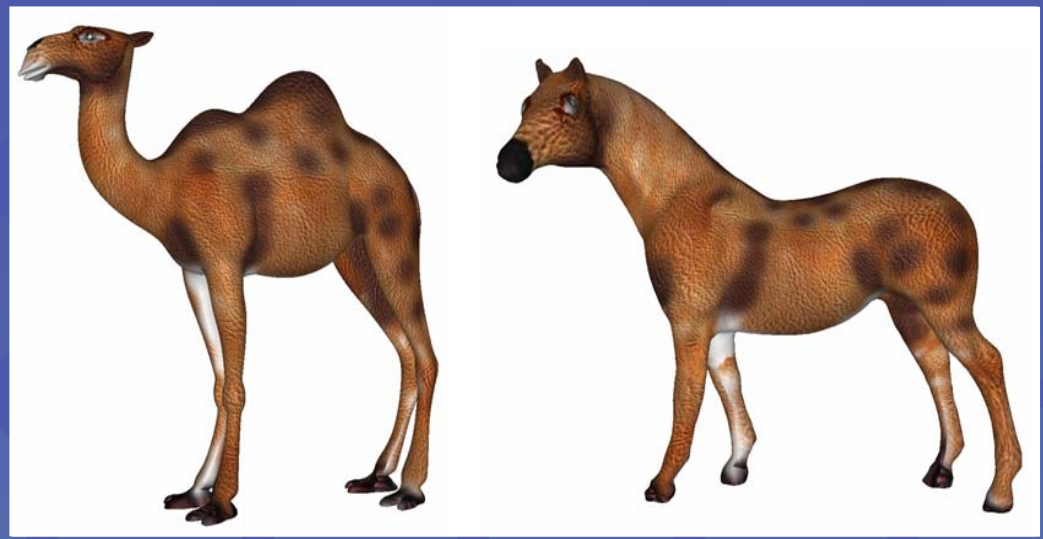


  - Editing – e.g. blending
  - Template fitting



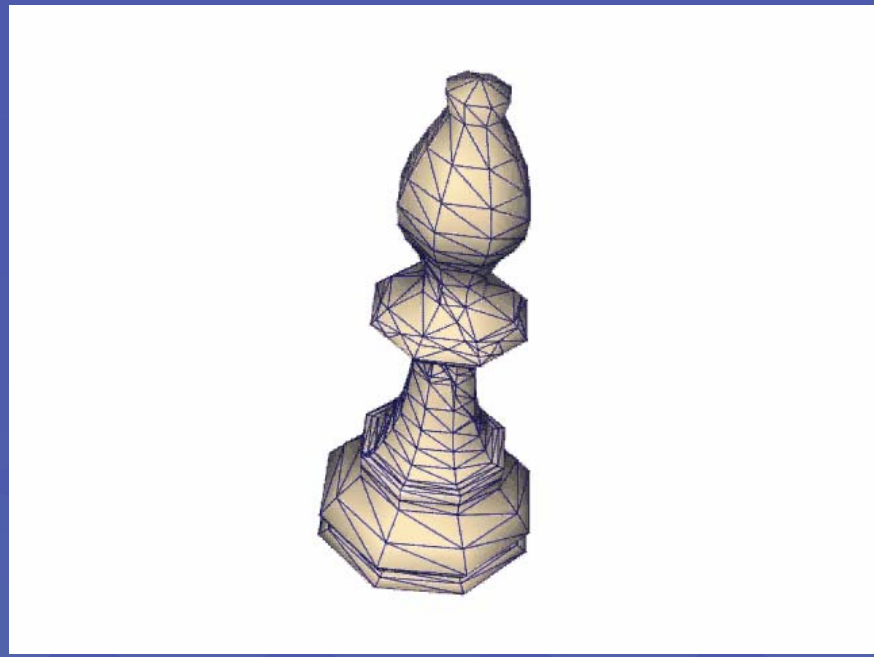
X-Parameterization

- Requirements
  - Bijectivity (one-to-one)
  - Feature correspondence
    - vertex to vertex
  - Low distortion

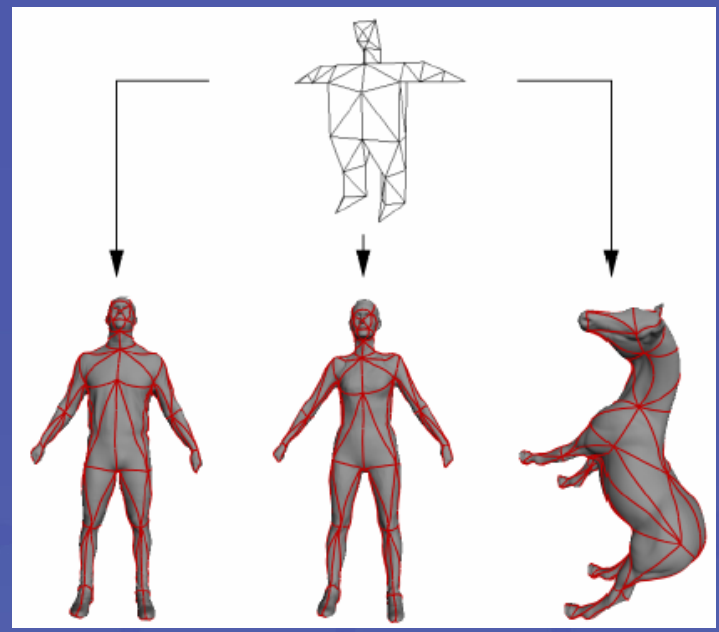


Compatible Remeshing

- Compatible meshes – meshes with identical connectivity
- Required by many applications of X-parameterization
  - Morphing
  - Editing
- Prerequisite: X-parameterization



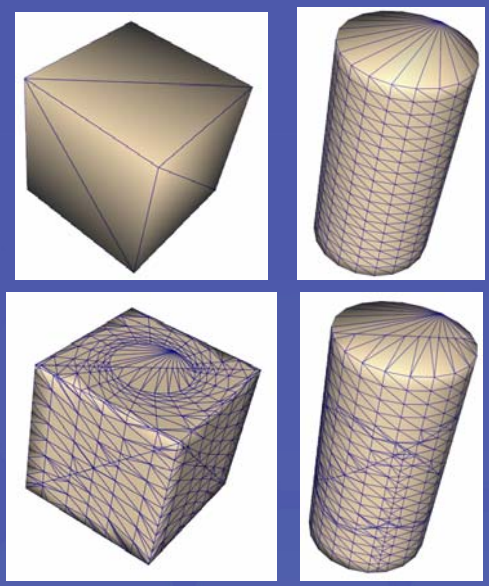
Previous work: X-parameterization

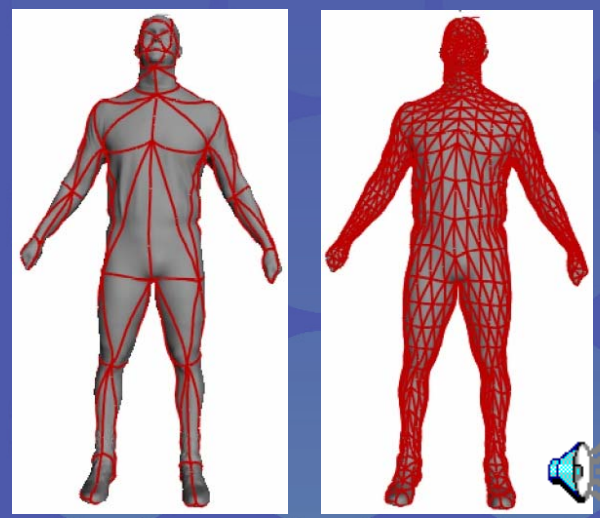


- [Lee et al. 1999, Alexa 2001, Michikawa et al. 2001, Praun et al. 2001, Allen et al. 2003, Schreiner et al. 04]
- Most use heuristics - can fail
- Base mesh [Lee et al. 1999, Michikawa et al. 2001, Praun et al. 2001, Schreiner et al. 04]
  - Segment meshes into triangular patches (same connectivity)
  - Map patches to base triangles
  - [Praun et al. 01] - given a base mesh robustly construct segmentation
  - [Schreiner et al. 04] – more later

Previous work: Compatible remeshing

- Mutual tessellation [Alexa 2000, Schreiner et al. 04]
  - Intersect meshes in parameter domain
- Regular base mesh refinement [Lee et al. 1999, Praun et al. 2001]
  - Remesh with subdivision connectivity
- Both methods: output meshes much larger (~x10) than input
  - For accurate approximation



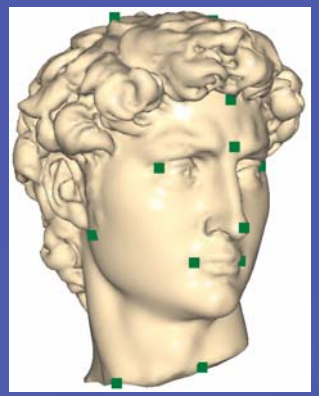


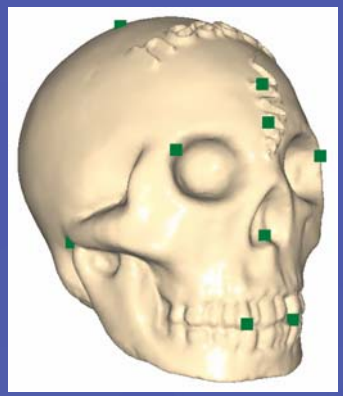
Technique Goals

- X-Parameterization
  - Bijective
  - Exact feature vertex correspondence
  - Low distortion (preserve shape)
  - Minimal user input: models + feature vertices
- Compatible remeshing
  - Closely approximate the input models
  - Similar (order of magnitude) number of elements as input
- Efficient & robust

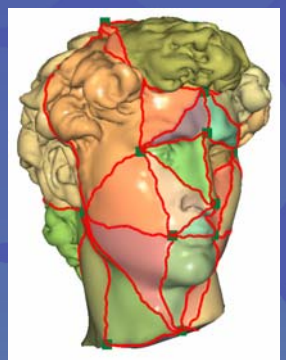
Algorithm Stages

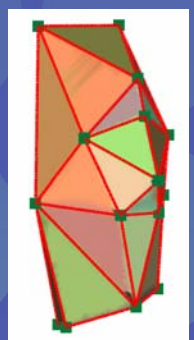
Input: models + features

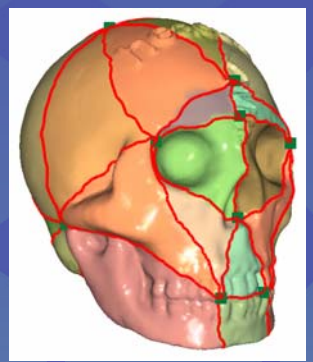




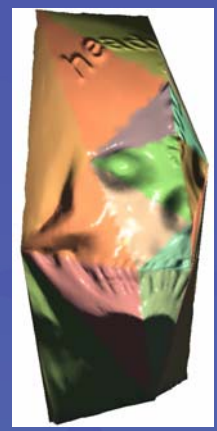
1. Common base mesh construction
   - Provably correct for genus 0

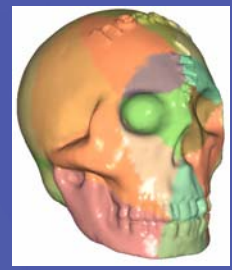




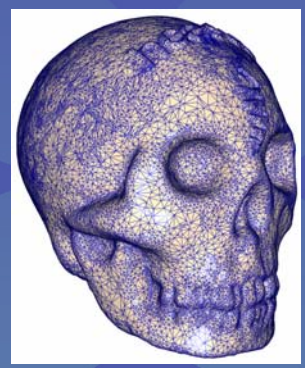


2. Low distortion, bijective X-parameterization



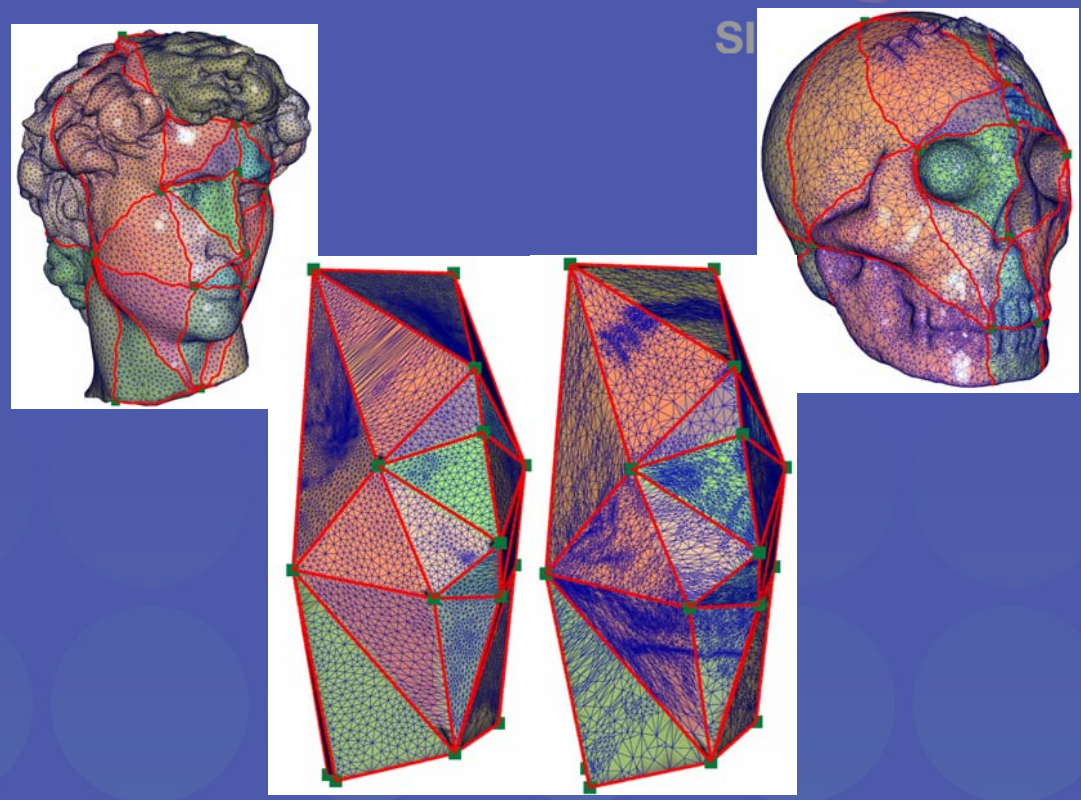


3. Compatible remeshing



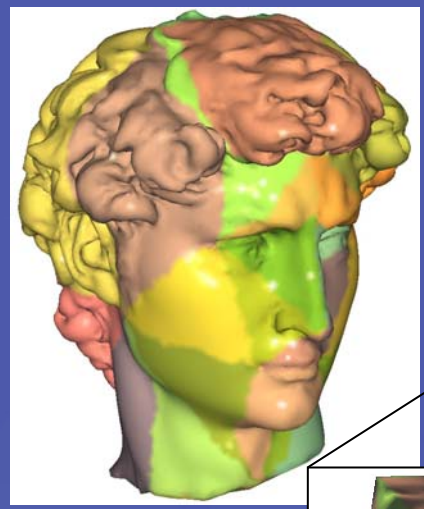
Initial X-Parameterization

- Map each patch to corresponding base triangle
  - Shape preserving parameterization [Floater 2003]
  - Guarantee bijectivity

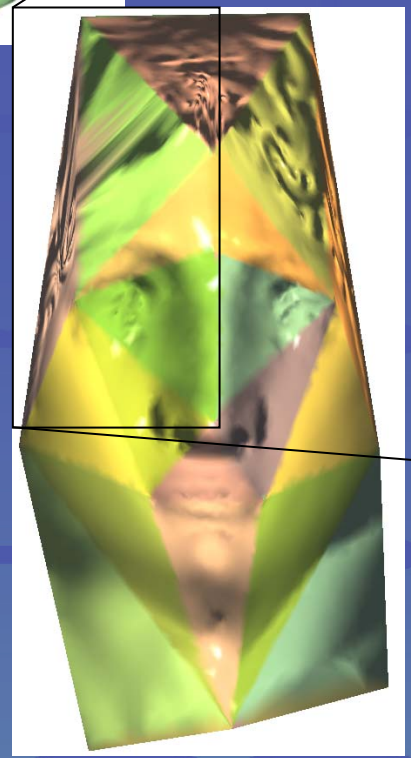


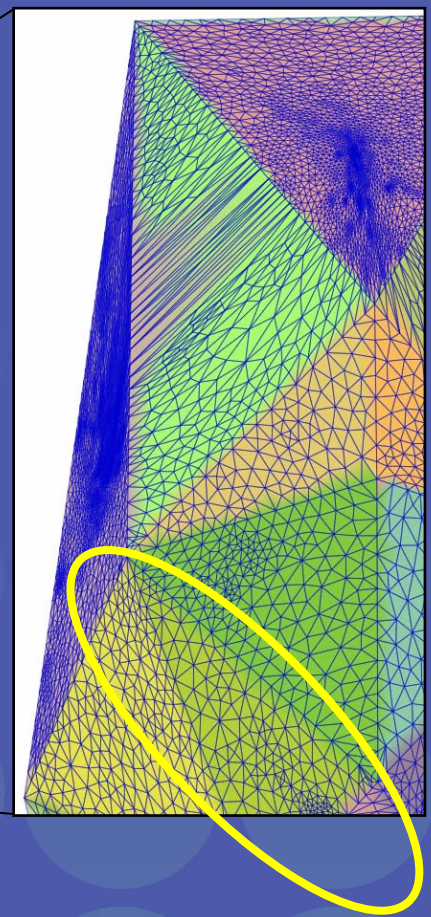
- Given a base mesh previous methods employed similar techniques
- Not good enough…

Distortion & Artifacts



- Badly shaped patches = high distortion
- Artifacts: map polyline patch boundaries to straight lines
- Need additional processing to reduce distortion



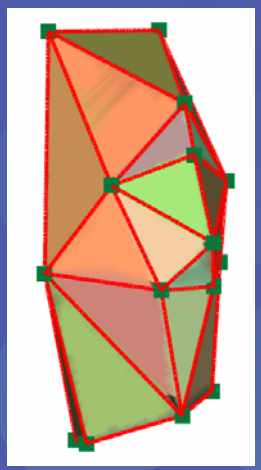


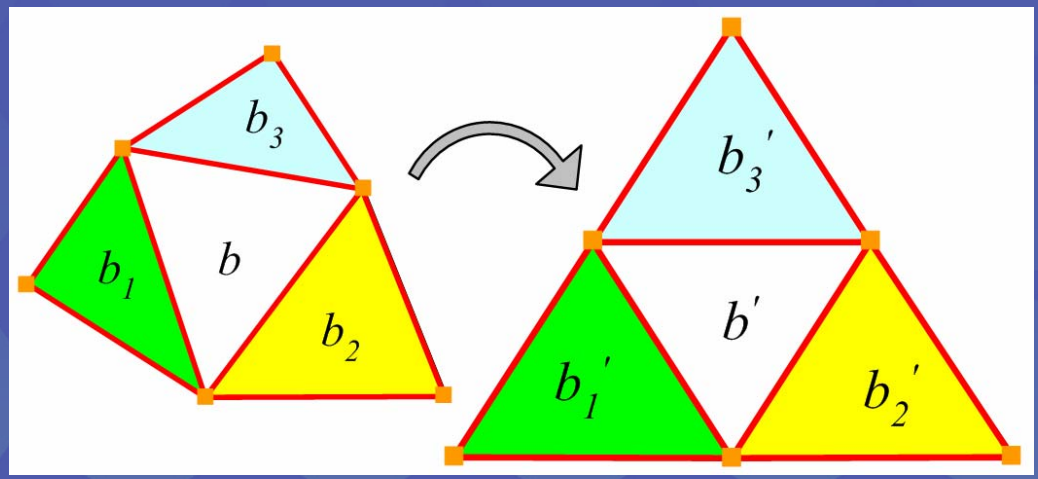
X-Parameterization: Smoothing

- Optimize (smooth) base mesh parameterization
  - Move vertices between base mesh triangles
- Unconstrained parameterization [Khodakovsky et al.,2003]
  - Solve (repeatedly) a global linear system - far from trivial…
  - No guarantee of bijectivity
- Our approach
  - Treat base as set of overlapping domains
  - Iteratively optimize mapping within each domain

Overlapping domain structure

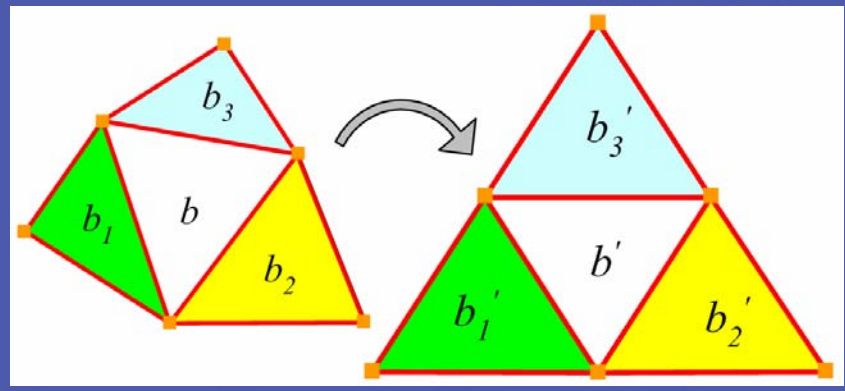
- Domain per base triangle
  - Contains base triangle + 3 adjacent
  - Mapped to equilateral triangle in 2D
    - Parameterize all vertices mapped to those triangles onto the domain

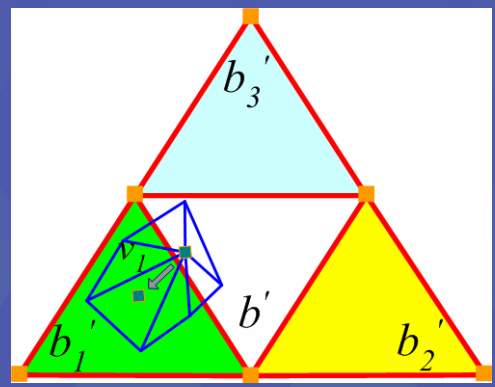


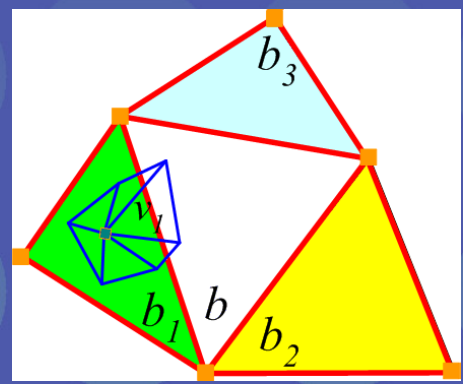


Smoothing

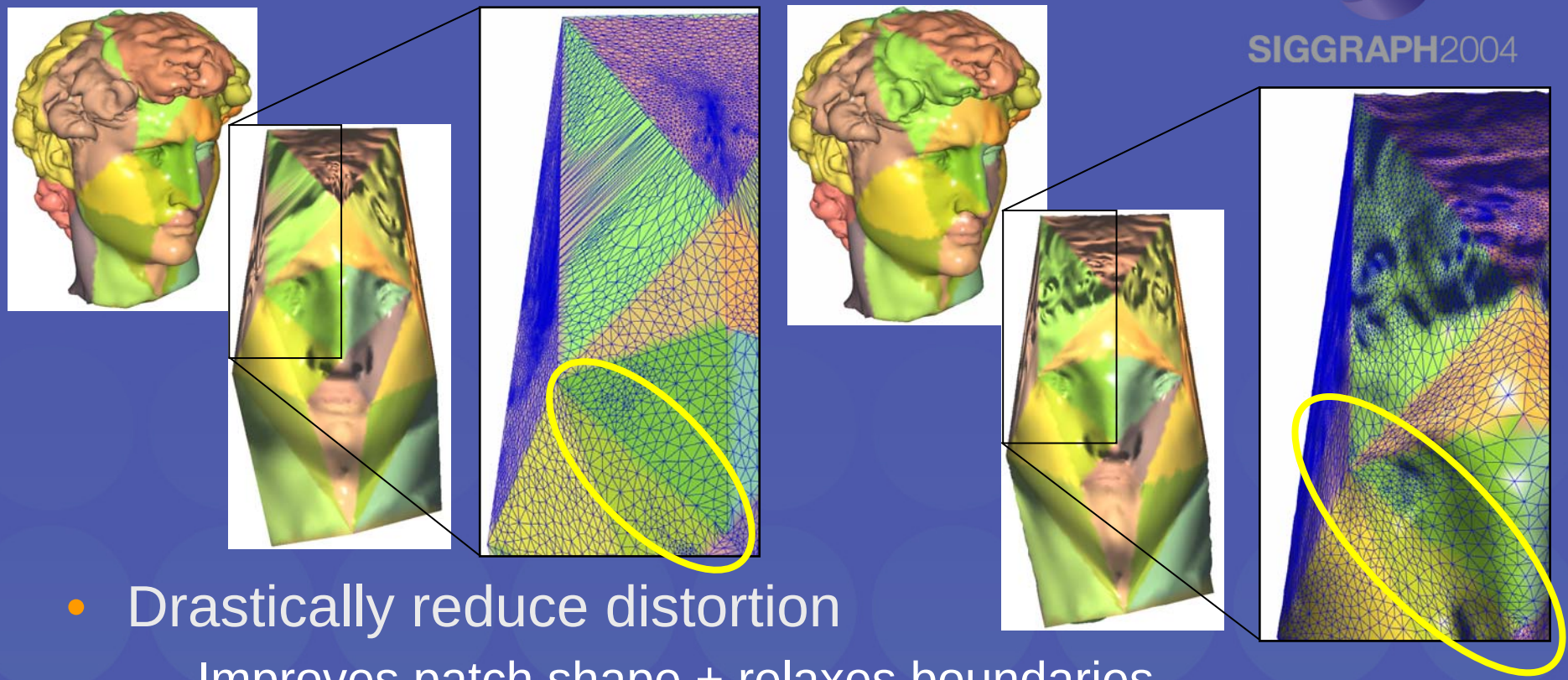
- For each base triangle b
  - Create corresponding overlapping domain
  - Compute new location in equilateral domain for each vertex on b
    - Based on neighbors
    - Shape preserving [Floater 2003]
  - Map vertices back to base mesh
    - Find base triangle & compute coordinates
- Repeat
- Adjacency assumption







Smoothing Framework

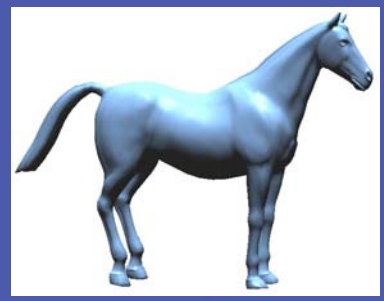


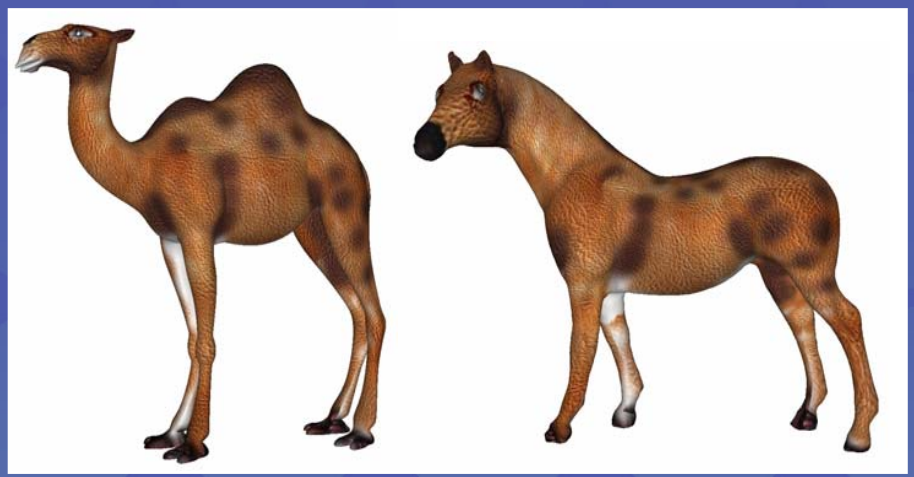
- Drastically reduce distortion
  - Improves patch shape + relaxes boundaries
- Preserve bijectivity

- Generic framework – can replace the shape preserving objective function by any other

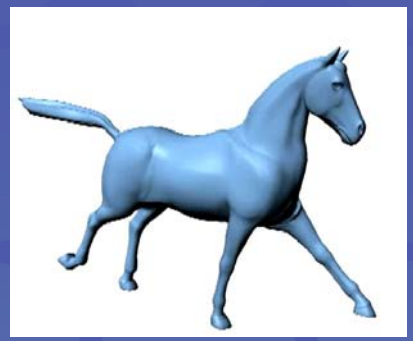
Results

Normal transfer
40K/40K faces
59 sec





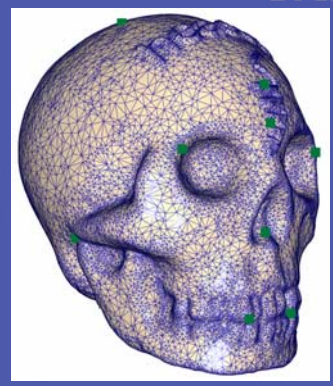
Texture transfer
80K/7K faces
56 sec

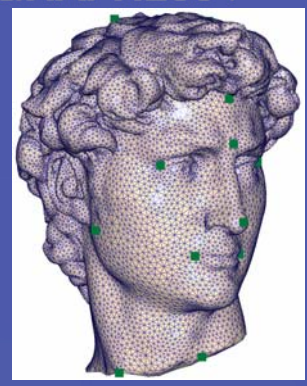


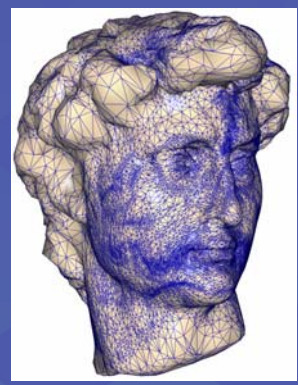
Motion transfer

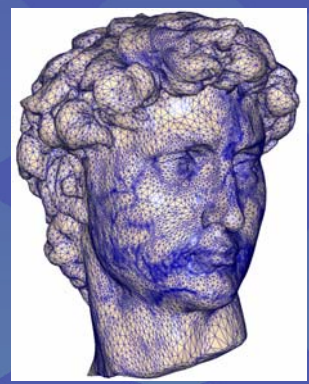
joint result with [Sumner & Popovic 04]

Compatible Remeshing





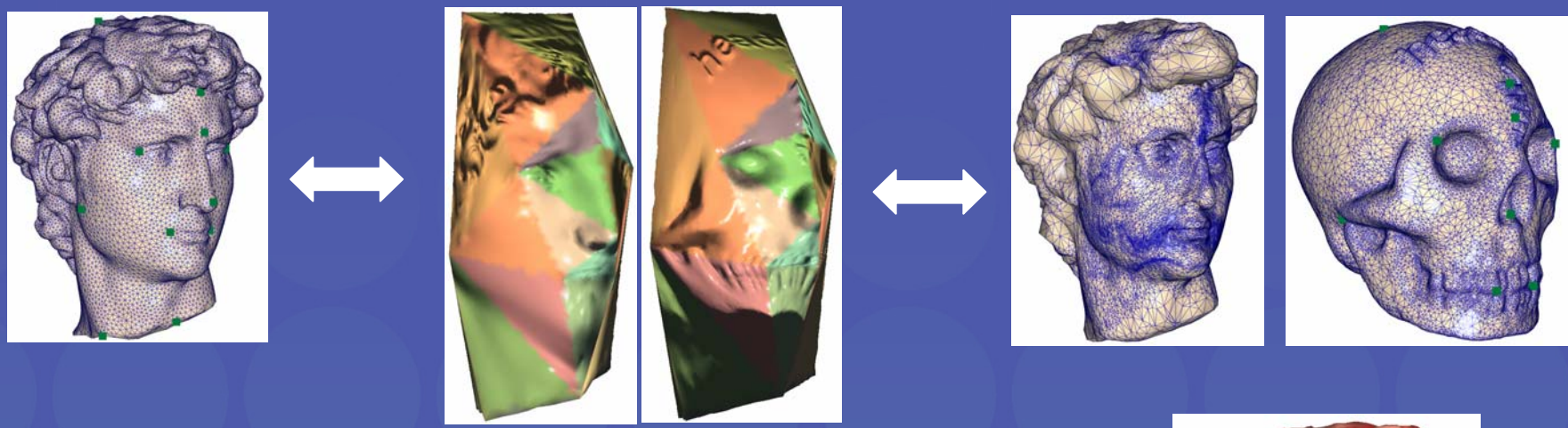




- Previous:
  - overlay or subdivision
  - increase mesh size by order of magnitude
- Idea:
  - Use connectivity of one model (“source”) as basis
  - Map to second model (“target”) using X-parameterization
  - Improve target approximation
    - local modifications

Mesh Improvement

- X-parameterization between target & approximation
  - Use intrinsic map between source and target approximation



- Use for
  - Computing approximation error
    - Error = distance between target vertex & its map
    - Conservative
  - Local modifications

Compatible Remeshing

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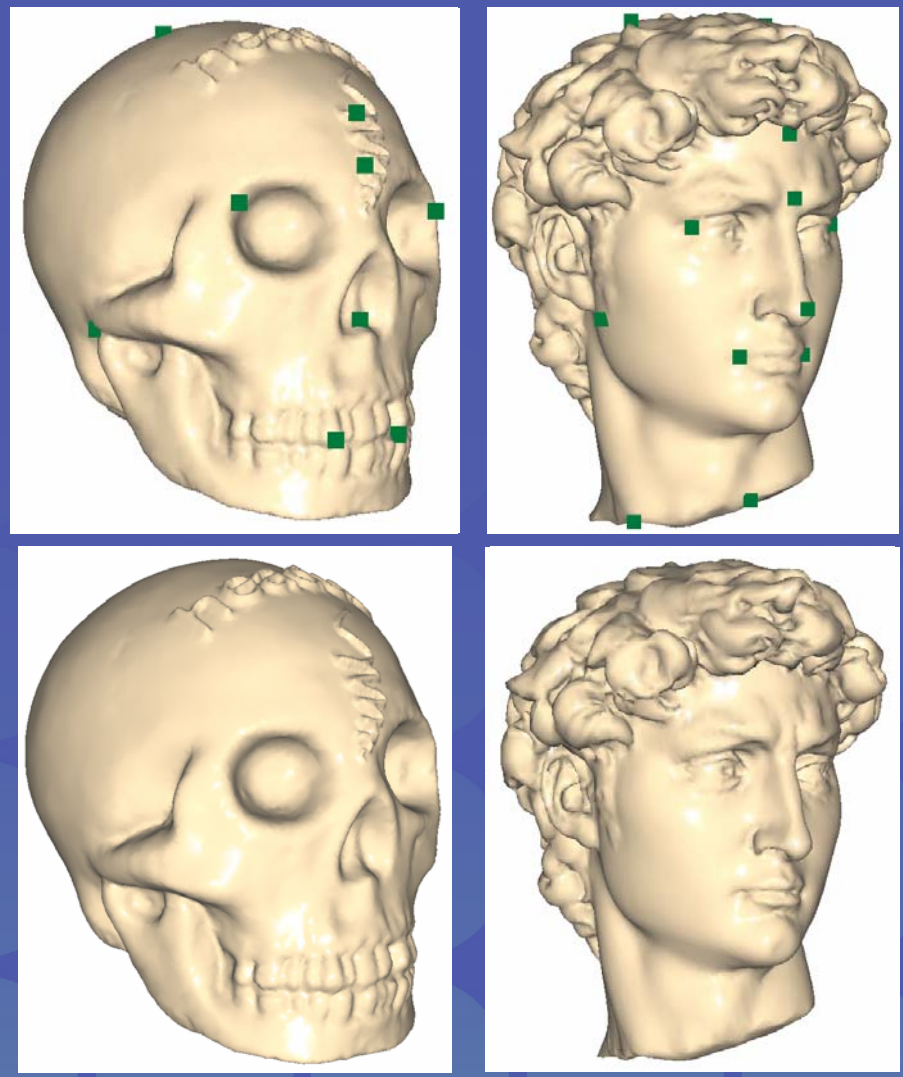
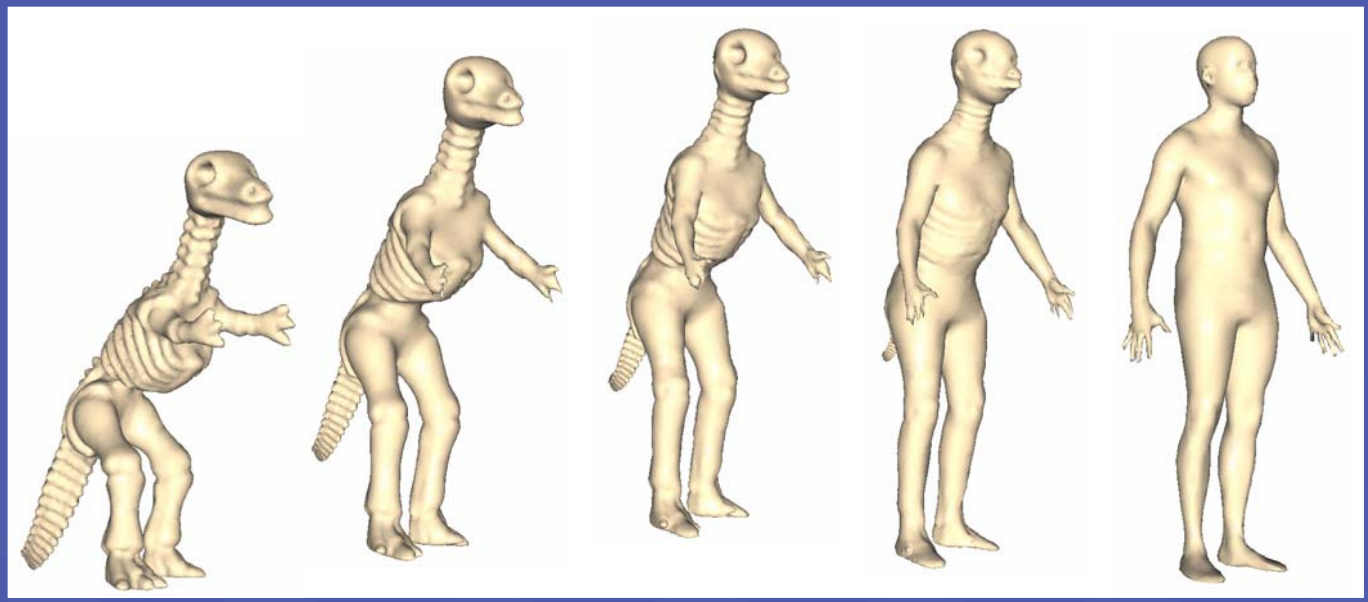
- Operations:
  - Smoothing
  - Refinement
- Smoothing
  - Use overlapping domains framework
  - Error based relocation formula
- Refine edges based on error
- Iterate



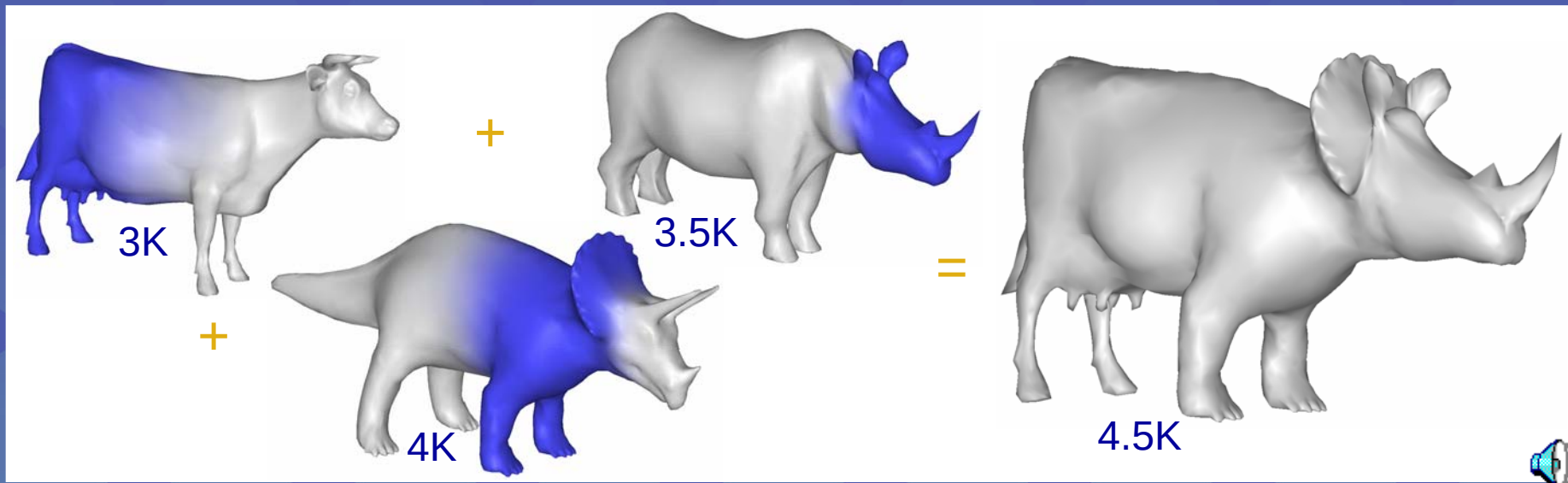
40K/40K faces – 49K faces

Results



Morphing
28K/8K - ZK

Blending



Summary

- Robust method for constrained X-parameterization
  - Input: two (or more) models + corresponding feature vertices
  - Automatic construction of base mesh
    - Provably correct for genus=0
    - For genus > 0 works most of the time
- New framework for low-distortion parameterization on base mesh
  - Independent of patch structure
  - Can be applied with different objective functions
  - Efficient

Summary

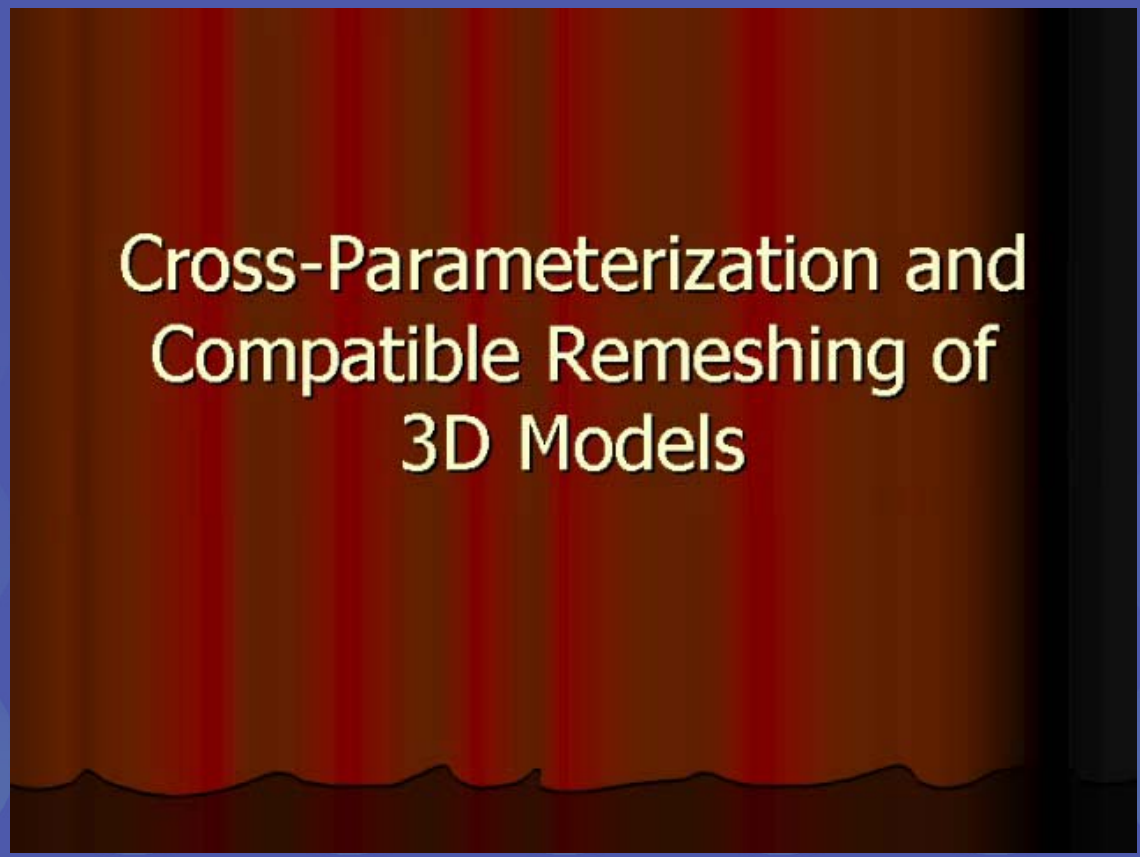
- New compatible remeshing scheme
  - Closely approximate input
  - Small output mesh
    - ~20% more triangles

- Future
  - Using smoothing framework for unconstrained parameterization

Comparison to [Schreiner et al. 04]

	Our method	**[Schreiner et al. 04]**
Base Construction		More robust for genus > 0 (add extra feature vertices)
Smoothing	2 min 64K (overlapping domains)	2 hours 64K (overlay smoothing)
Constraints	Exact constraints	Relax constraints to reduce distortion
Remeshing	output: ~x1.2 triangles as source input (parameterization based scheme)	output: ~x8 triangles as inputs (typical) (mutual tessellation)

Movie !!!


Cross-Parameterization and
Compatible Remeshing of
3D Models