

SHAPE FROM X

One image:

- Texture
- Shading

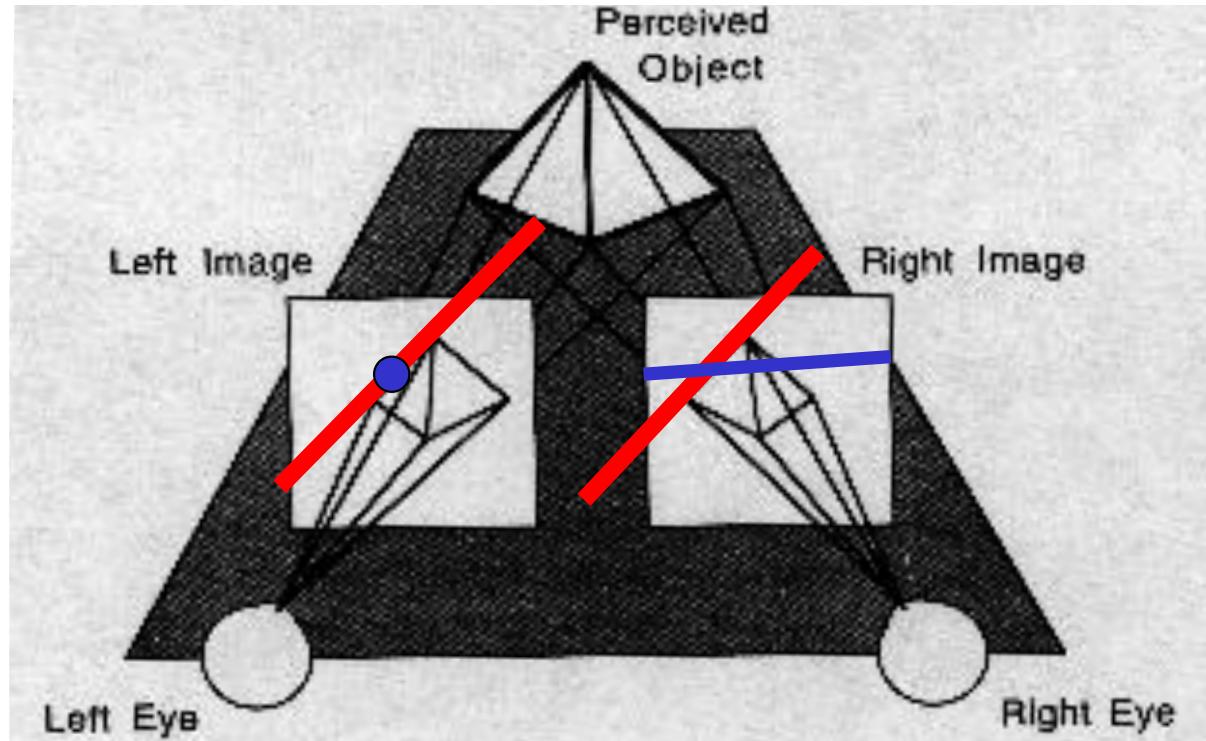


Two images or more:

- Stereo
- **Contours**
- Motion



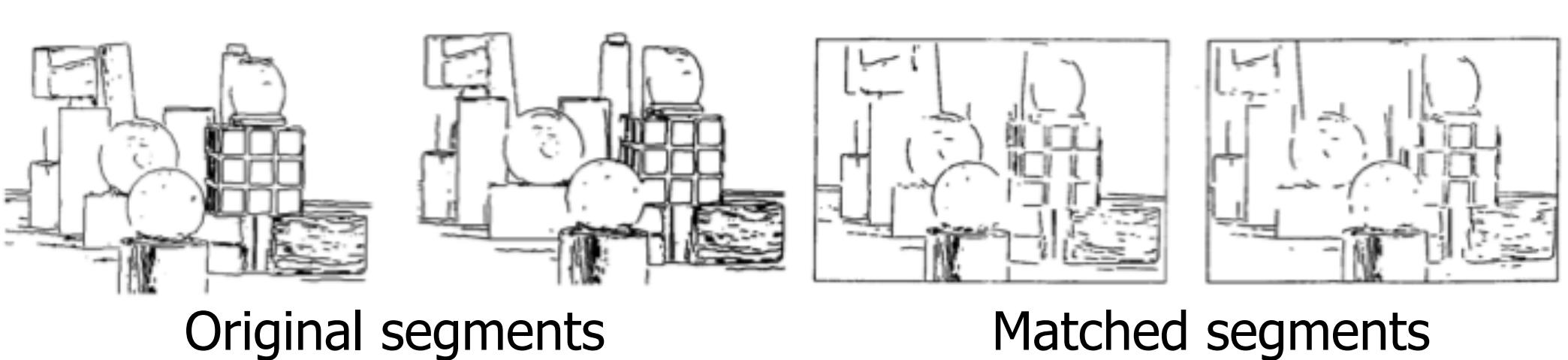
EDGE-BASED STEREO



Matching edges yields stereo information but

- Potential ambiguities
- Edge detection is unreliable

EARLY STEREO APPROACH



Original segments

Matched segments

Pro:

- Little computational power required.

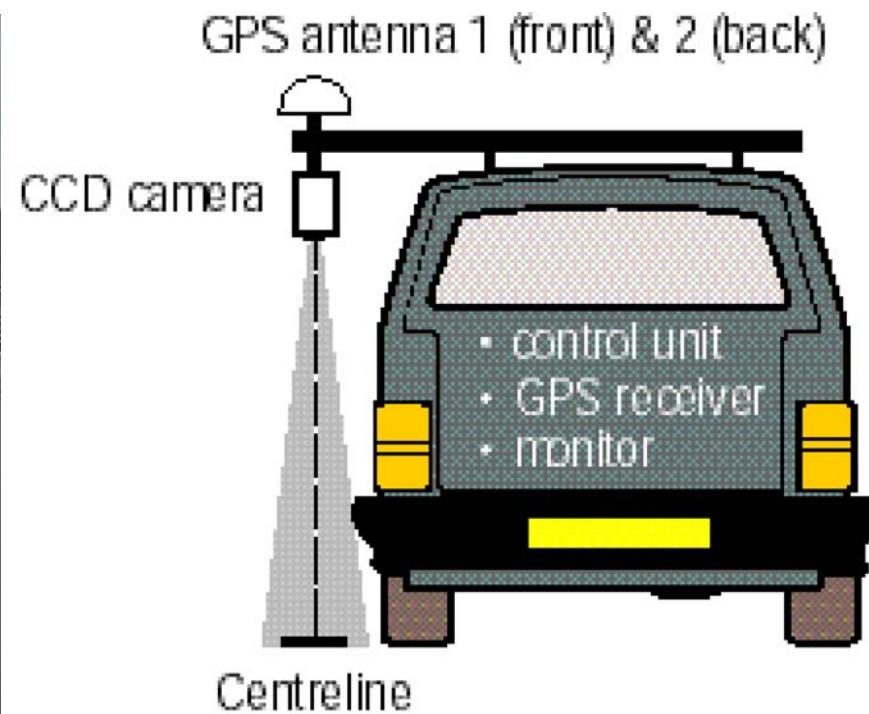
Con:

- Very ambiguous.

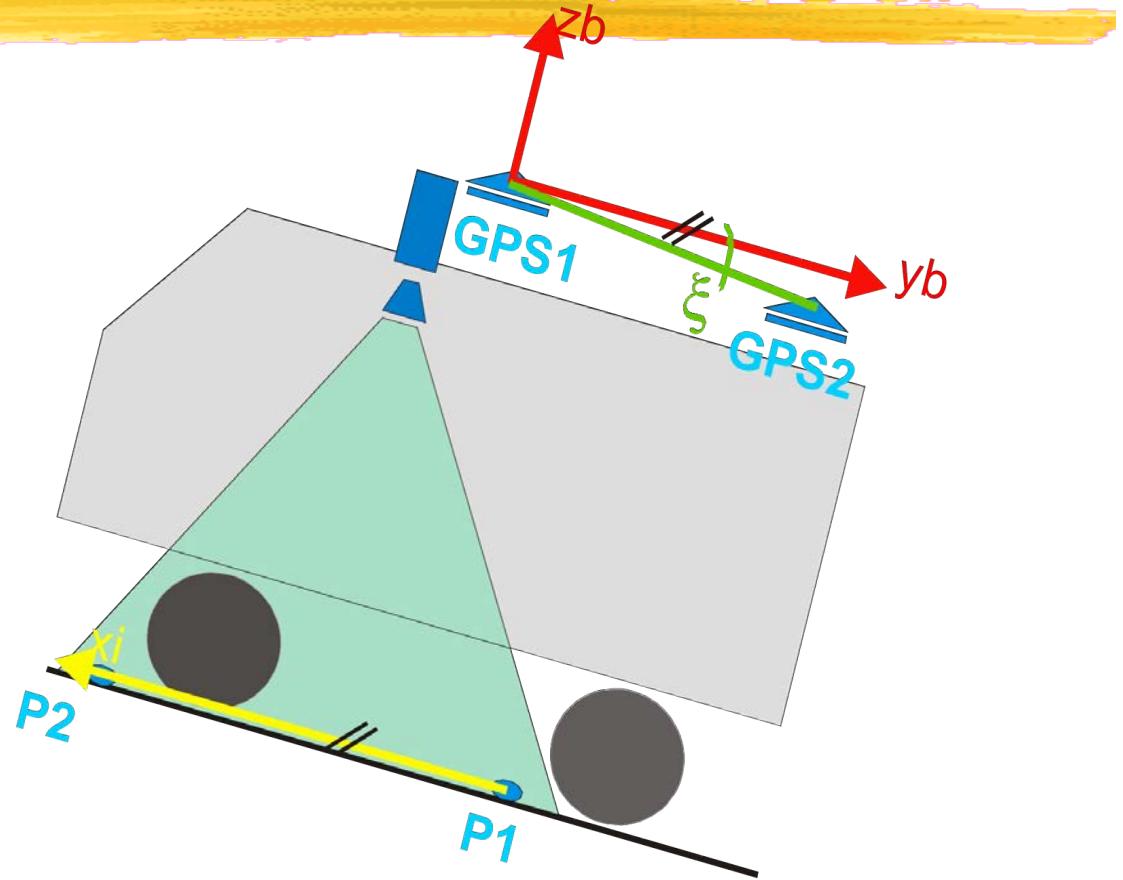
Partial remedy:

- Use three or more images to disambiguate.

PHOTOBUS



CALIBRATION

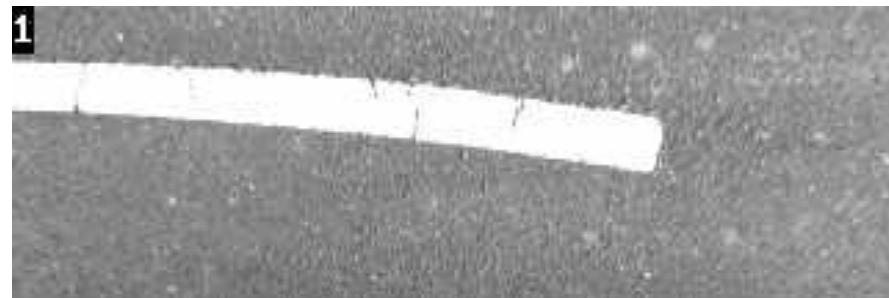
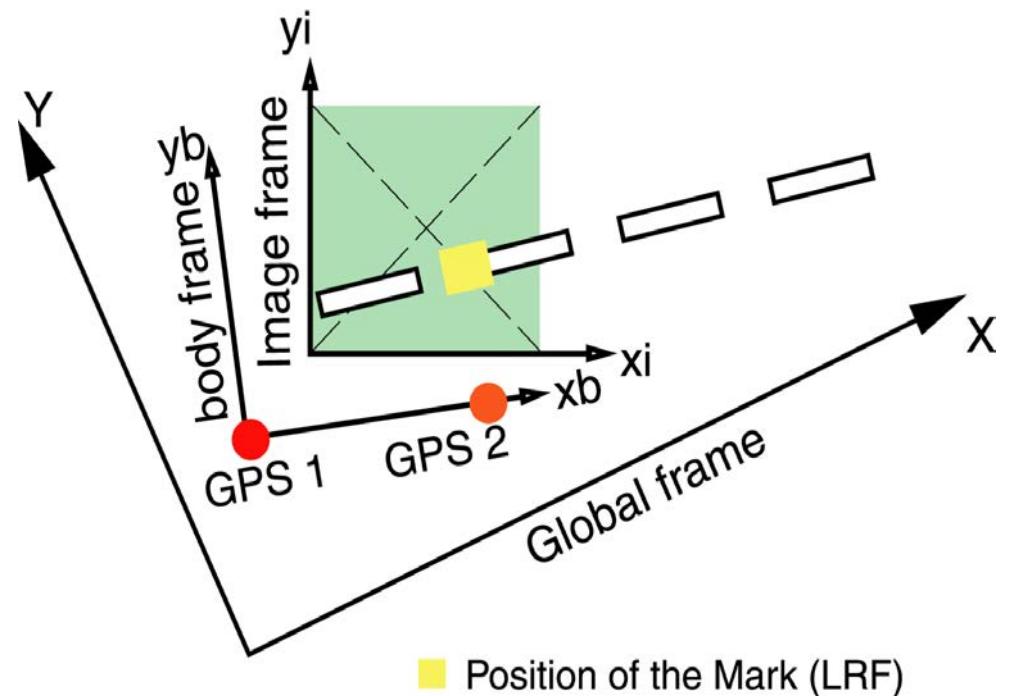


GPS1, GPS2 -> azimuth + pitch

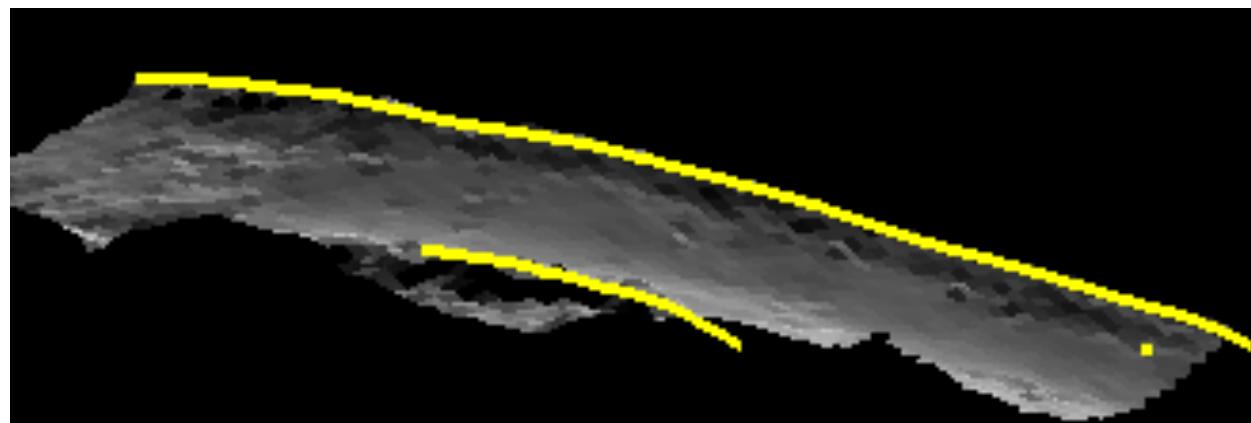
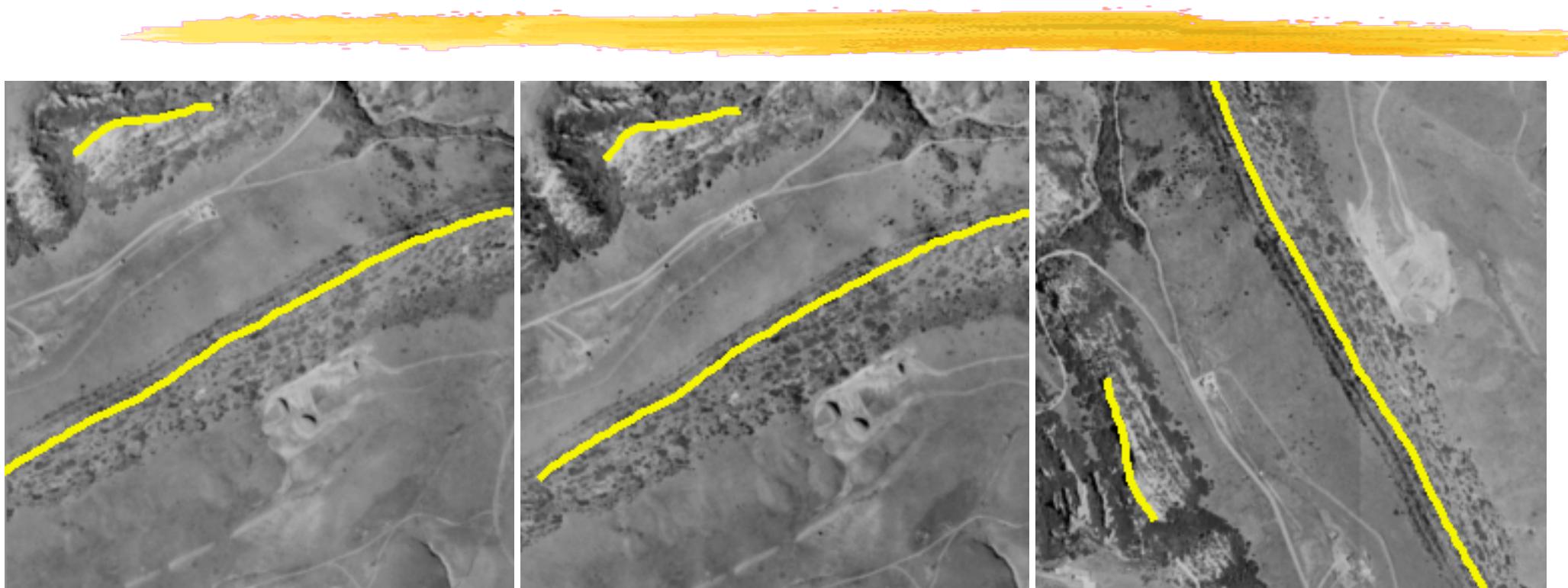
Centerline = Vehicle trajectory + Image coordinates
= two GPS + one CCD

ROAD MARKINGS

- Real-time feature extraction.
- Store only object coordinates.



RIDGE LINES



BUILDINGS

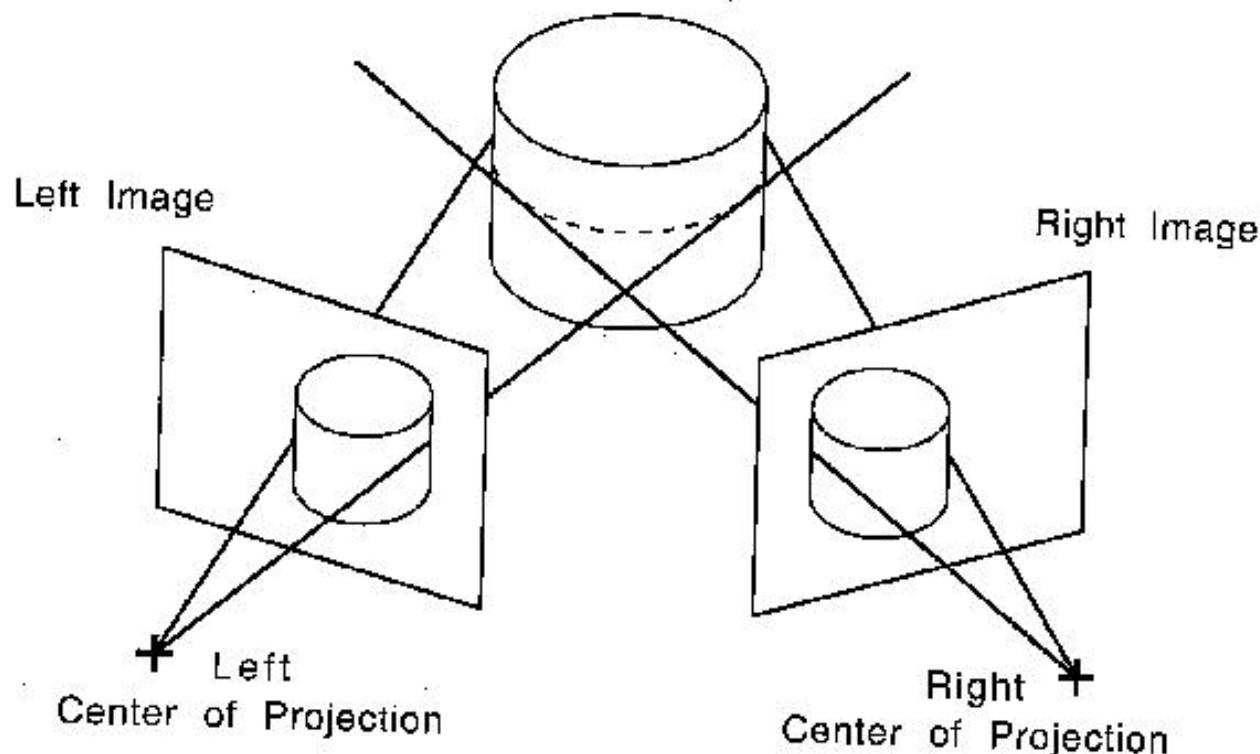


The deformable model encodes the endpoints of the segments.

RACING SPINNAKER



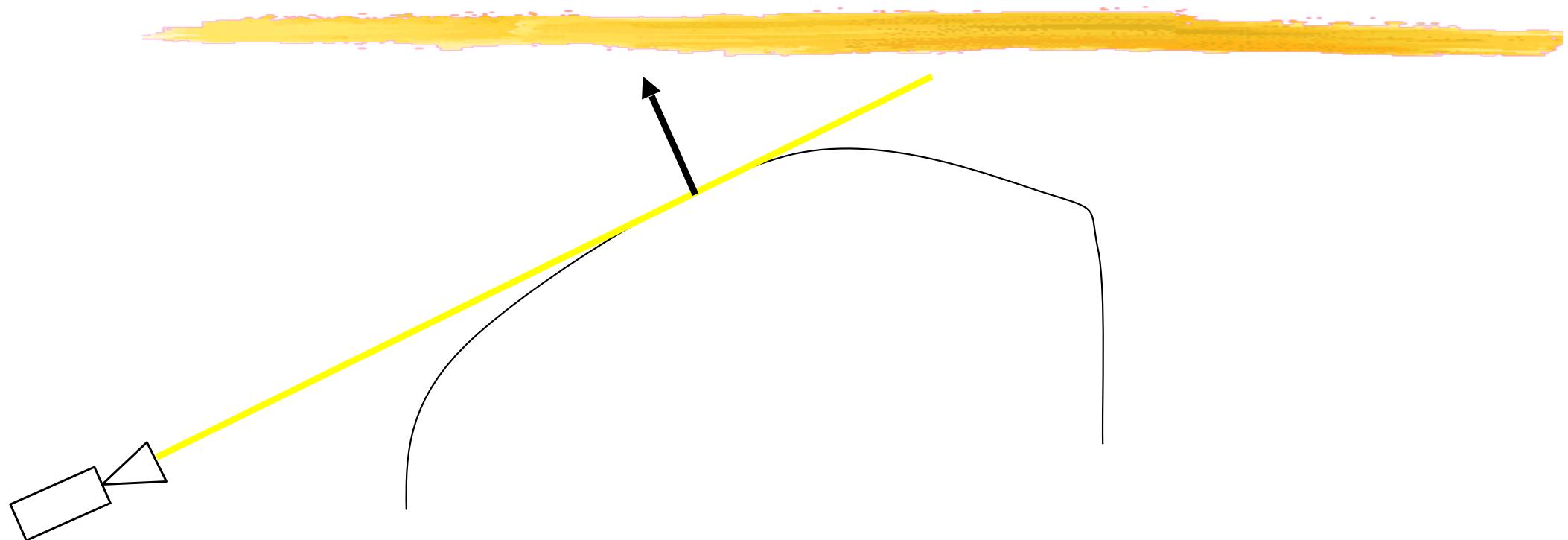
OCCLUDING CONTOURS



Silhouettes let us carve the space:

- on one side is the object,
- on the other empty space.

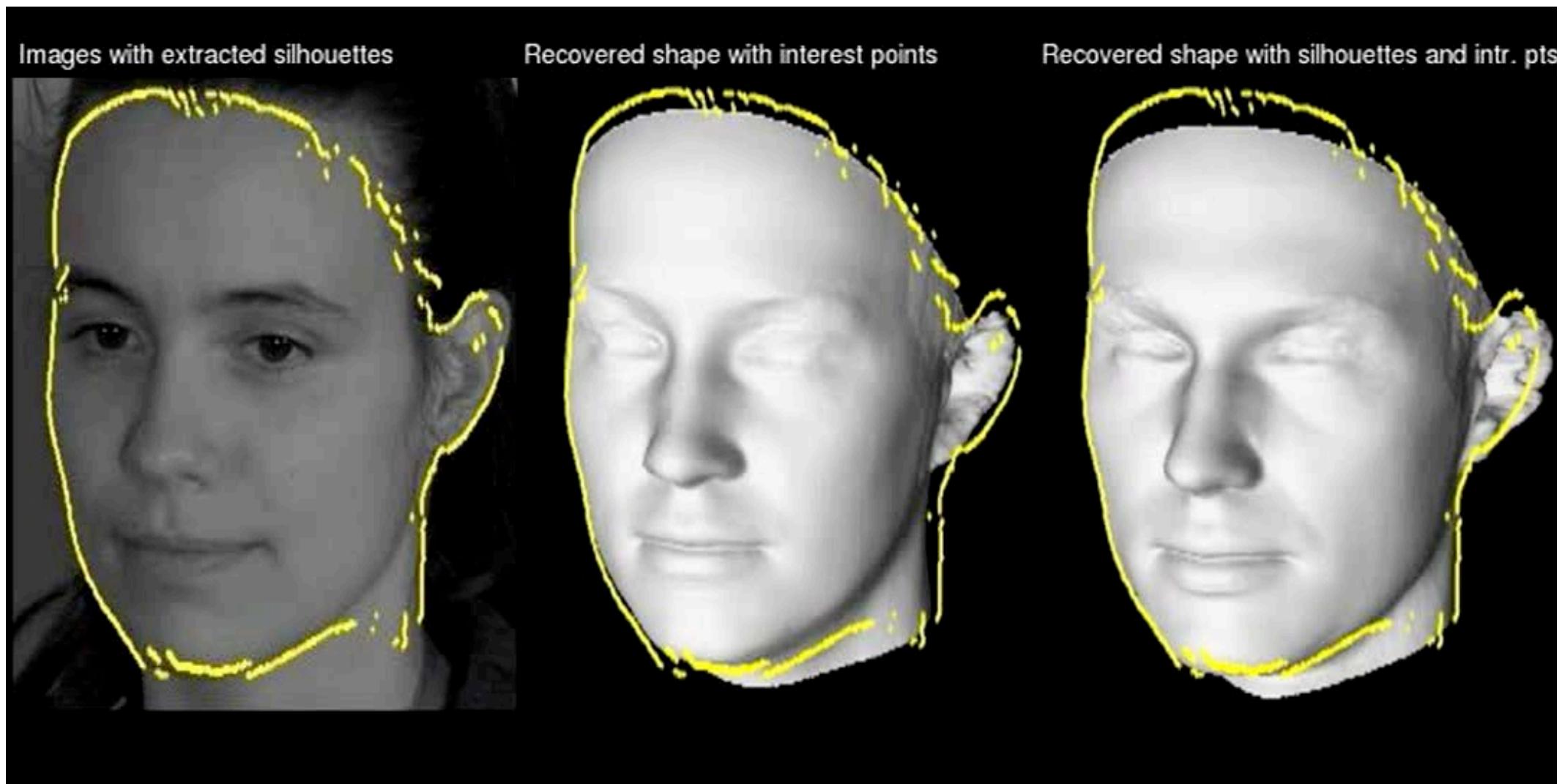
LINE OF SIGHT



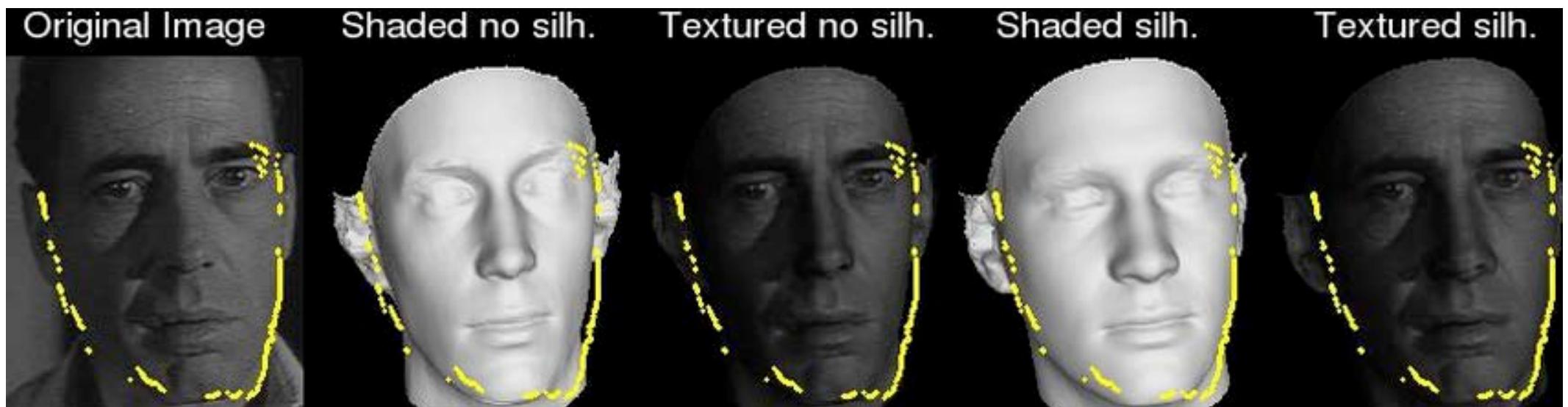
The line of sight is tangent to the surface. In at least one point:

- The distance to the line of sight is zero
- The surface normal is perpendicular to it.

COMBINING STEREO AND SILHOUETTES

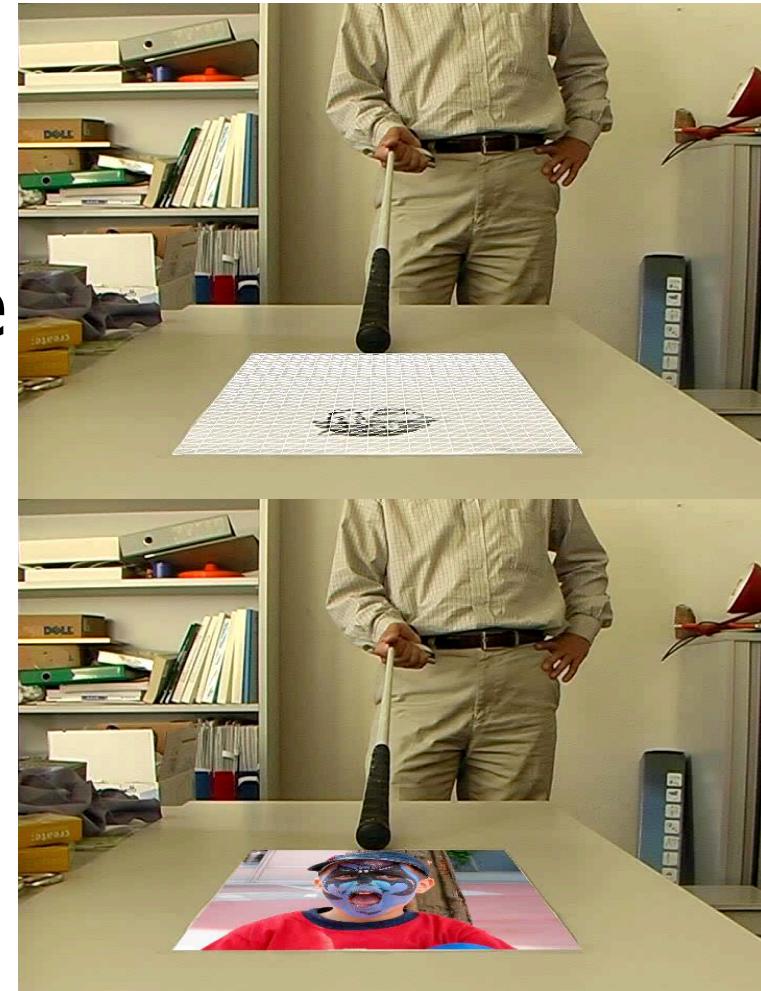


COMBINING STEREO AND SILHOUETTES



TRACKING A DEFORMABLE PIECE OF PAPER

- Track feature points on page
- Fit page boundary
- Detect and use silhouettes when they appear.



CHANGING BACKGROUND



Original



Textured



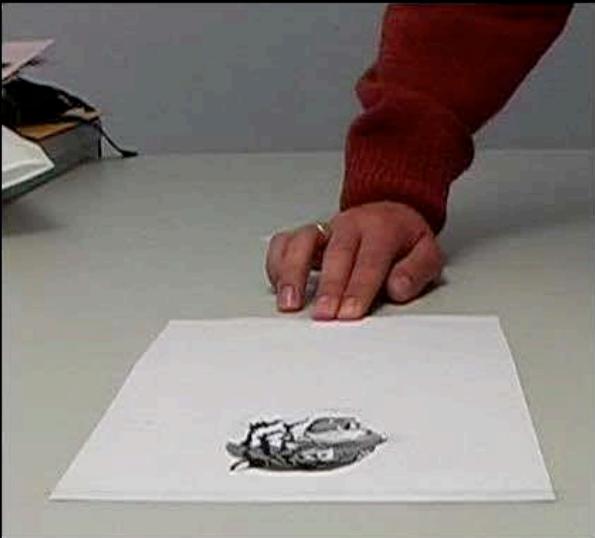
Side View



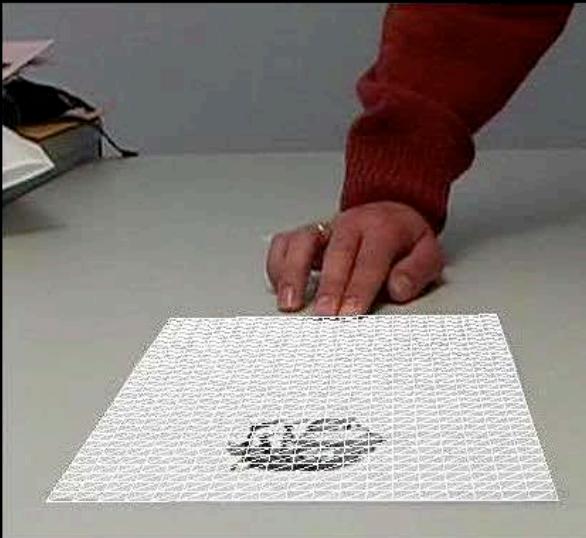
HANDLING OCCLUSIONS



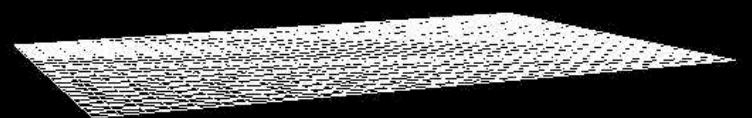
Original



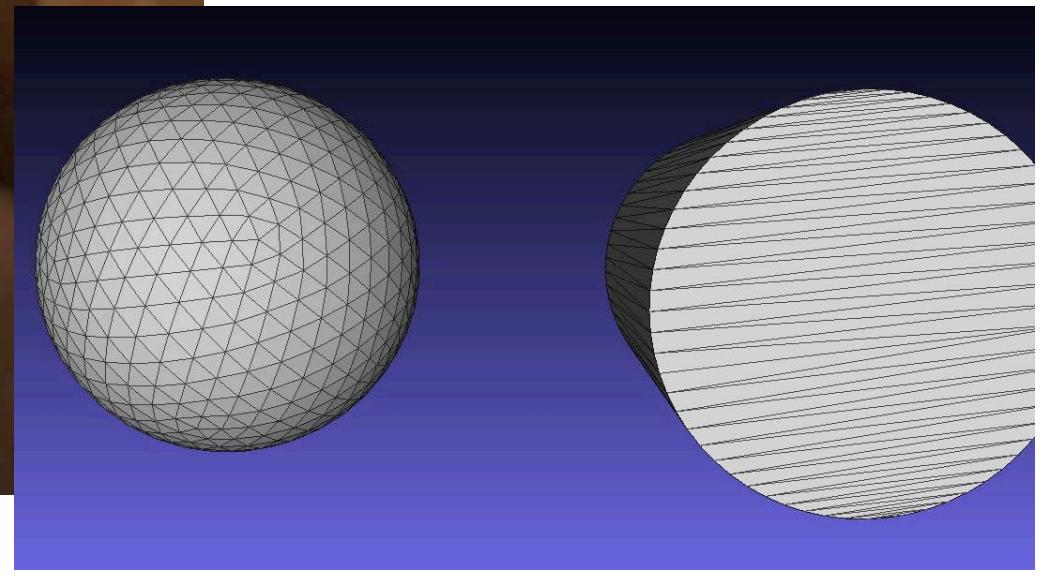
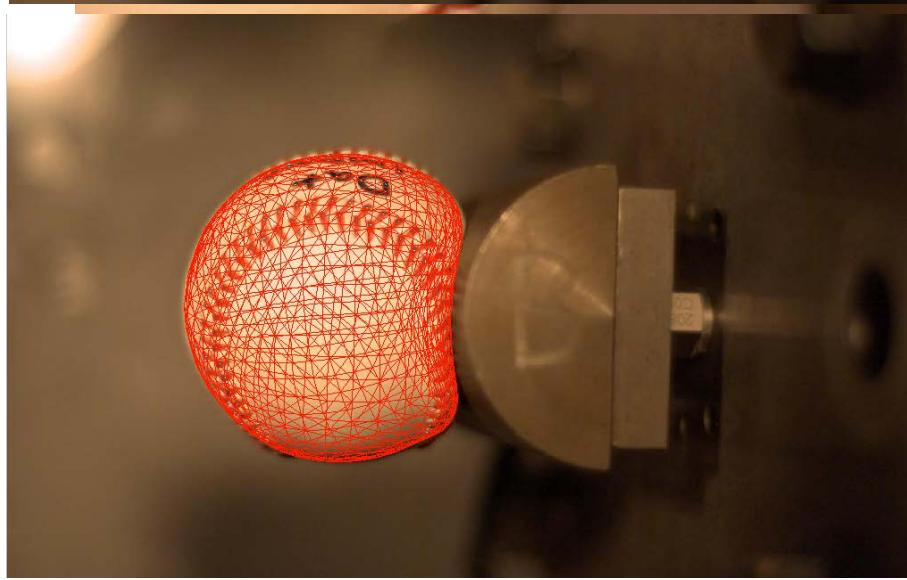
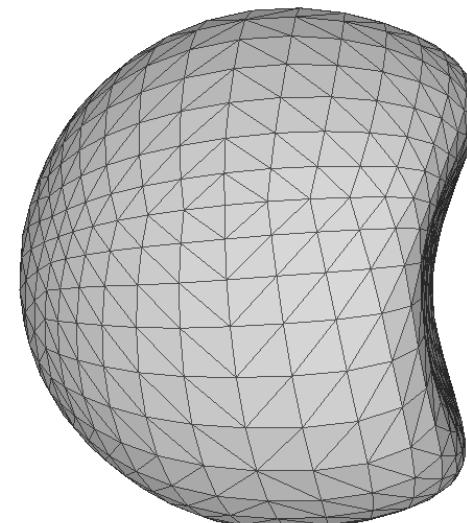
Mesh



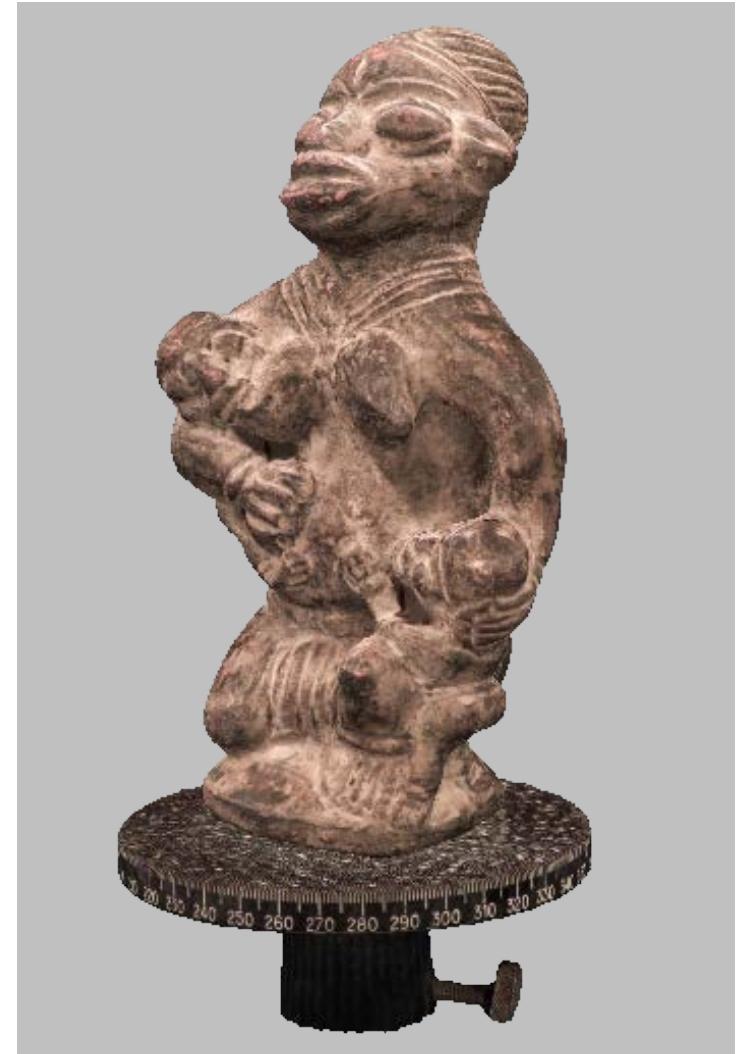
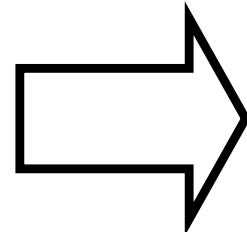
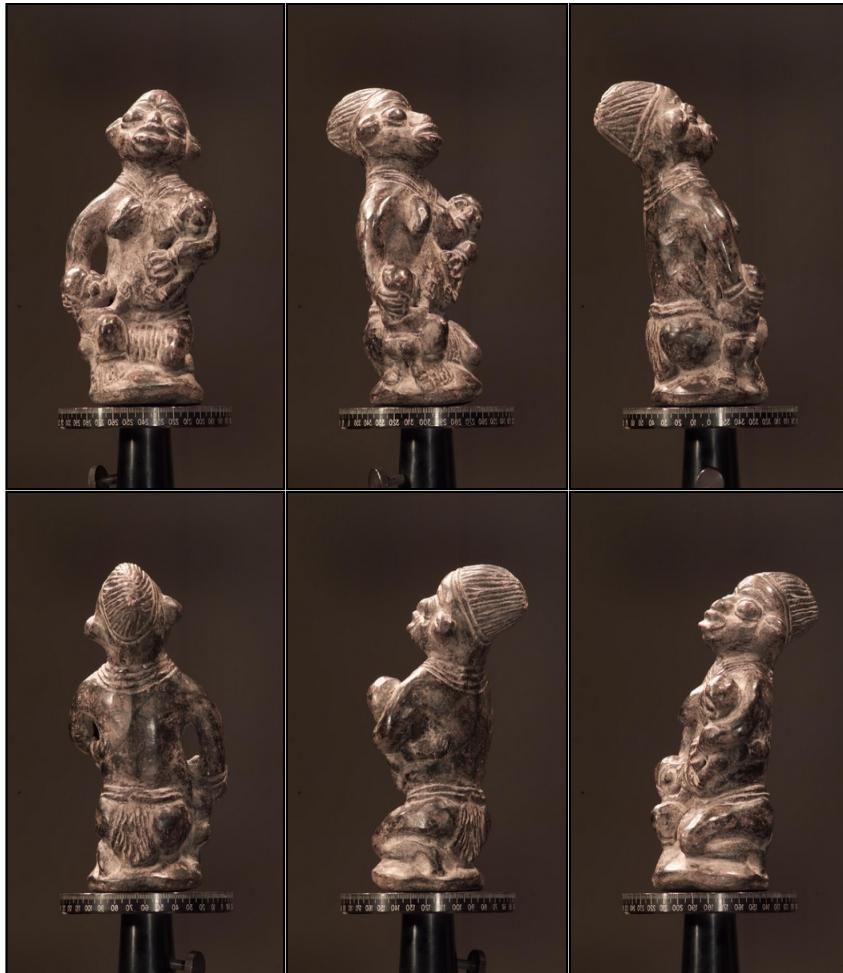
Side View



BASEBALL AND BAT

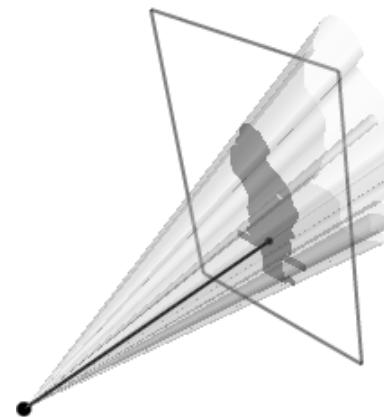
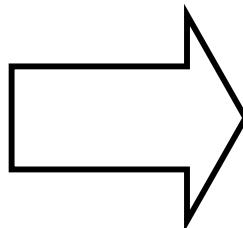
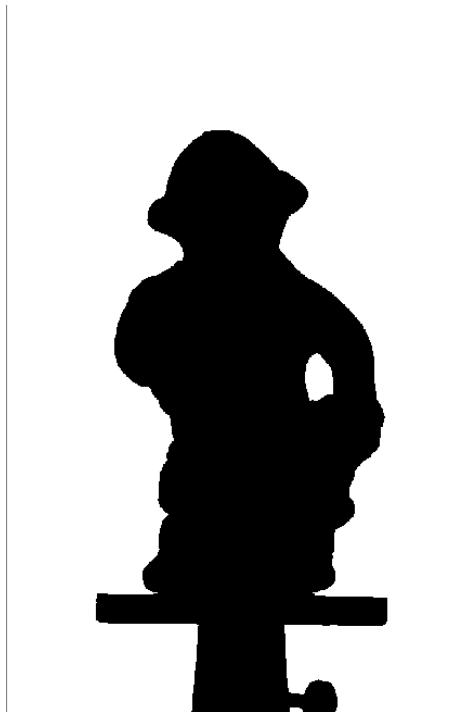


MODELING FROM MANY PHOTOGRAPHS

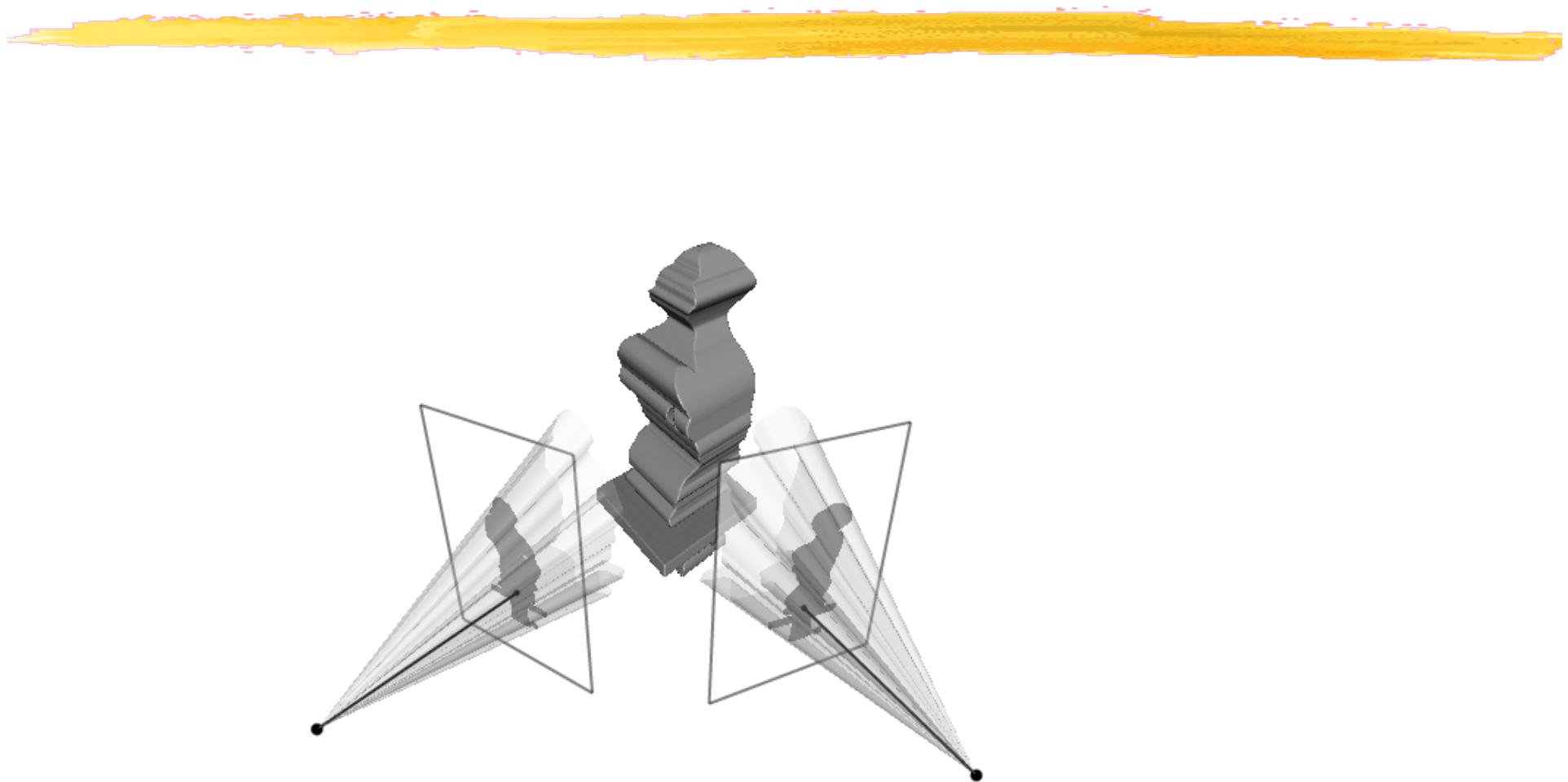


C. Hernandez, PhD ENST, 2004

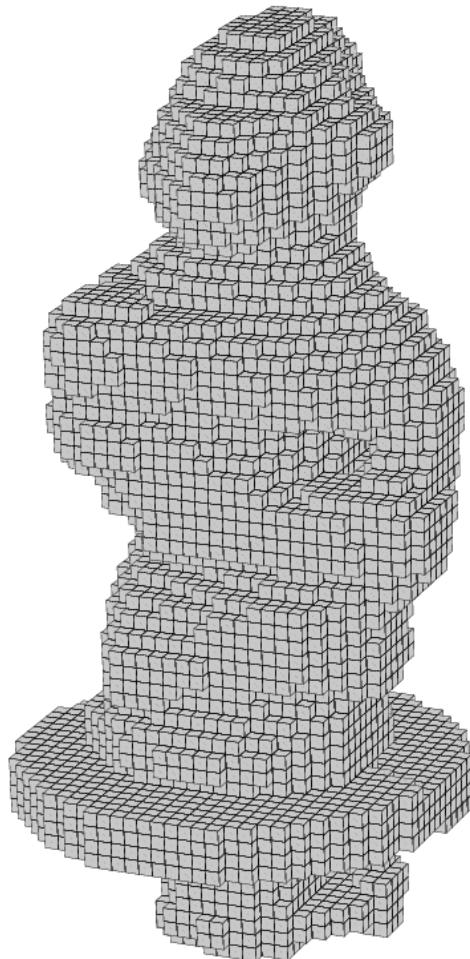
VISUAL HULL ONE IMAGE



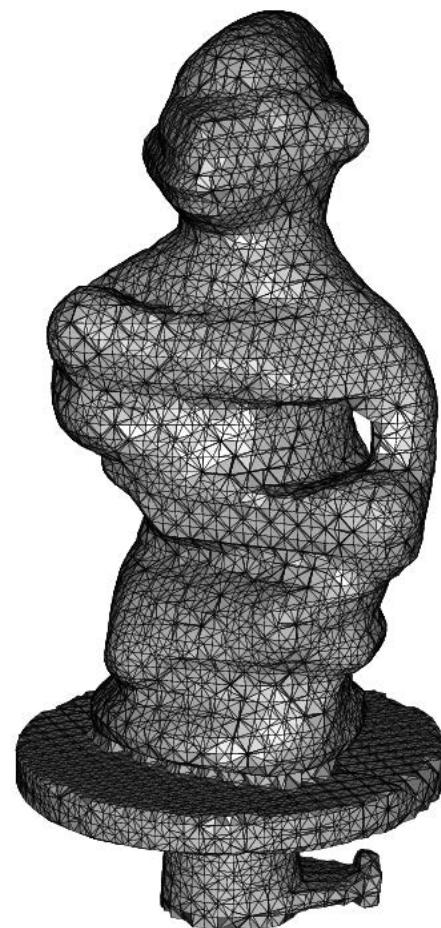
VISUAL HULL TWO IMAGES



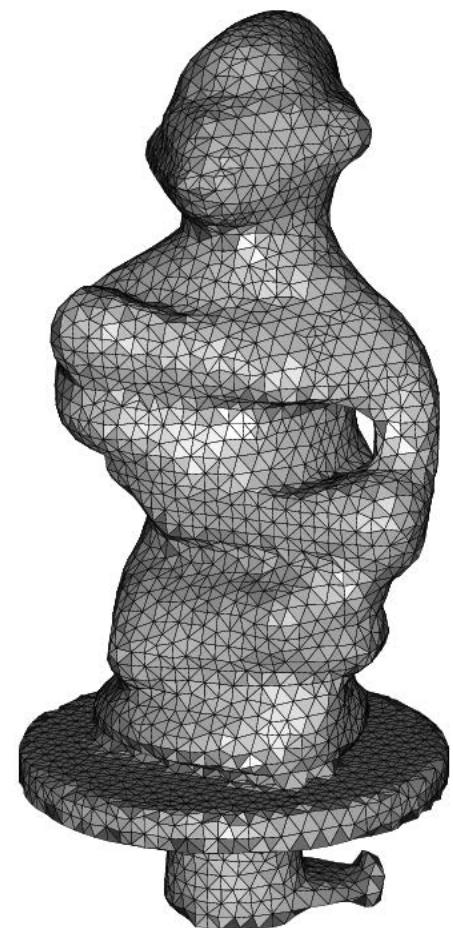
VISUAL HULL MANY IMAGES



Octree volume



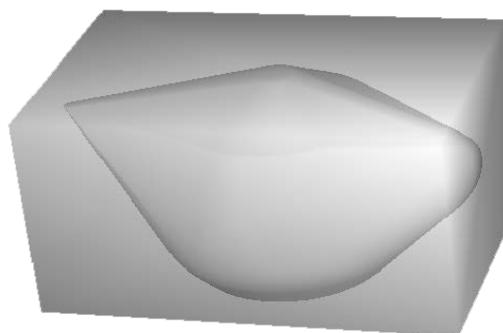
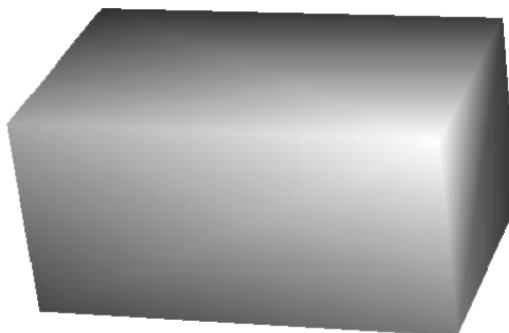
Mesh



Simplified mesh

LEVELS OF DETAIL

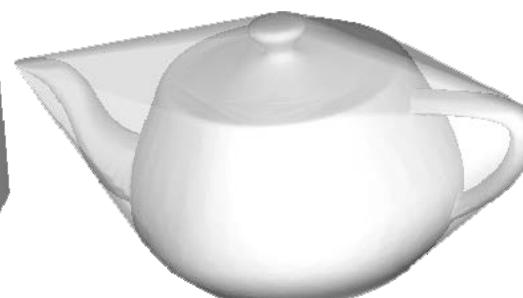
Bounding box Convex Hull



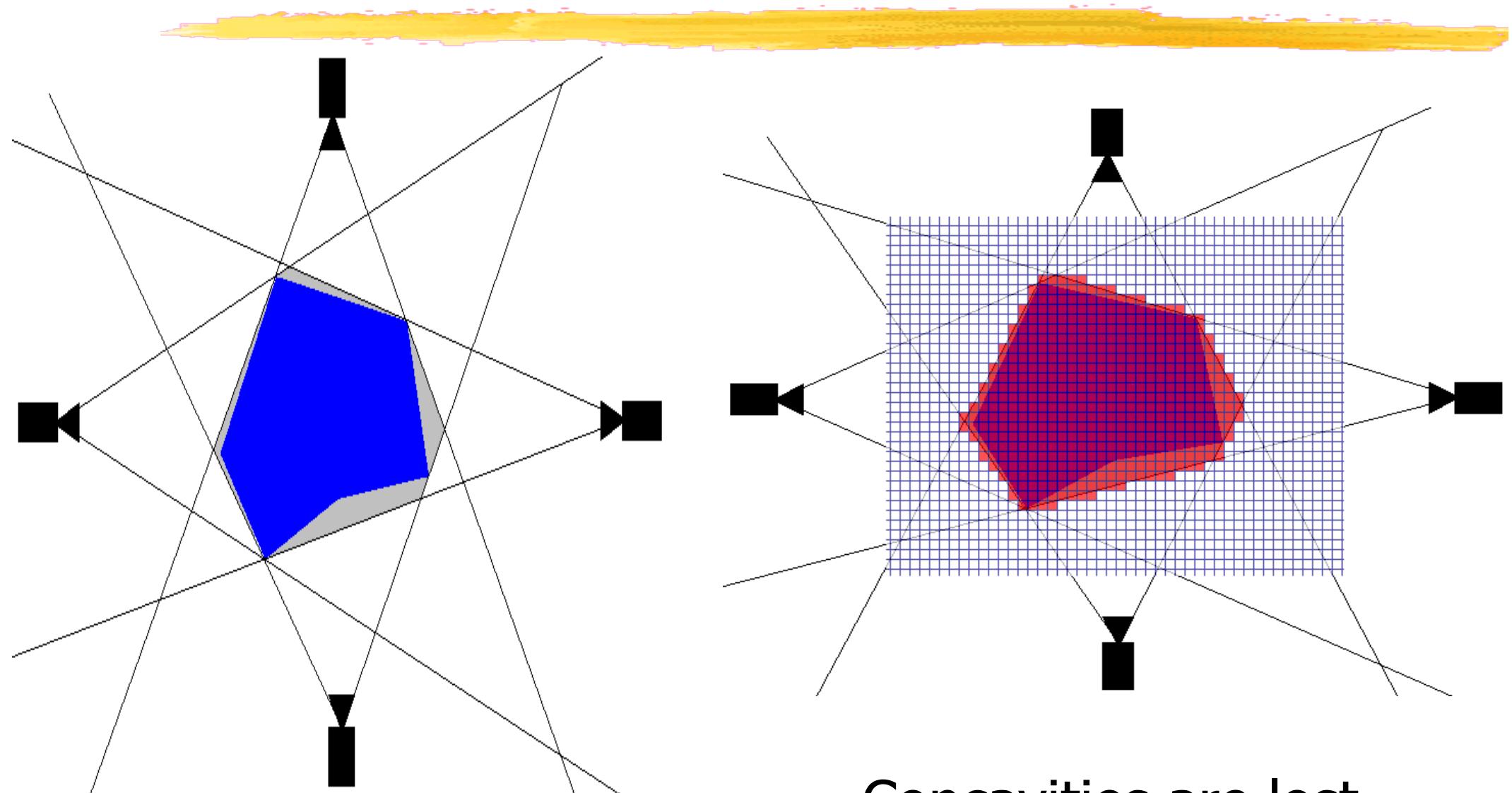
Visual Hull



Real Object



VISUAL HULL IN 2D



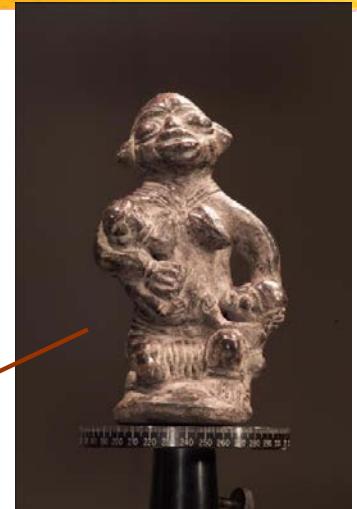
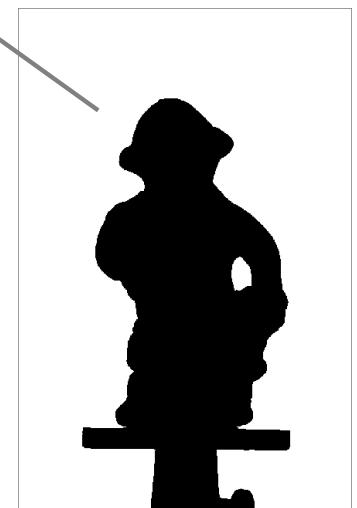
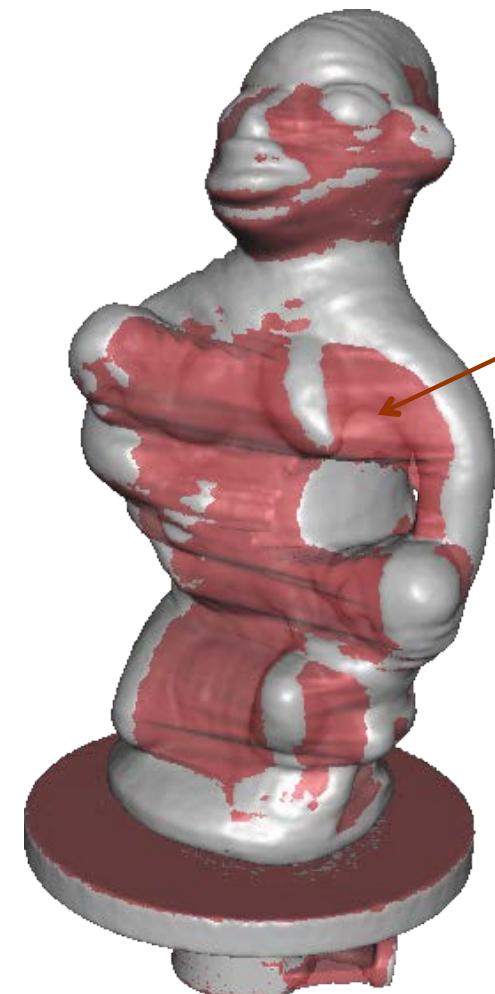
COMBINING STEREO AND SILHOUETTES



Real Surface



Visual Hull



MODELING PROCESS

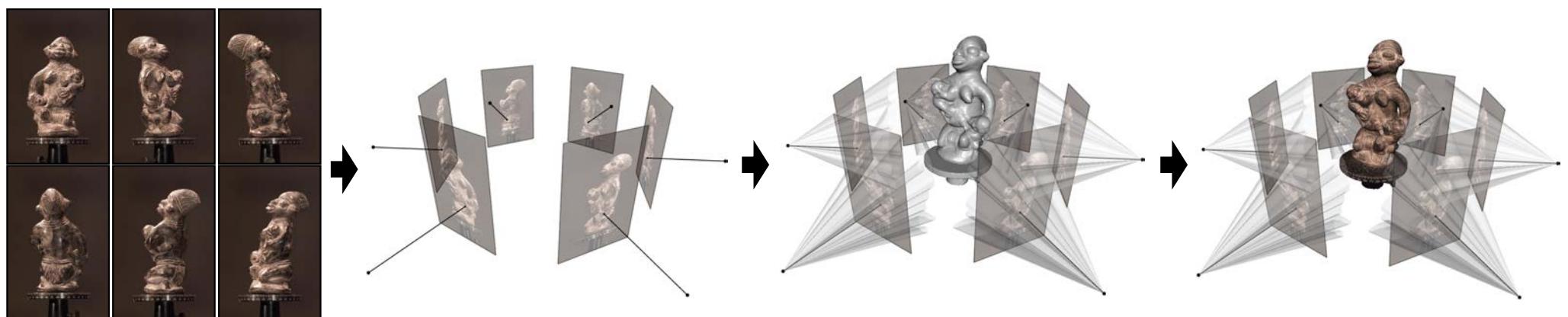


Image
Acquisition

Camera
Calibration

3-D
Reconstruction

Texture
Mapping

IMAGE ACQUISITION

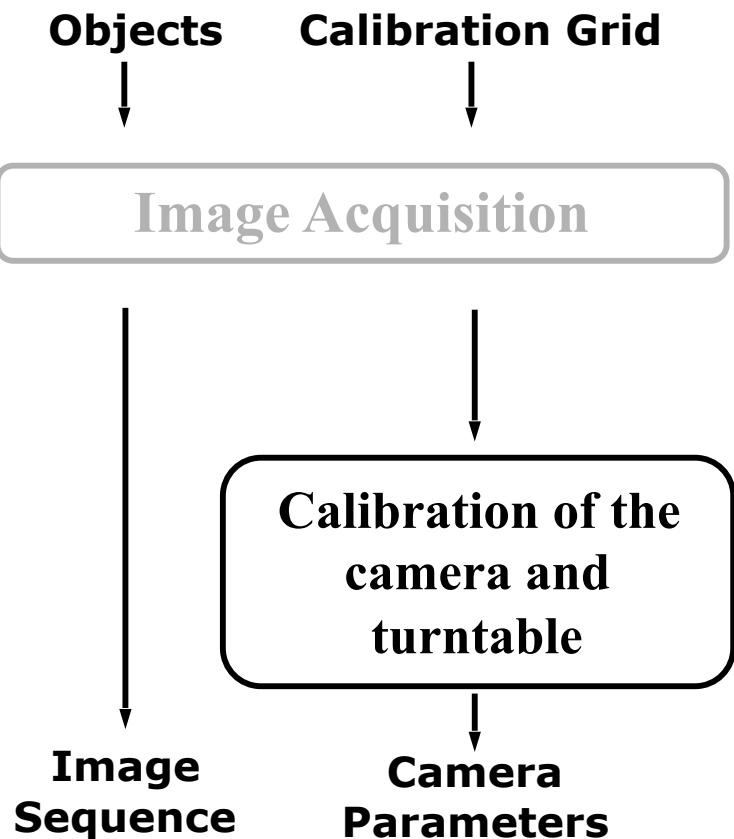


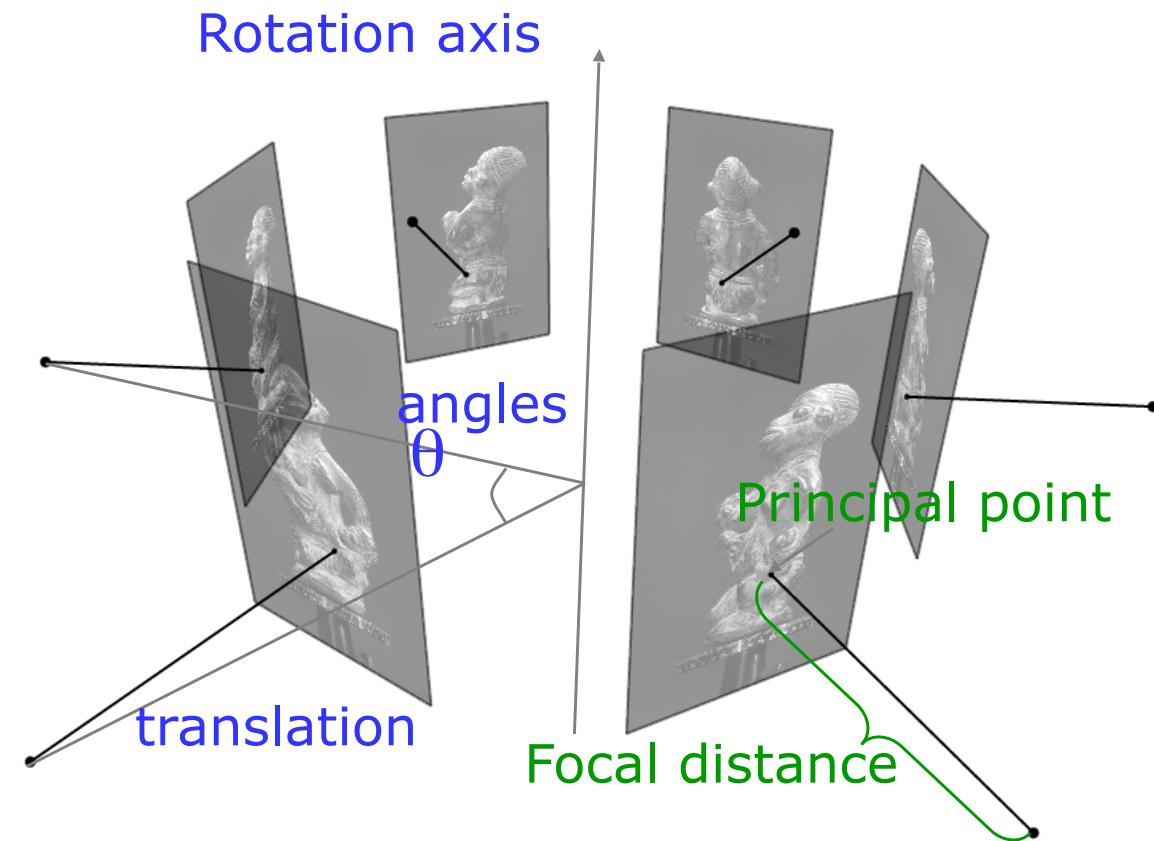
IMAGE ACQUISITION



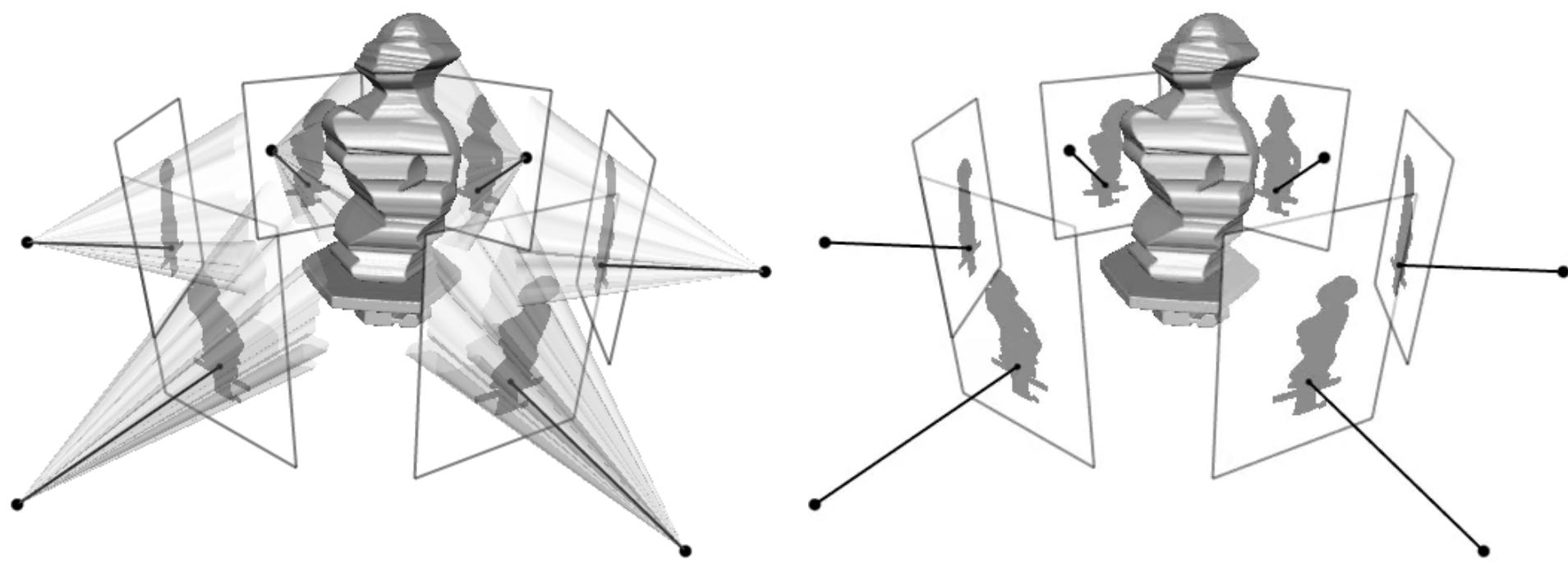
CIRCULAR CAMERA MOTION CALIBRATION

Parameters to be estimated:

- Rotation axis
- Translation
- Rotation angles
- Focal distance
- Principal point



VISUAL HULL N IMAGES



Correct Calibration

Decalibrating

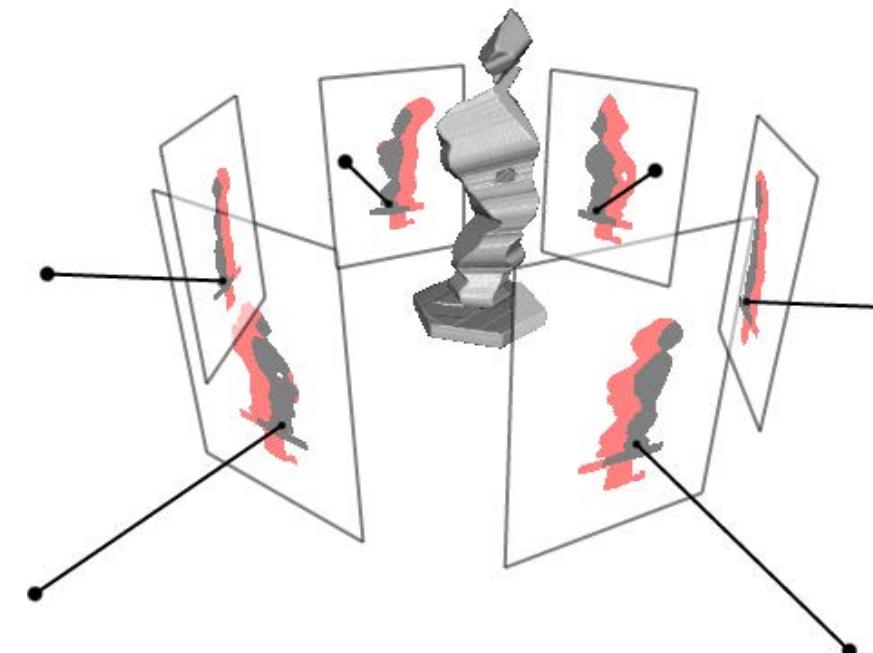
VISUAL HULL REPROJECTION

In theory:

$$\text{Silhouettes of Visual Hull} \subseteq \text{Original Silhouettes}$$

In practice:

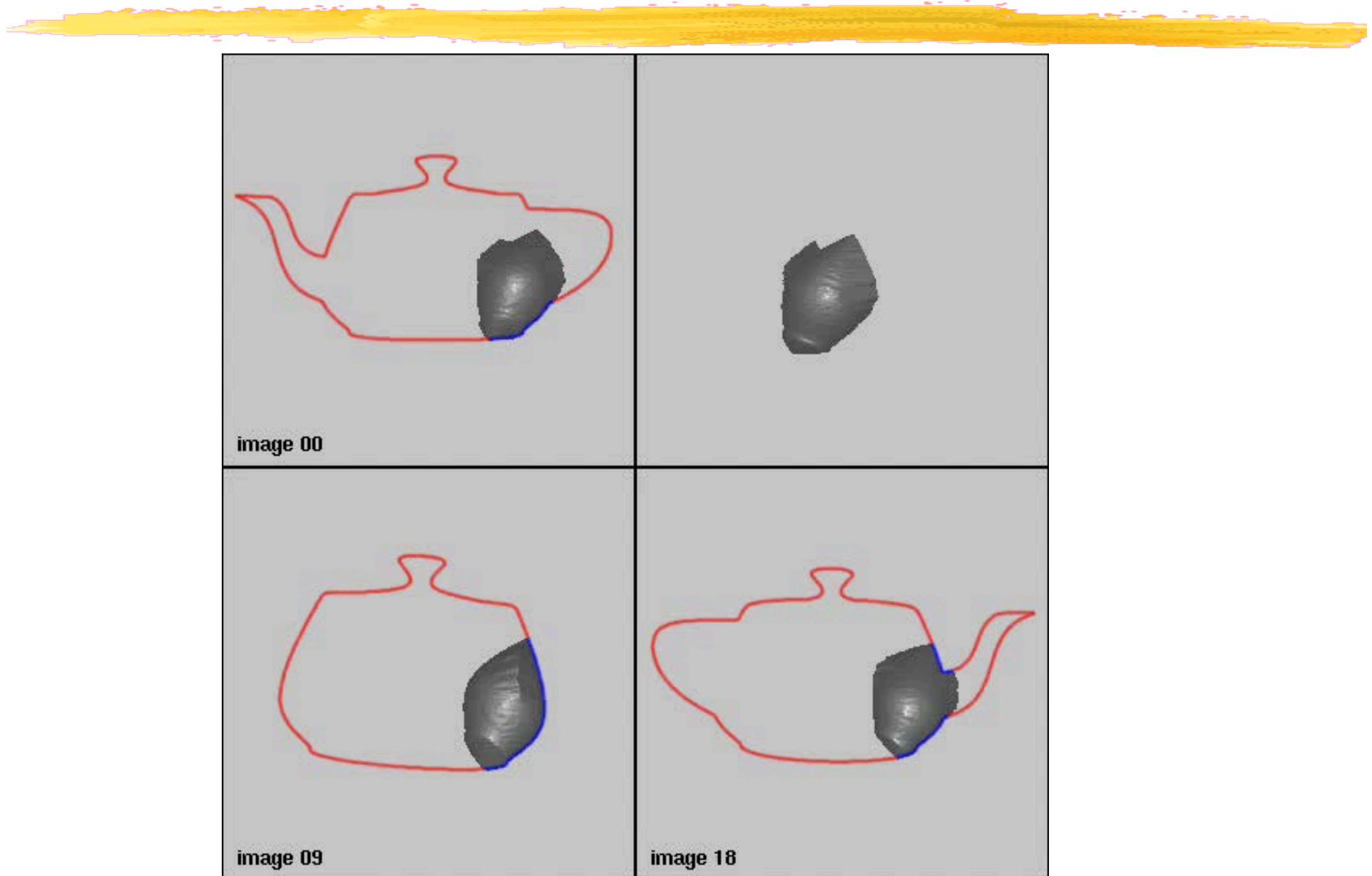
$$\text{Silhouettes of Visual Hull} \subset \text{Original Silhouettes}$$



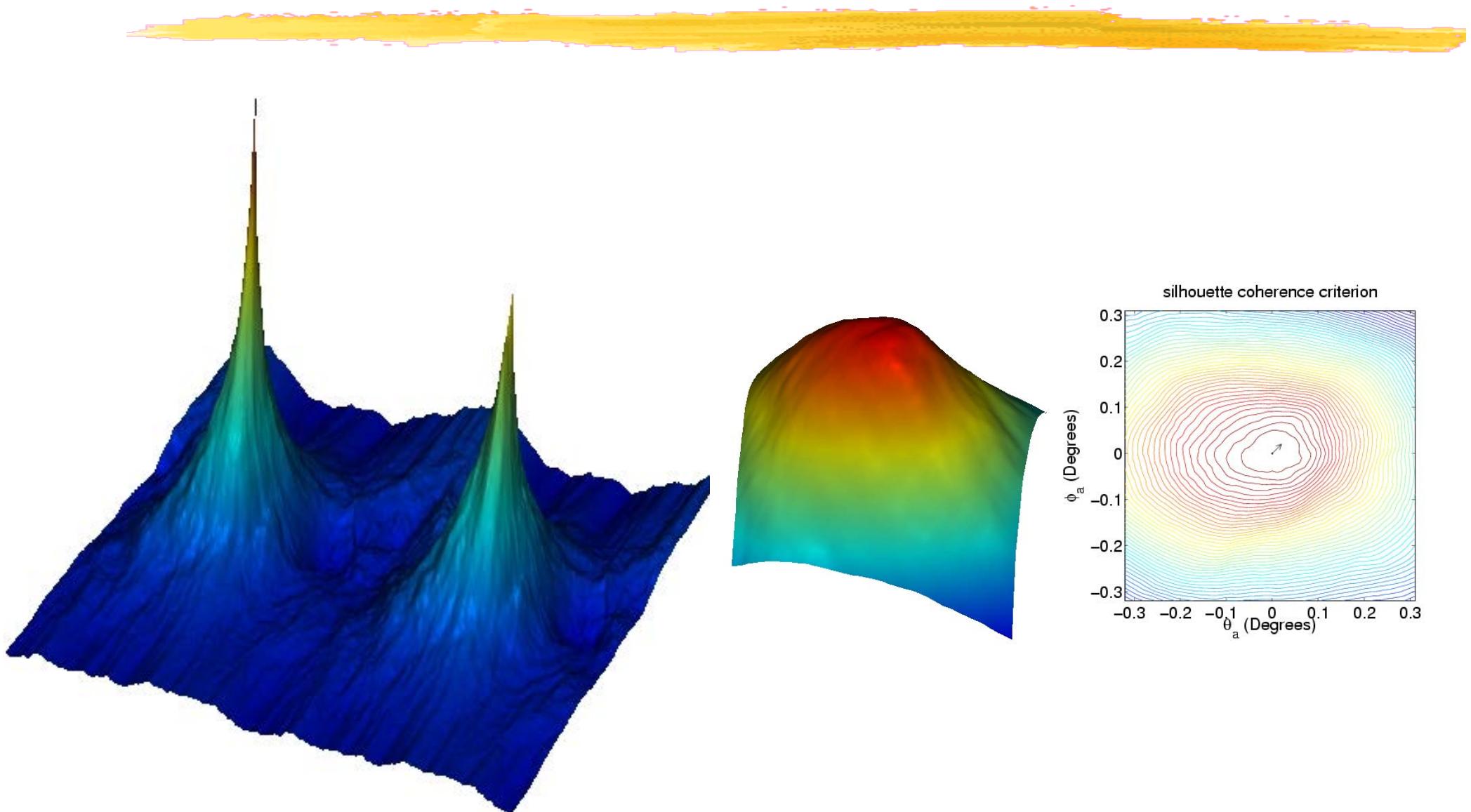
→ **Calibration heuristic:**

Maximize overlap of re-projected visual hull and silhouettes

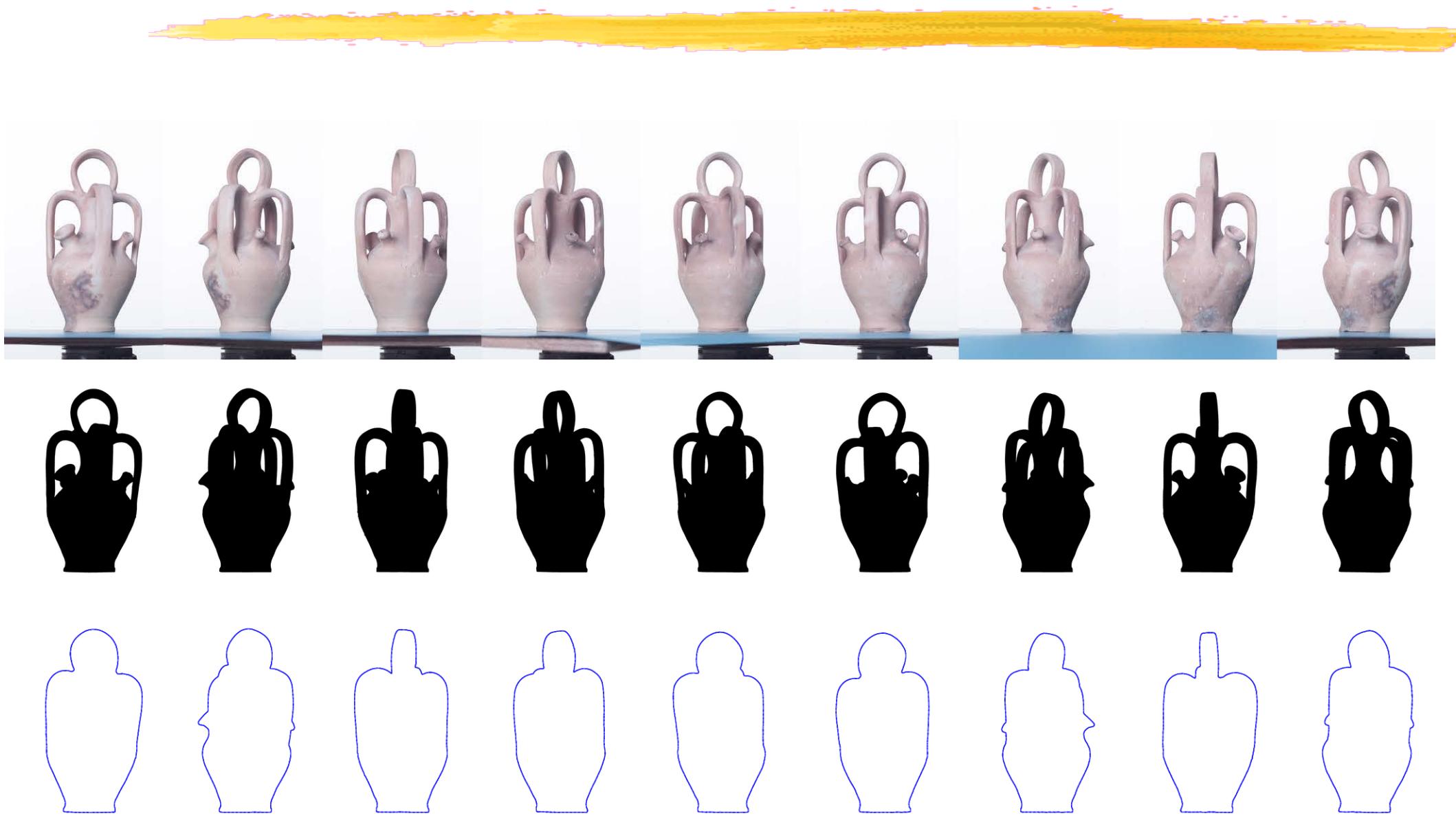
CONSISTENCY MAXIMIZATION



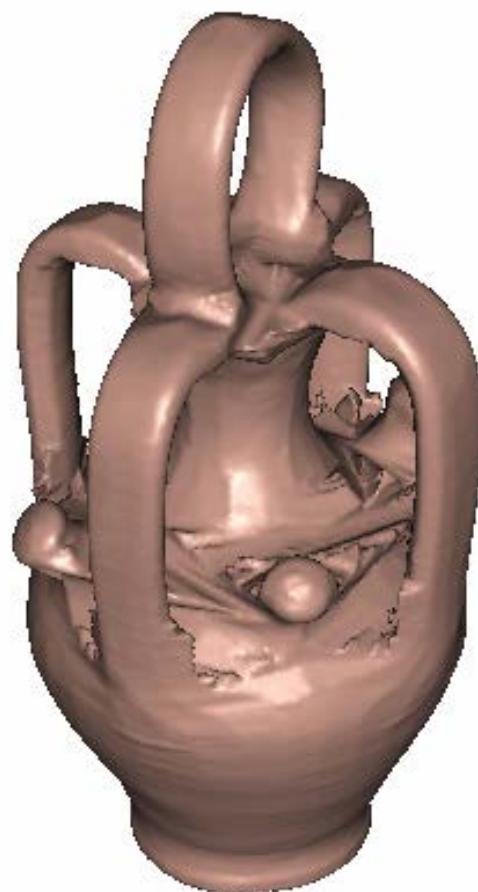
CONSISTENCY AS A FUNCTION OF THE ROTATION AXIS



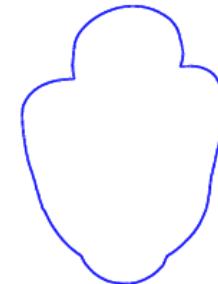
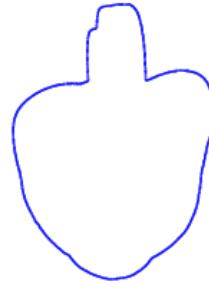
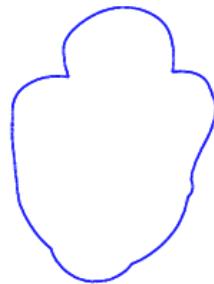
ROTATING SEQUENCE



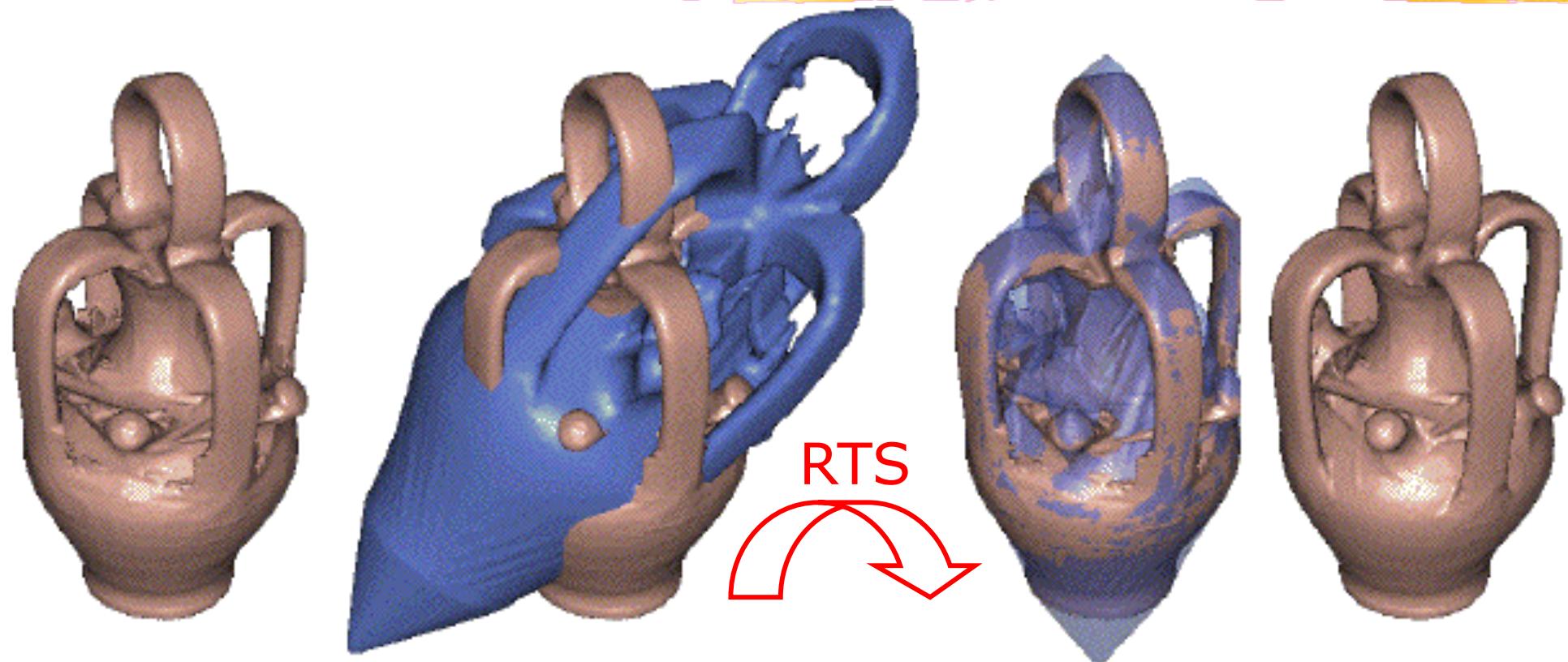
VISUAL HULL



SECOND ROTATING SEQUENCE



COMBINING THE SEQUENCES



Rigid motion + Scaling

MODELING PROCESS

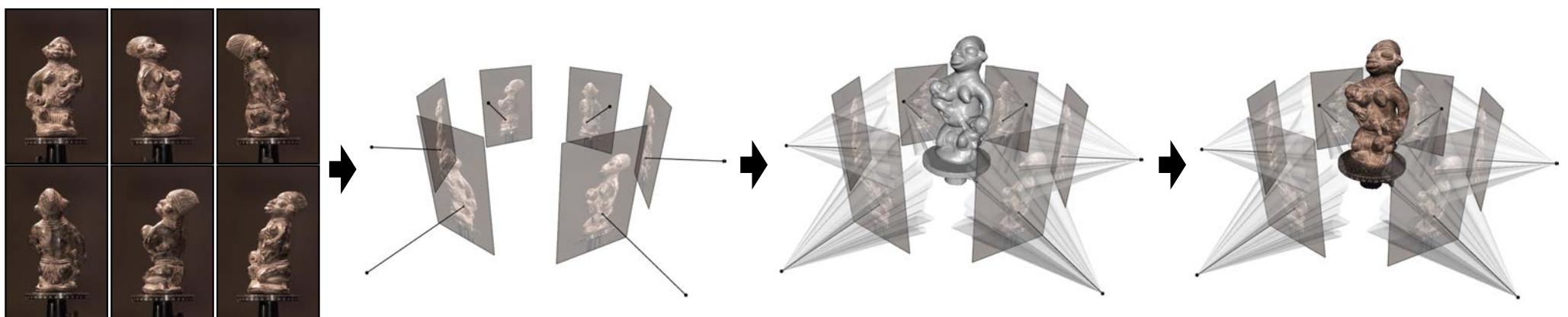


Image
Acquisition

Camera
Calibration

**3—D
Reconstruction**

Texture
Mapping

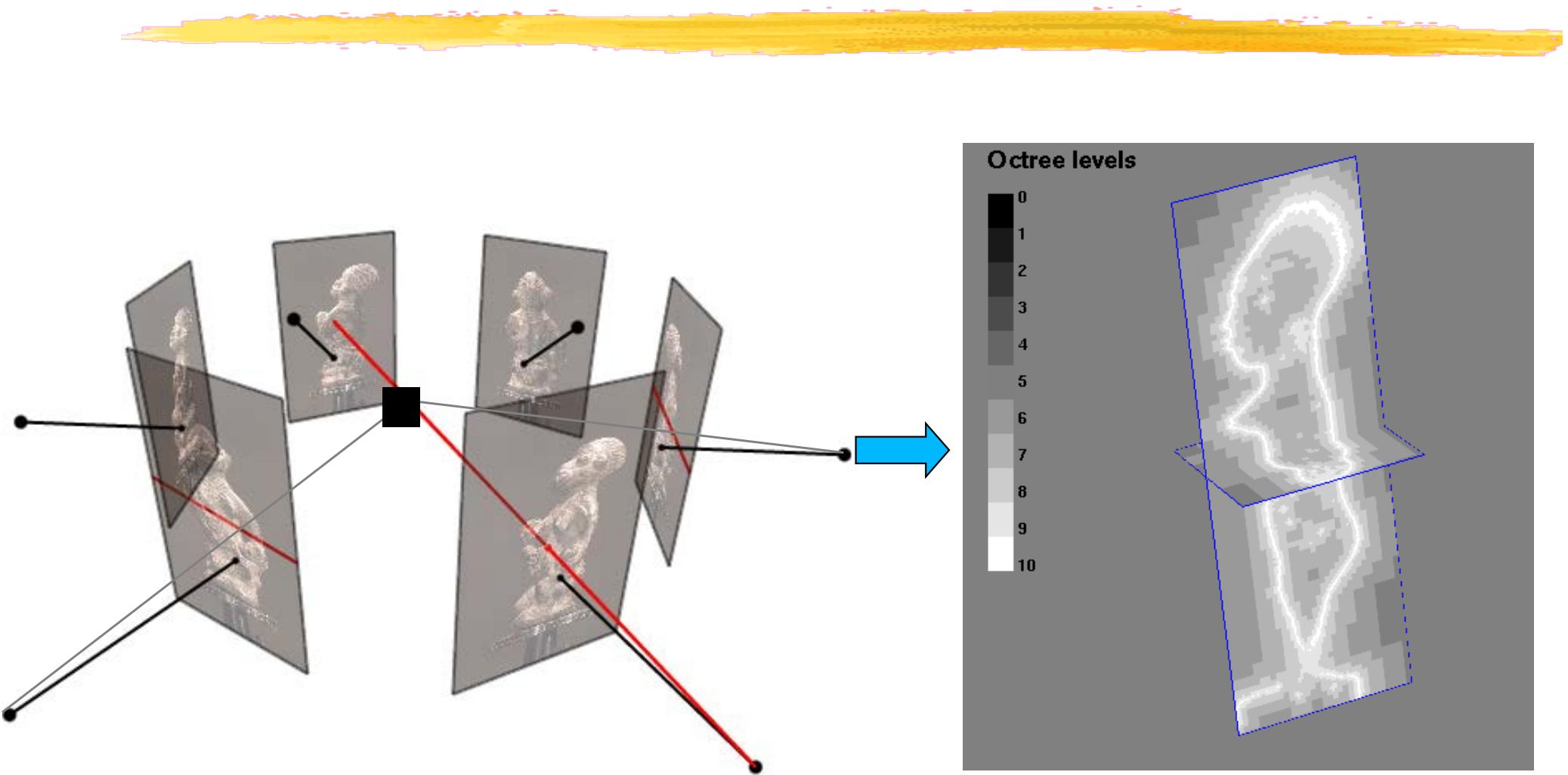
3-D DEFORMABLE MODEL



- 1.** Initialization of the model

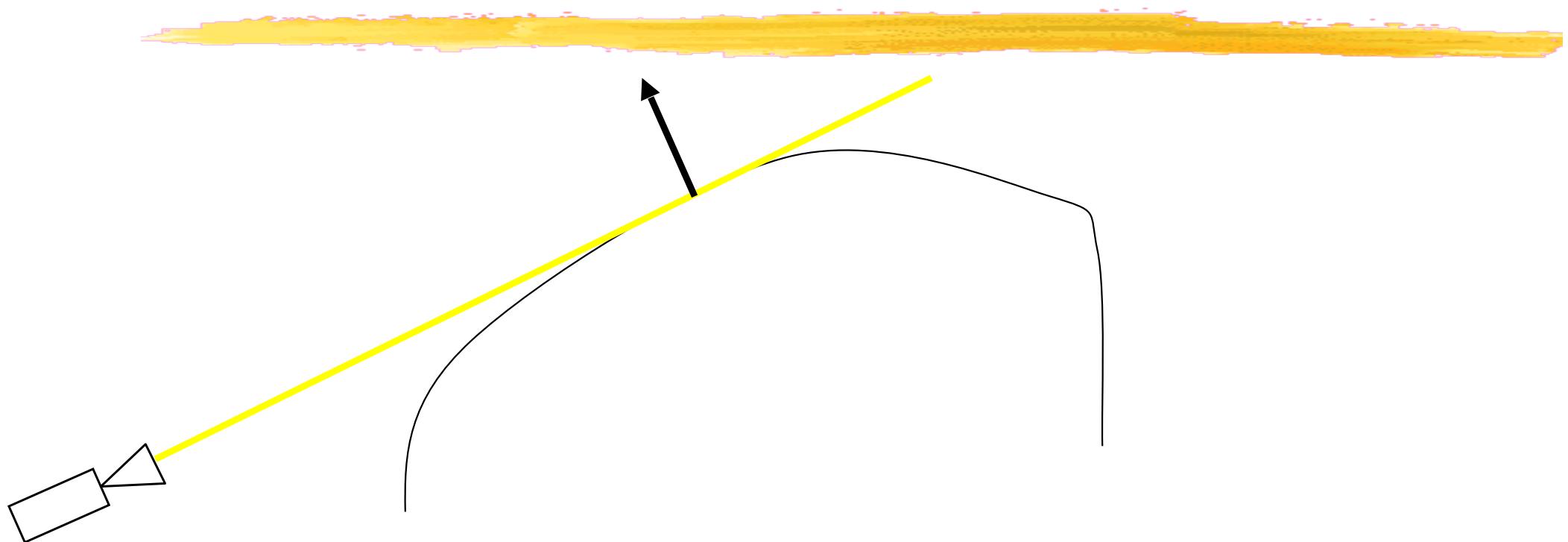
- 2.** Minimization of
 - Texture energy
 - Silhouette energy
 - Deformation energy

TEXTURE ENERGY



Multi-image correlation represented by an octree

SILHOUETTE ENERGY



The line of sight is tangent to the surface. In at least one point:

- The distance to the line of sight is zero
- The surface normal is perpendicular to it.

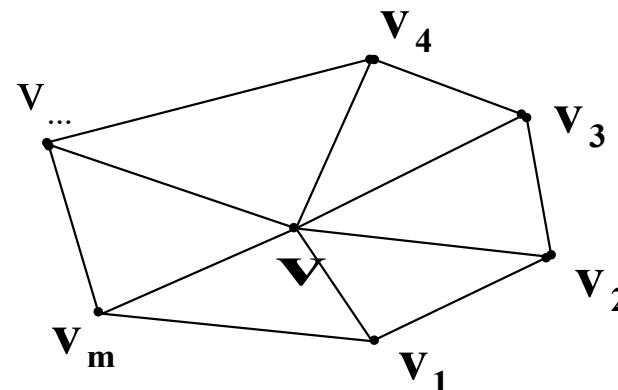
DEFORMATION ENERGY

Laplacian

$$\Delta v = \sum_{i=1}^m \frac{v_i}{m} - v$$

Biharmonic

$$\Delta^2 v = \frac{1}{1 + \sum_{i=1}^m \frac{1}{mm_i}} \Delta(\Delta v)$$



GRADIENT DESCENT

$$v_i^{k+1} = v_i^k + \Delta t(\nabla E_{tex}(v_i^k) + \beta \nabla E_{sil}(v_i^k) + \gamma \nabla E_{reg}(v_i^k))$$

∇E_x : Derivative of corresponding energy term x .

β : Silhouette coefficient.

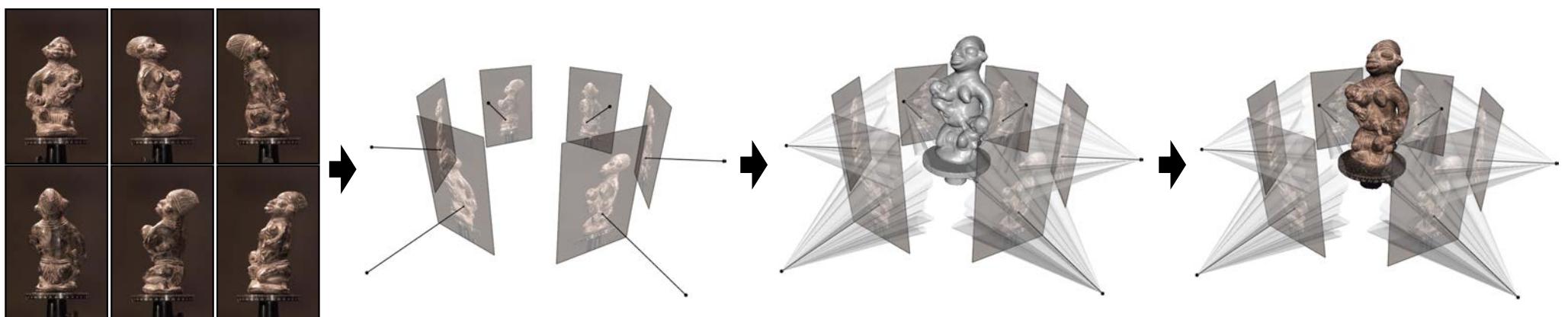
γ : Regularization coefficient.

RECONSTRUCTION



83241 vertices, 166482 triangles

MODELING PROCESS



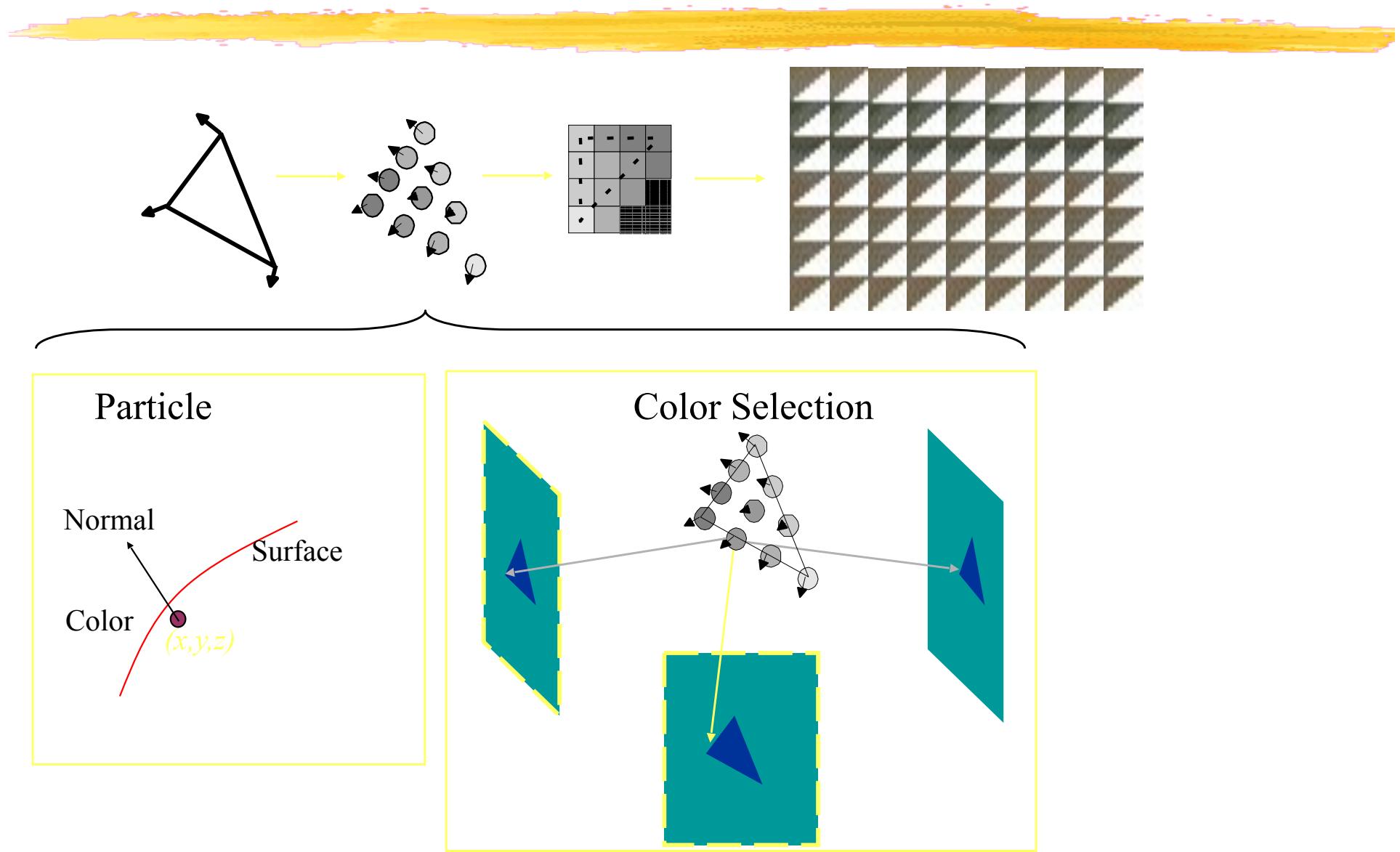
**Image
Acquisition**

**Camera
Calibration**

**3-D
Reconstruction**

**Texture
Mapping**

TEXTURE MAP



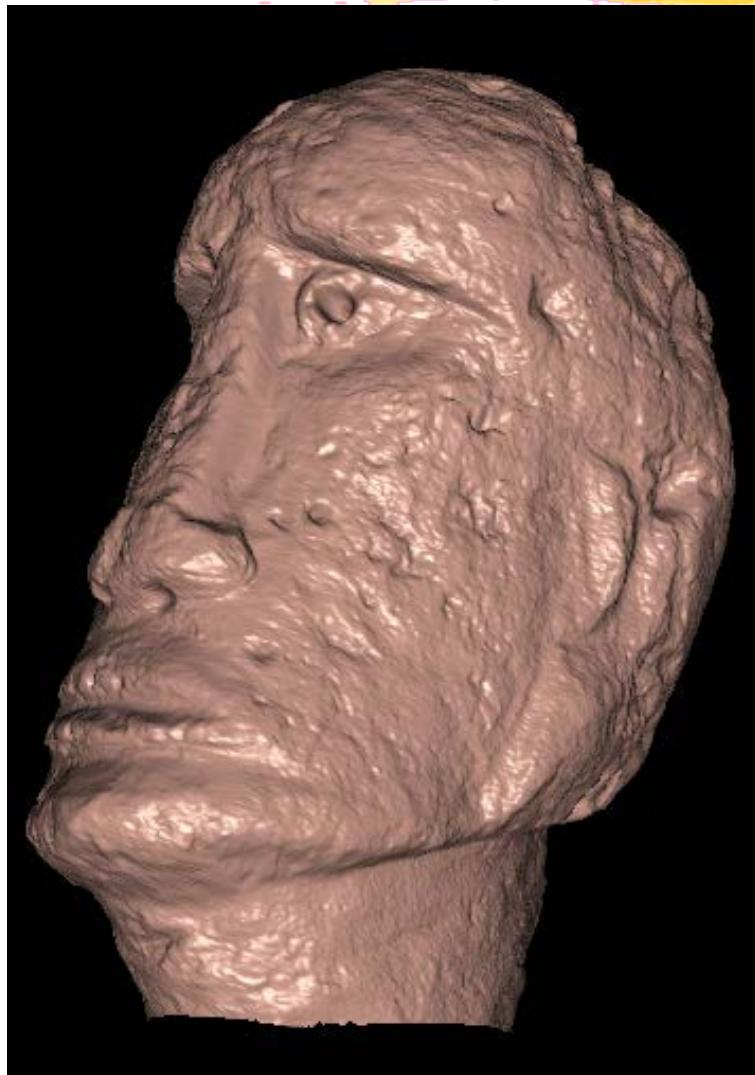
RECONSTRUCTION



57639 vertices, 115282 triangles

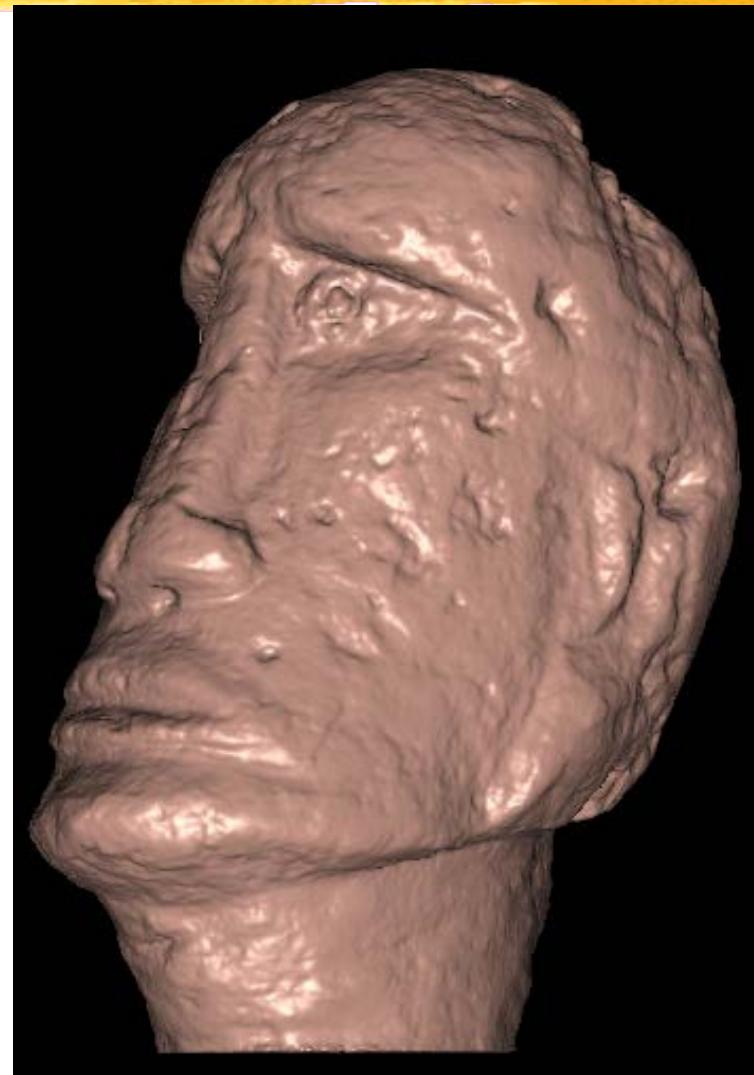
LASER vs IMAGES

Minolta
Laser
Scanner



385355 vertices
770209 triangles

Silhouettes



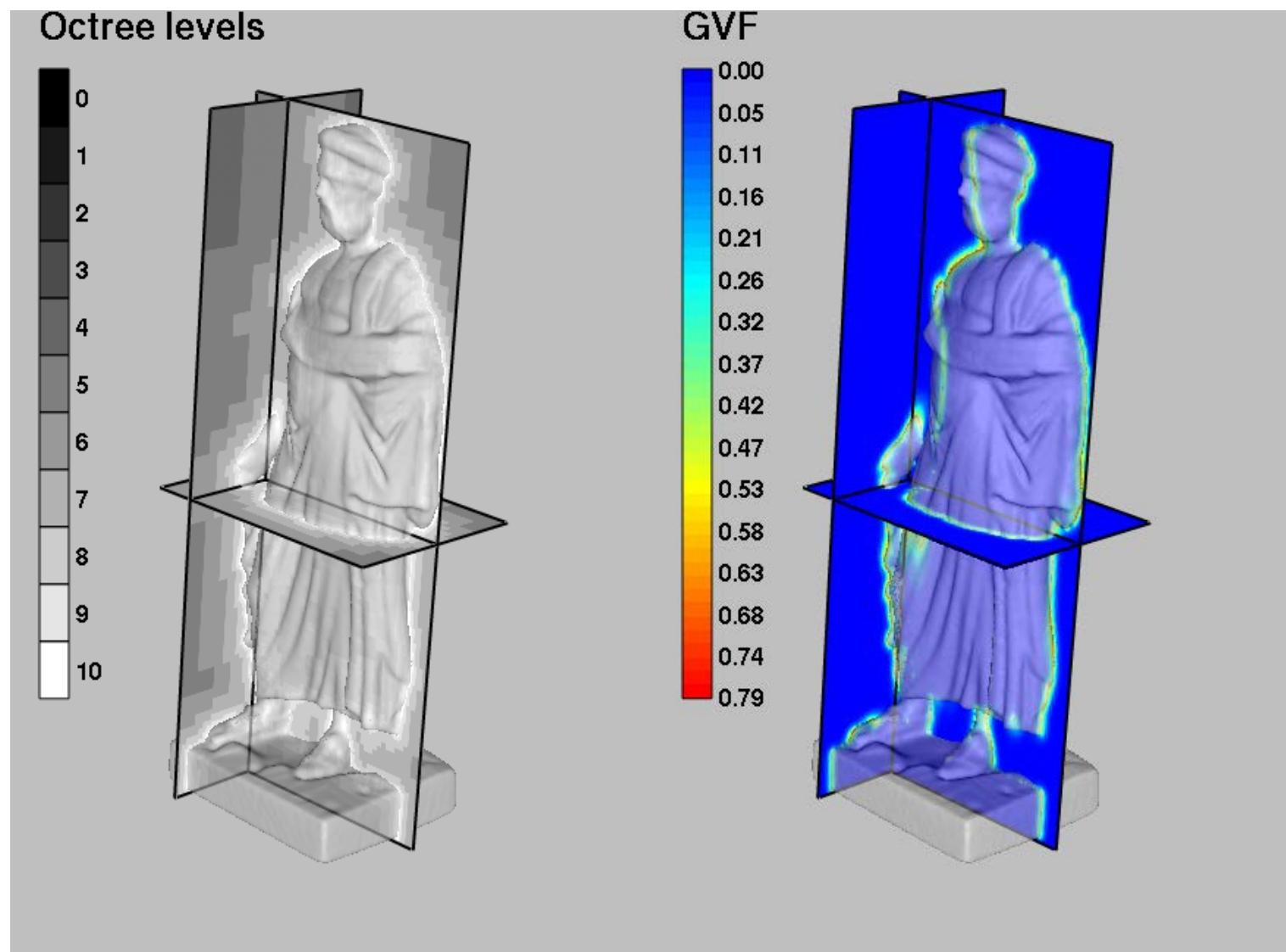
233262 vertices
466520 triangles

RECONSTRUCTION



47159 vertices, 94322 triangles

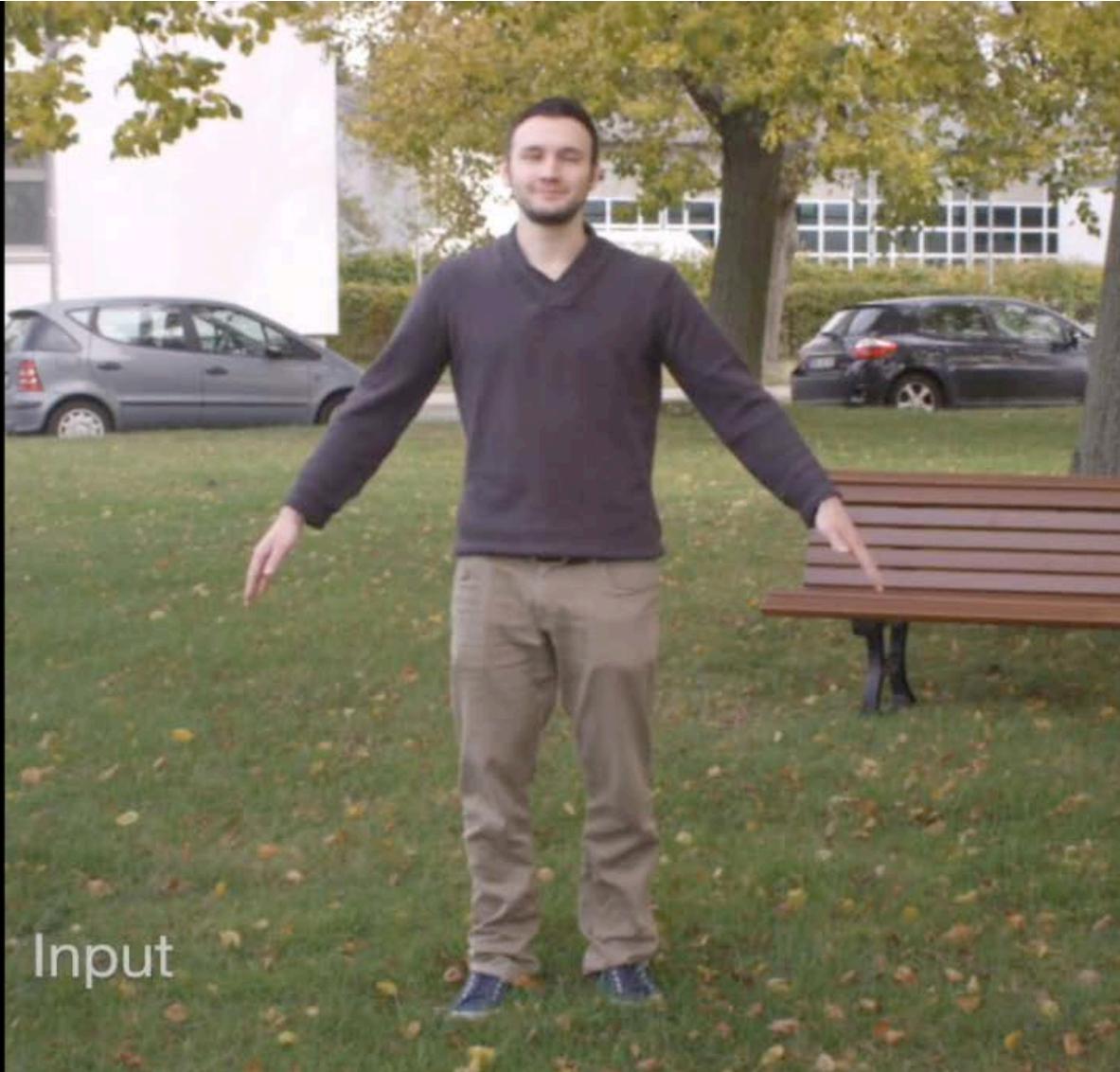
TEXTURE ENERGY



RECONSTRUCTION



GENERALIZATION TO ARTICULATED OBJECTS

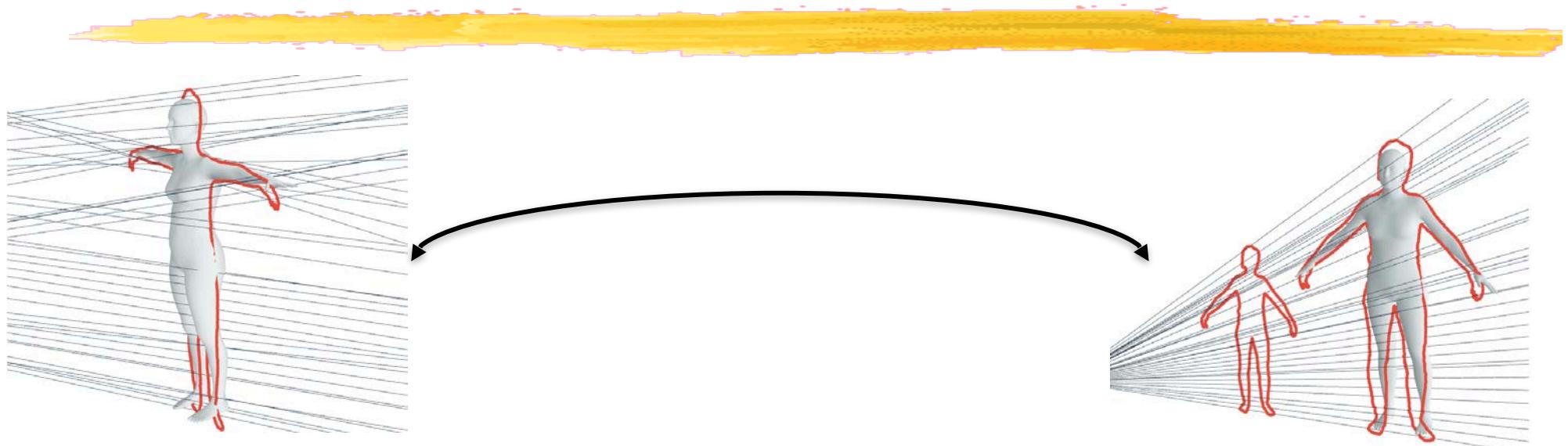


CHALLENGE



- The person is moving
 - The visual hull algorithm expects static contours.
- Transfer to a canonic pose.

REGISTER VISUAL CONES



$$\mathbf{r} = \left(\sum_{k=1}^K w_{k,i} G_k(\boldsymbol{\theta}, \mathbf{J}_{\beta}) \right)^{-1} \mathbf{r}' - b_{P,i}(\boldsymbol{\theta}).$$

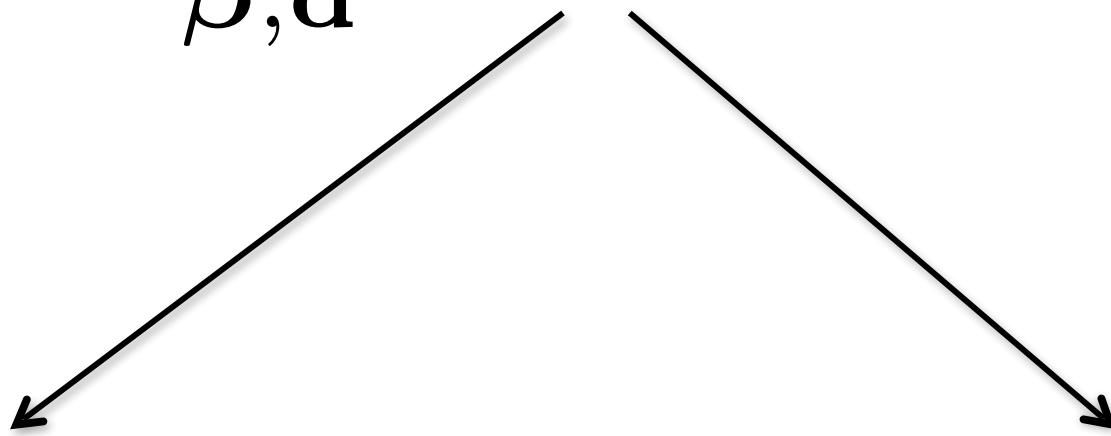
Ray in Canonical Frame

Inverse Articulated Motion

Ray

MINIMIZE OBJECTIVE FUNCTION

$$\arg \min_{\beta, d} E_{\text{cons}}(\beta, d)$$



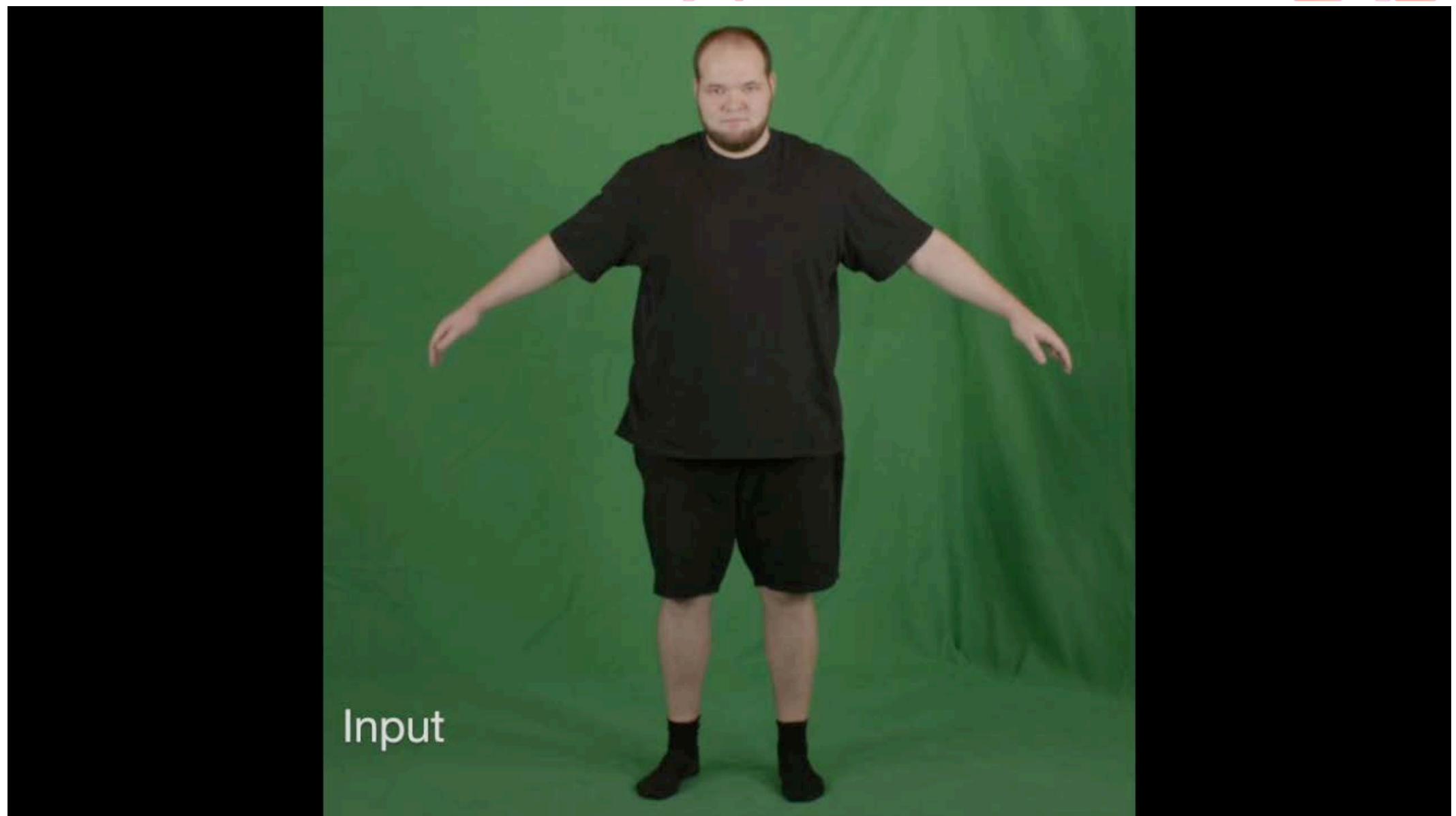
$$E_{\text{data}} = \sum_{(\mathbf{v}, \mathbf{r}) \in \mathcal{M}} \rho(\mathbf{v} \times \mathbf{r}_n - \mathbf{r}_m)$$

Sum of point to line distances

Prior Terms:

- Symmetry
- Prior on Shape
- Surface Smoothness

RECONSTRUCTIONS



STRENGTHS AND LIMITATIONS



Strengths:

- Practical method for recovering shape.
- Produces high quality texture maps.

Limitations:

- Requires large number of views.
- Silhouettes must be precisely extractable.