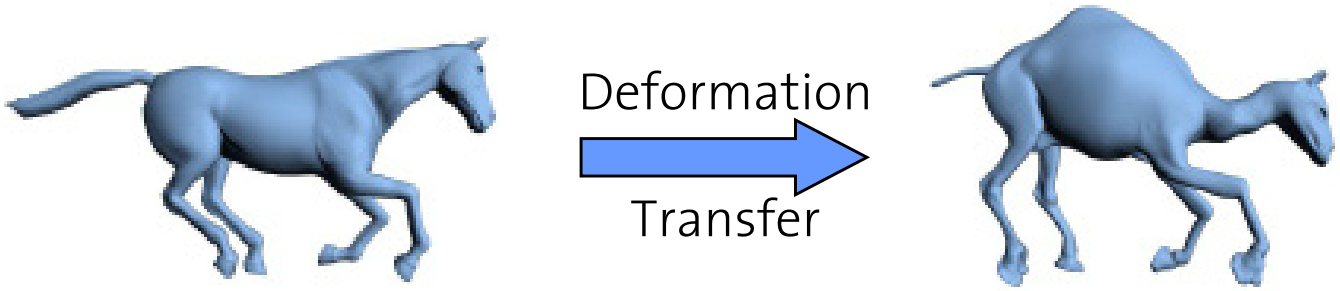
Deformation Transfer for Triangle Meshes

a Paper (SIGGRAPH 2004) by Robert W. Sumner & Jovan Popovic
presented by Roni Oeschger



Source deformed

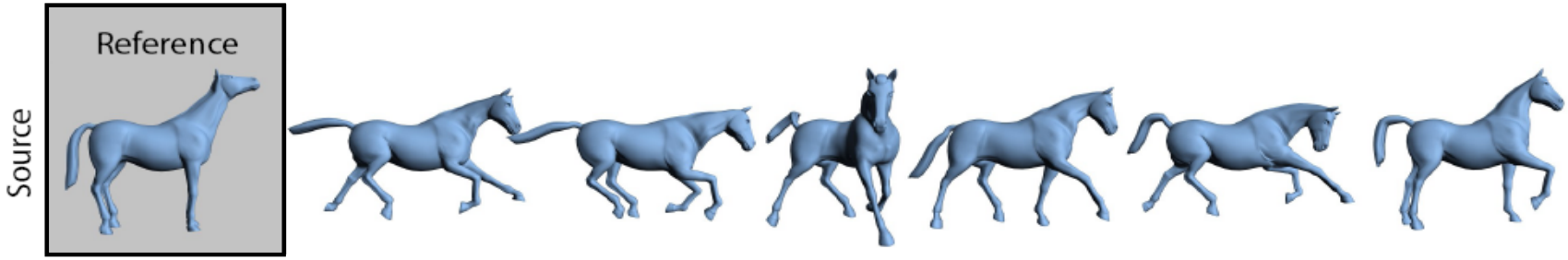
Target deformed

Outline of my presentation

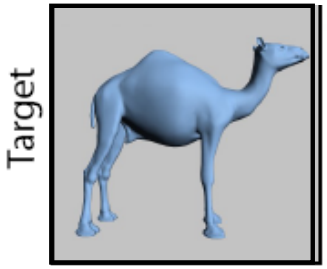
- Introduction & Motivation
- Deformation Transfer
- Correspondence
- Results
- Conclusions
  - by the authors
  - by me

What is it all about?

- Given a source mesh in a reference pose and several deformations of it:

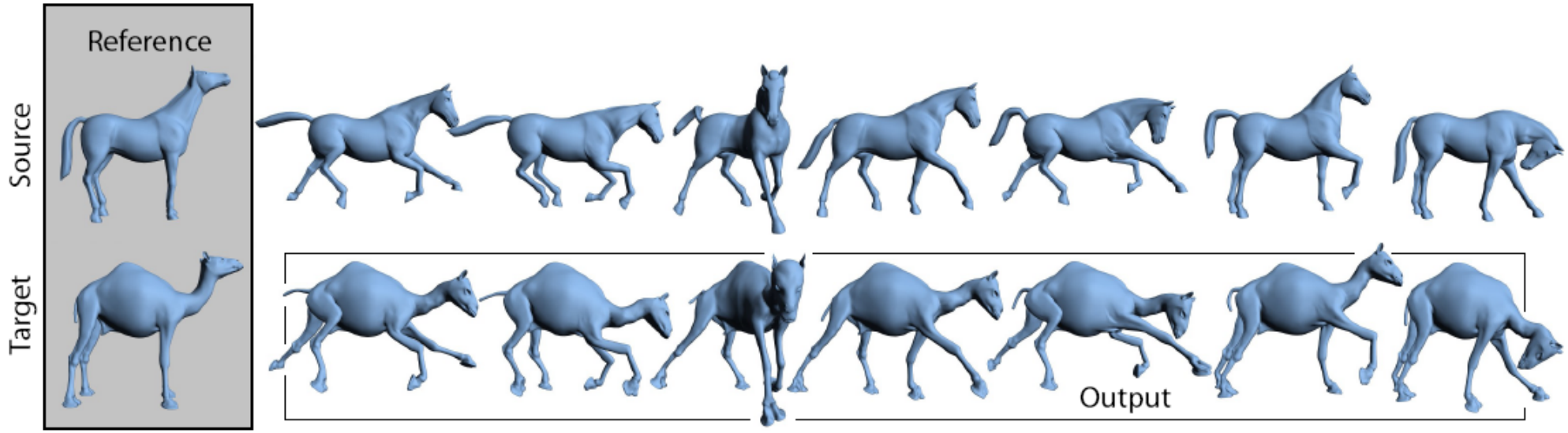


- Given another mesh, called Target in same reference pose:



What is it all about?

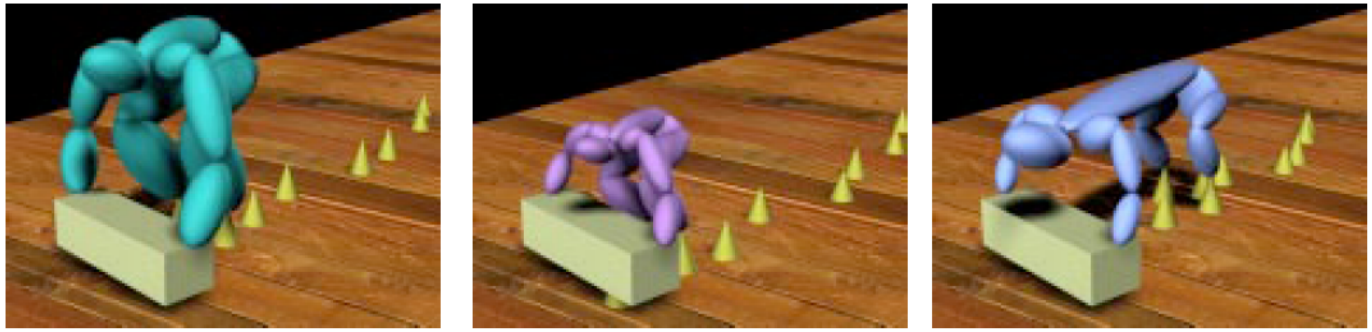
- Transfer the deformations to the target:



- Reuse of deformations which were probably created with a lot of effort

Related Work

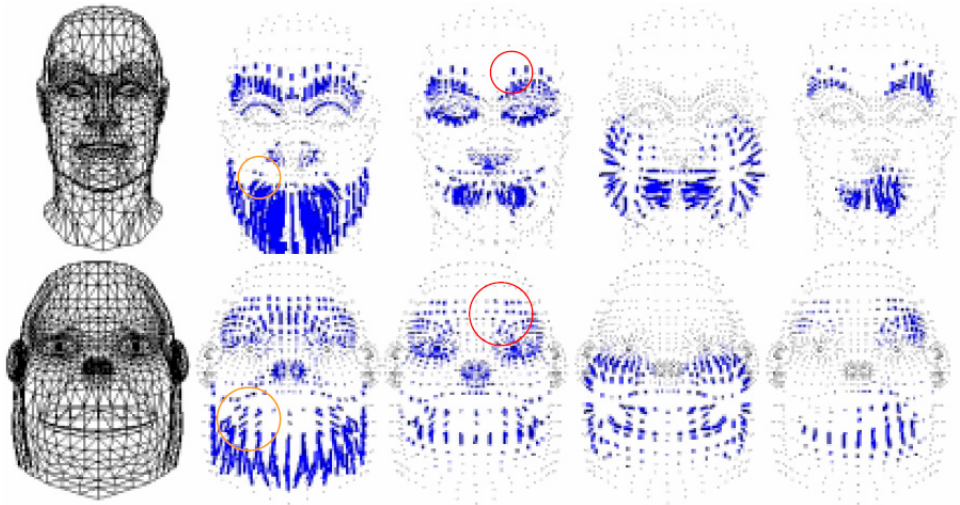
- Method proposed by M. Gleicher*
  - similar goal
  - different conditions
    - based on skeletons and applies to a target skeleton with the same structure



* GLEICHER, M. 1998. Retargeting motion to new characters.

Related Work

- Noh and Neumann* achieve the same for facial deformations
  - Based on displacement vectors
  - No generalization to full-body deformations

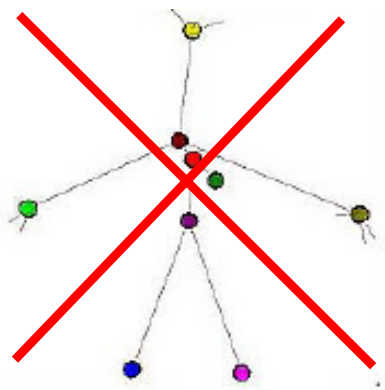


* NOH, J., AND NEUMANN, U. 2001. Expression cloning.

Deformation Transfer

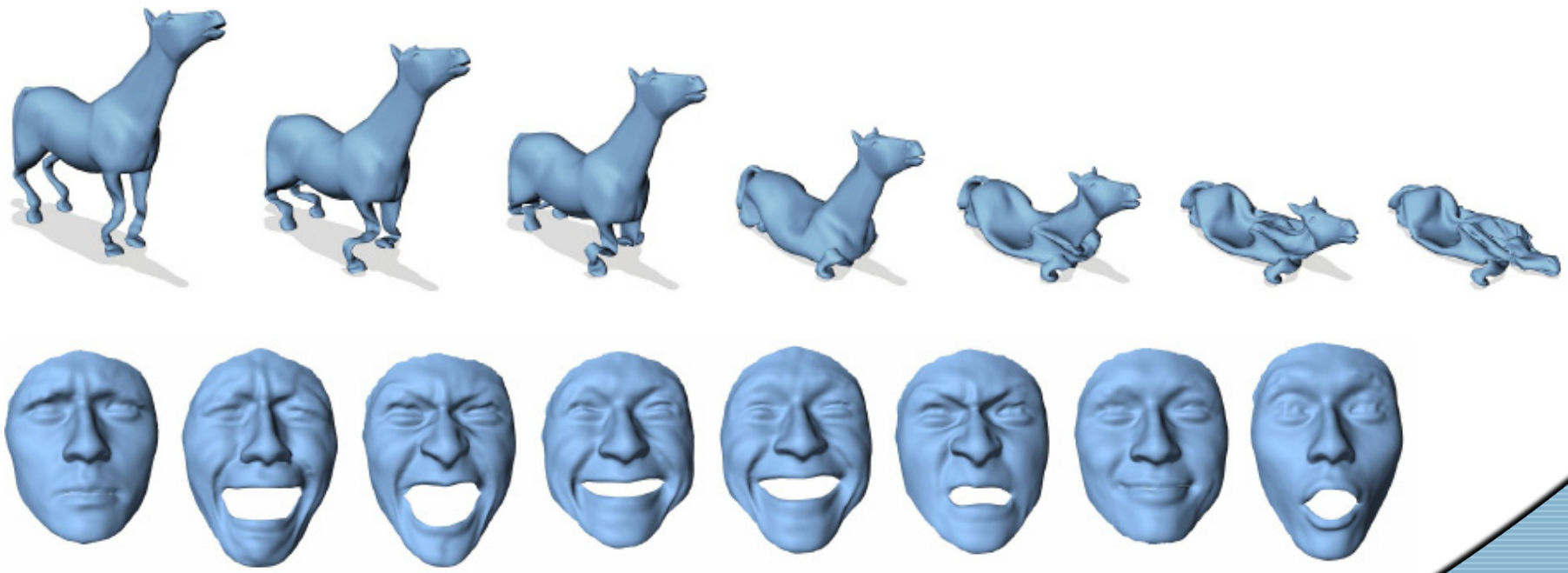
- Deformation Transfer is purely *mesh-based*

- No need for an underlying skeleton structure



Wider Area of Application

- *Not skeletal-driven* deformations
  - non-rigid or facial deformations etc.

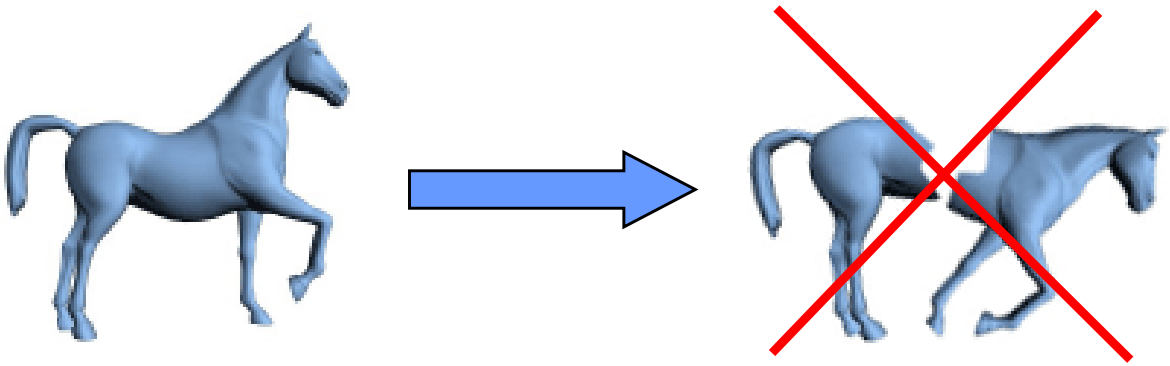


Wider Area of Application

- If *no skeletal information* is available
  - hand-made deformations etc.

Deformations

- Deformations can be arbitrary but they must *preserve the topology* of the mesh
  - No cracks, fractures etc.

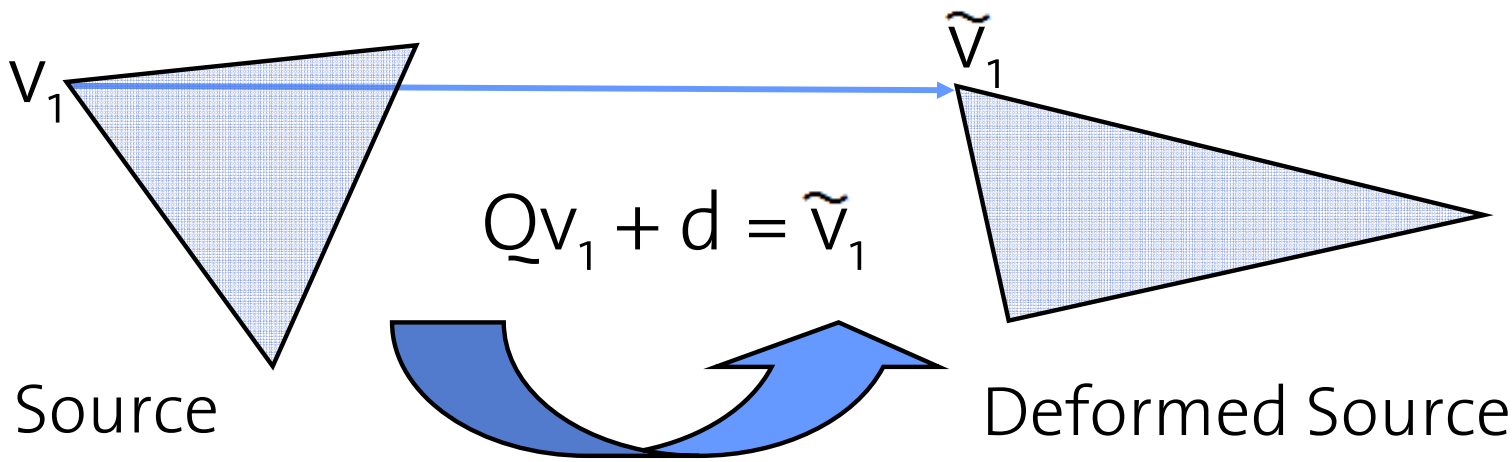


The Approach

- Compute the deformation S_i for every source triangle (orientation, scale, skew)
- Compute mapping from source to target triangles (correspondence)
- Apply S_i to the corresponding target triangles

Deformation Details

- Deformation based on *per-triangle affine transformation* $\mathbf{Q}\mathbf{v}_i + \mathbf{d} = \tilde{\mathbf{v}}_i, \quad i \in 1 \ldots 4$



Closed Form Solution

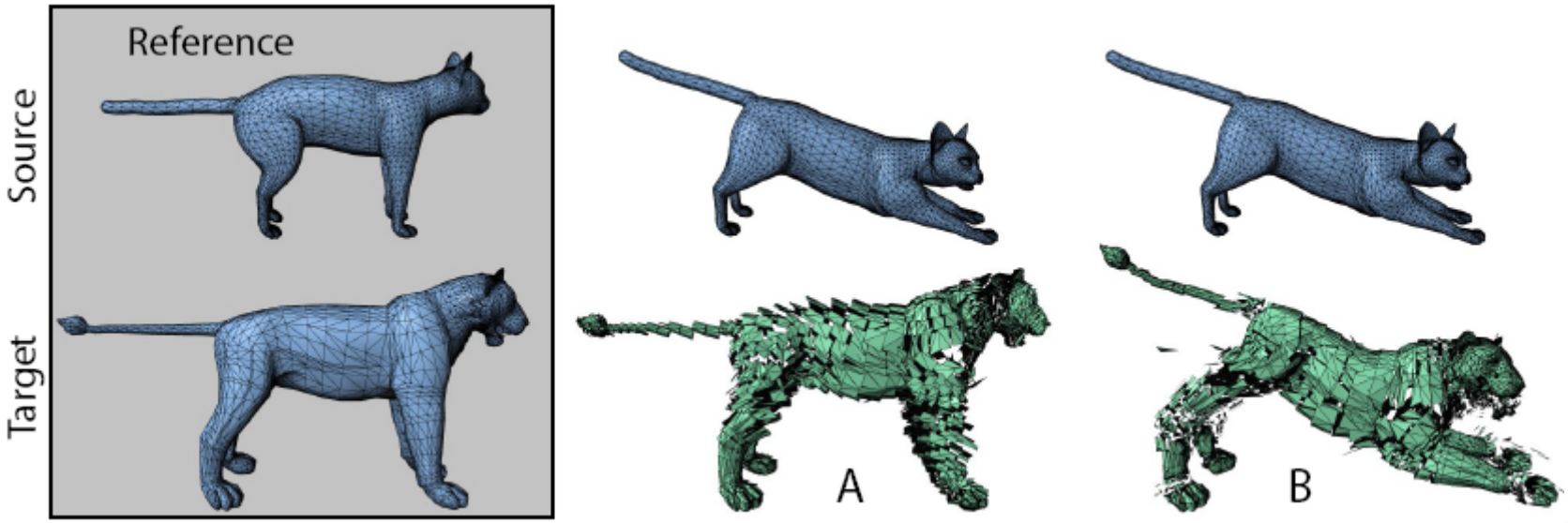
- *Closed form solution* of Q:

$$\mathbf{Q} = \tilde{\mathbf{V}}\mathbf{V}^{-1}$$

- "Deformation Gradient" Q depends on
  - triangle in reference pose
  - triangle in deformed pose

Resulting Meshes

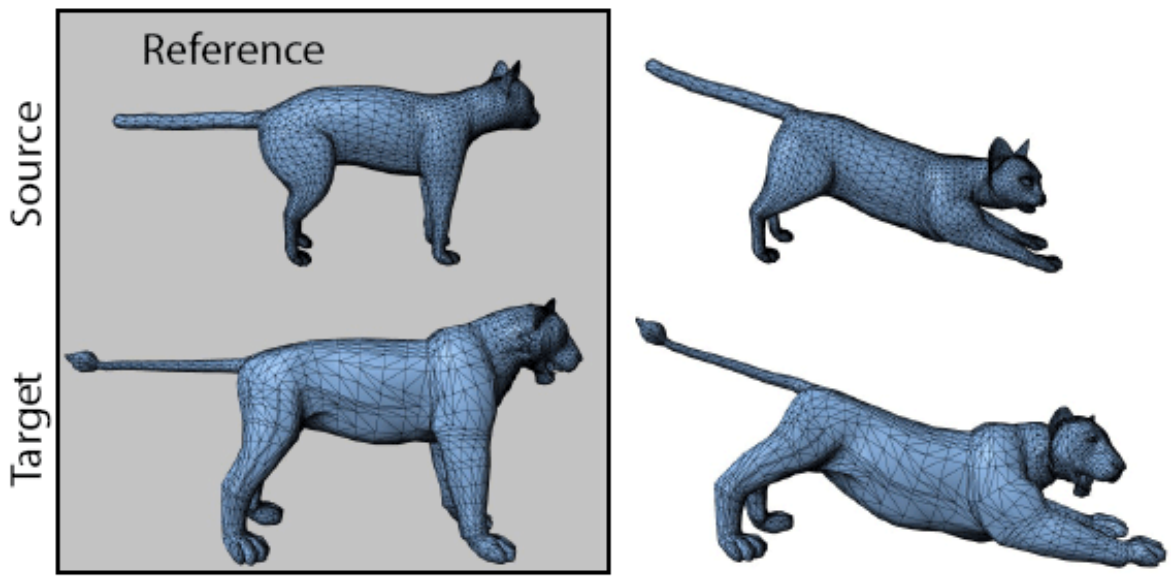
- Leads to holes in the resulting mesh (B)
- Used representation affords *too many degrees of freedom*



Minimization Problem

- Preservation of consistency leads to a *optimization problem:*

$$\min_{\tilde{\mathbf{v}}_1 \ldots \tilde{\mathbf{v}}_n} \sum_{j=1}^{|M|} \left\| \mathbf{S}_{s_j} - \mathbf{T}_{t_j} \right\|_F^2$$



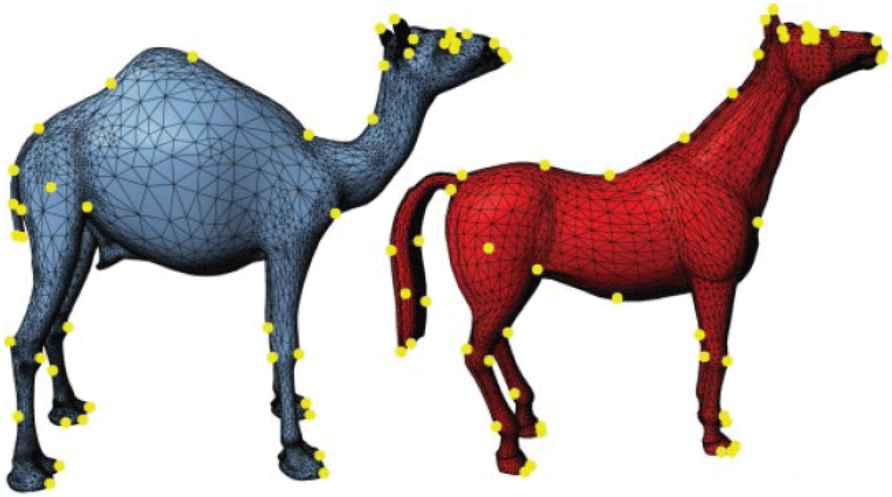
Performance

- Reformulation as *system of linear equations*
  - Solve with linear least squares
  - New poses efficiently computed with *backsubstitution*

Example	Number of Markers	LU Factor-ization	Back-substitution
Horse/Camel	65	1.559s	0.293s
Cat/Lion	77	0.299s	0.057s
Face/Head	42	1.252s	0.298s
Horse/Flamingo	73	1.495s	0.406s

Correspondence

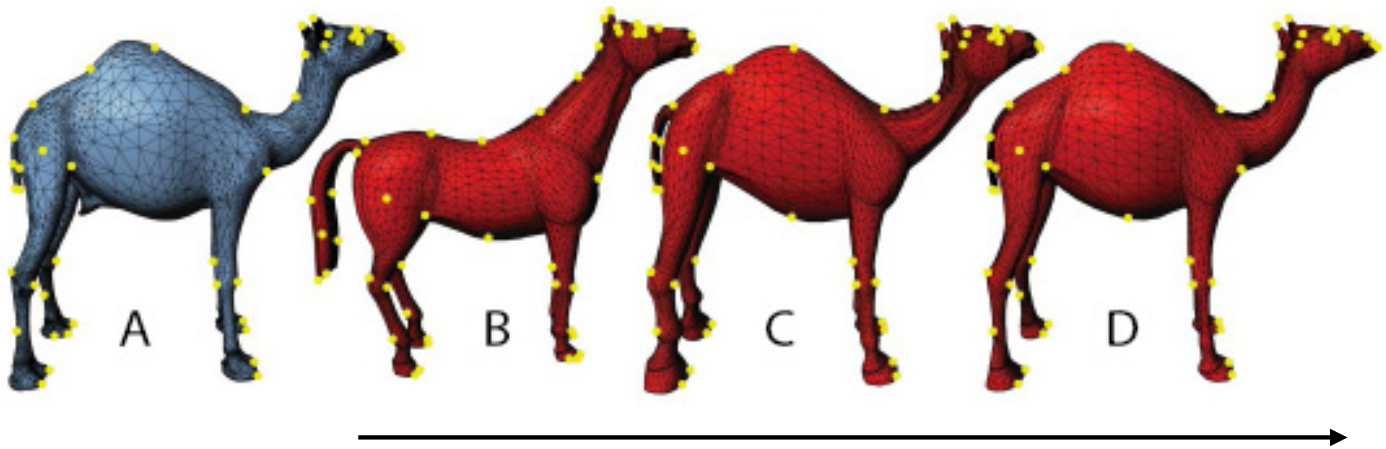
- Triangle correspondences computed by deforming one mesh *into* the other
- User sets *Markers* as hard constraints for deformation



Target Source

Iterative Solution

- Iterative approach with weighting to
  - approximate Target as good as possible
  - keep deformation as smooth as possible



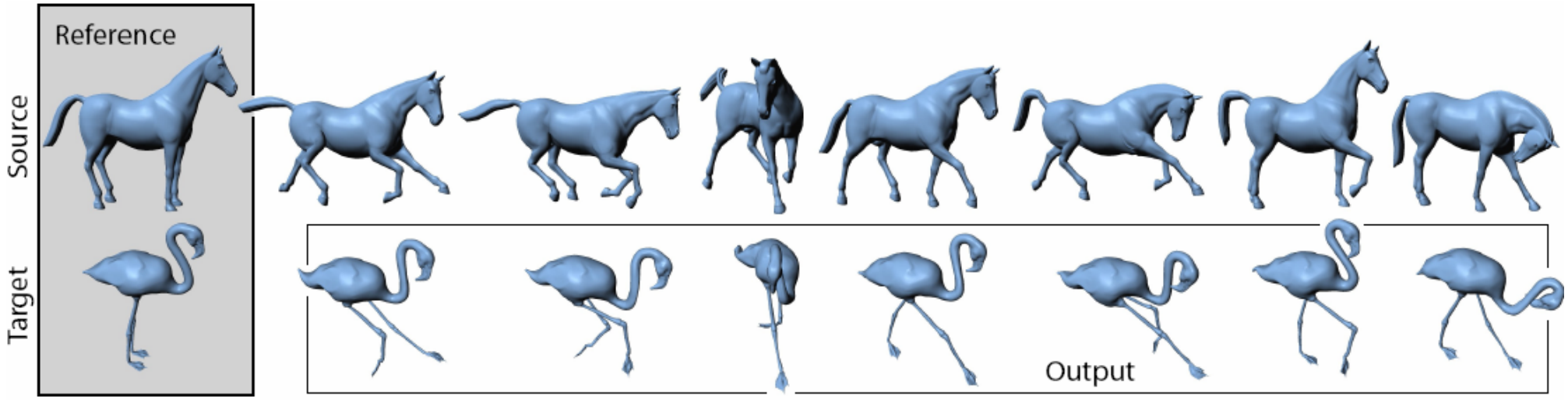
Target Source iteratively deformed

Results: Face to Head

Results: Horse/Camel Video

- 2 Types of Deformation, both animated
  - Galloping animation
  - Collapsing animation

Results: Horse to Flamingo



- No direct semantic correspondence
- Many Markers necessary at neck
- Anatomically incorrect

The Authors' Conclusions

- Control of deformation through
  - correspondence mapping
  - additional vertex constraints

  → no way to transfer *animation controls*

- *Semantic Similarity* between the meshes required

The Authors' Conclusions

- Optimization problem is unique up to a *global translation*
  - Key Poses: just fix 1 Vertex in space
  - Animation Sequences: must be done at each point in time with constraints

Results: Face to Head

- Eyeballs omitted because of global positioning problem

The Authors' Conclusions

- Optimization problem is unique up to a *global translation*
  - Key Poses: just fix 1 Vertex in space
  - Animation Sequences: must be done at each point in time with constraints

My Conclusions: Ideas

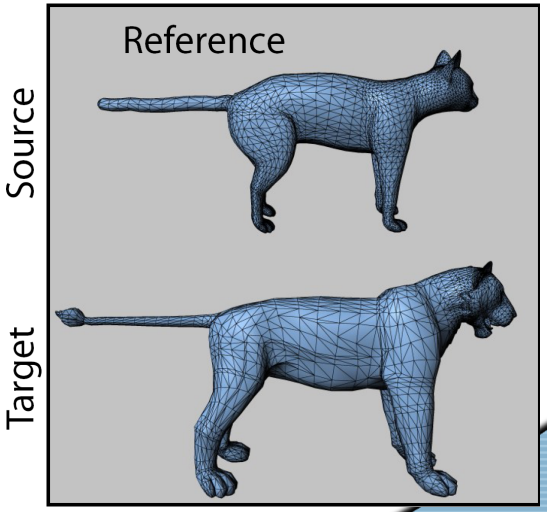
- Fractures, cracks and cuts can't be handled; same is true for liquids etc.

- Sensitive to errors during Marker setting (hand-made) because of hard constraints

My Conclusions: Ideas

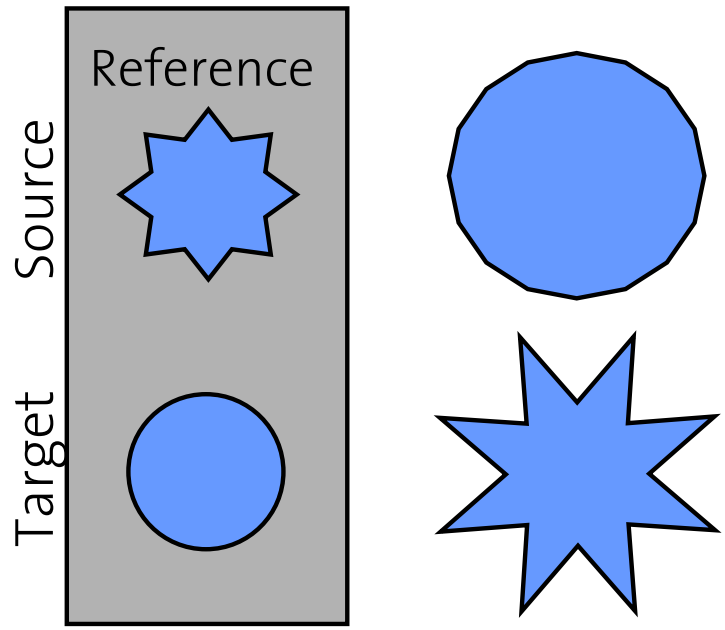
- Be aware:
  - no direct preservation of volumes
  - collision detection not considered

- Reference poses needed



My Conclusions: Ideas

- Problem if source deformation involves mesh details which Target doesn't posses



Example: balloon-like blow up

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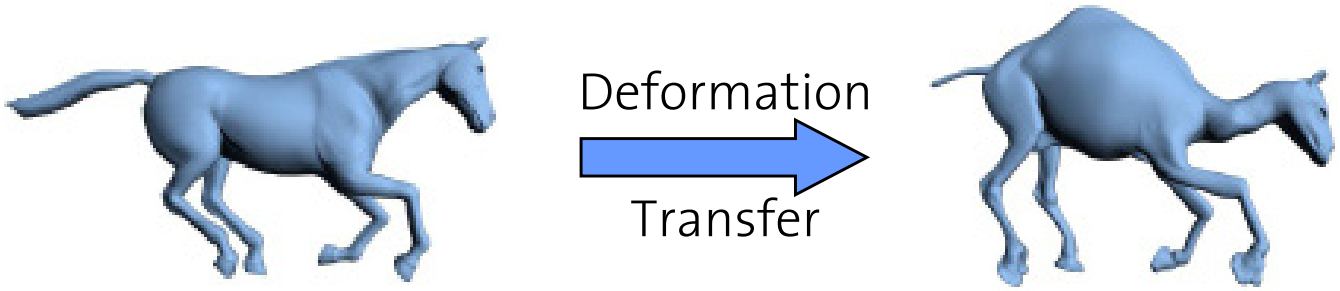

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Target deformed