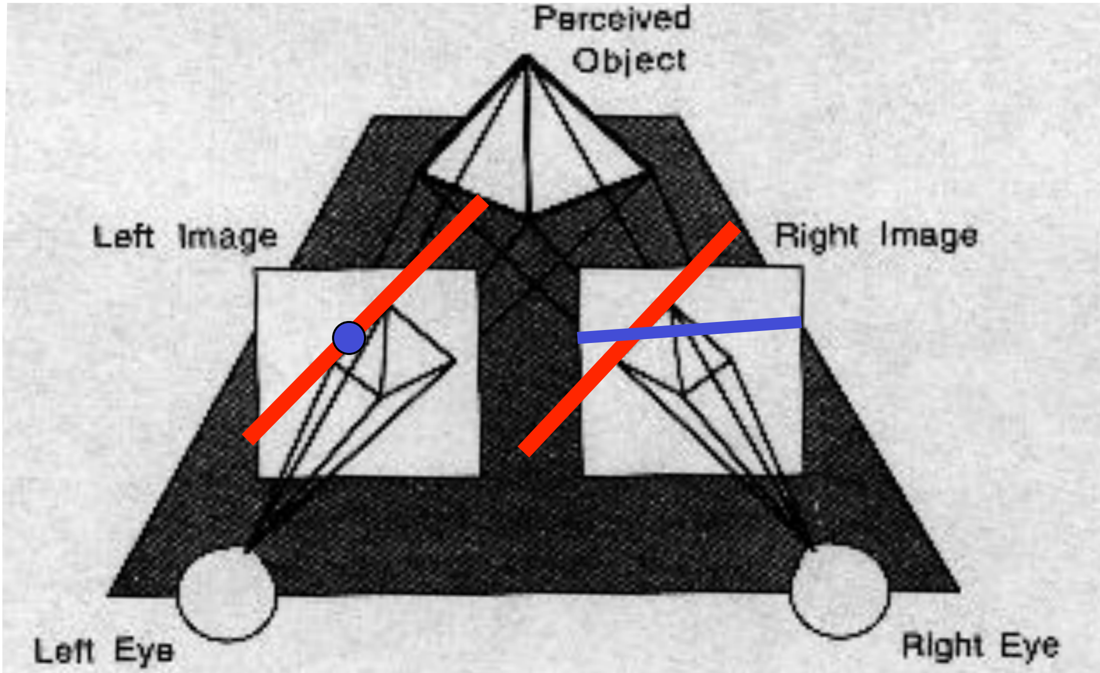
SHAPE FROM X

One image:
- Texture
- Shading

Two images or more:
- Stereo
- **Contours**
- Motion

EDGE-BASED STEREO

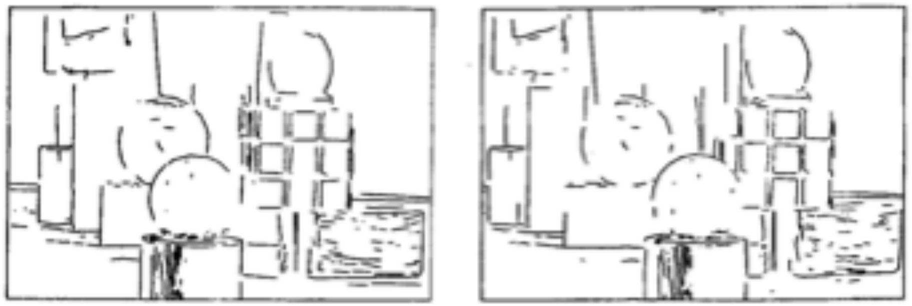


Matching edges yields stereo information but

- Potential ambiguities
- Edge detection is unreliable

EARLY STEREO APPROACH

Original segments



Matched segments

Pro:

- Little computational power required.

Con:

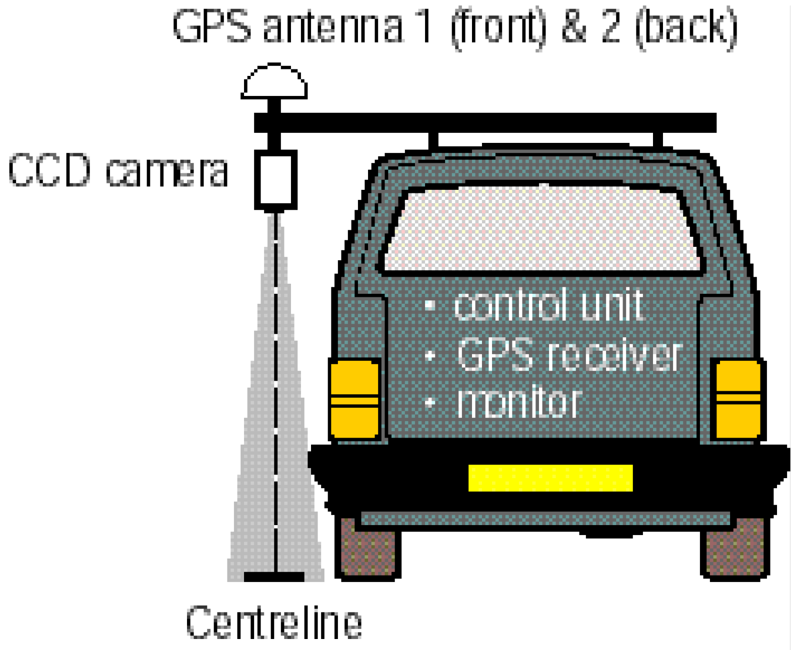
- Very ambiguous.

Partial remedy:

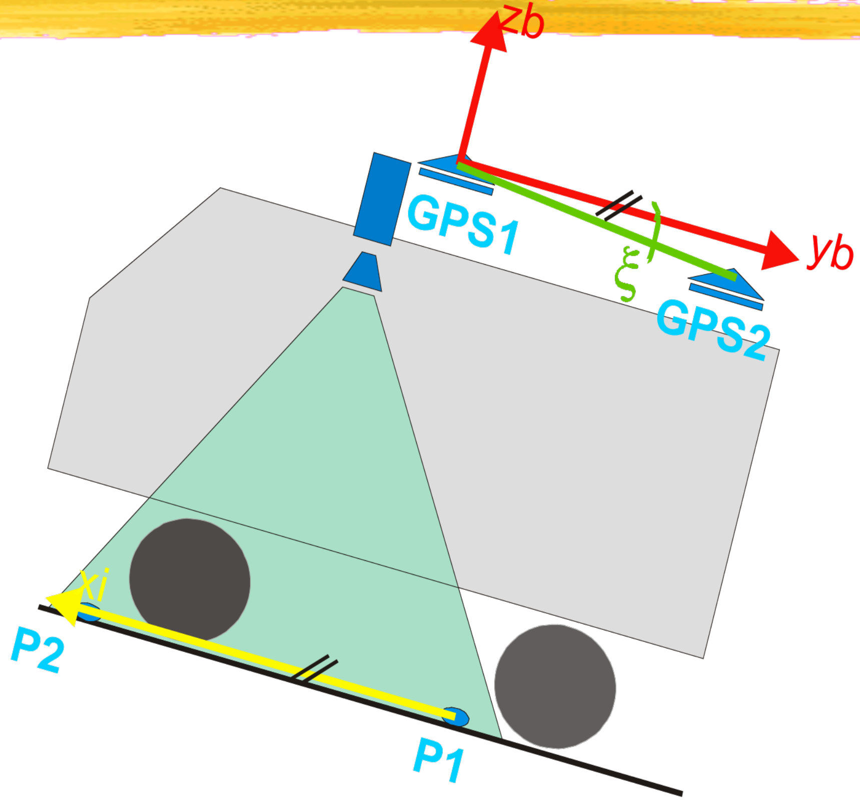
- Use three or more images to disambiguate.

Medioni & Nevatia, CVGIP’85

PHOTOBUS


GPS antenna 1 (front) & 2 (back)
CCD camera
• control unit
• GPS receiver
• monitor
Centreline

CALIBRATION

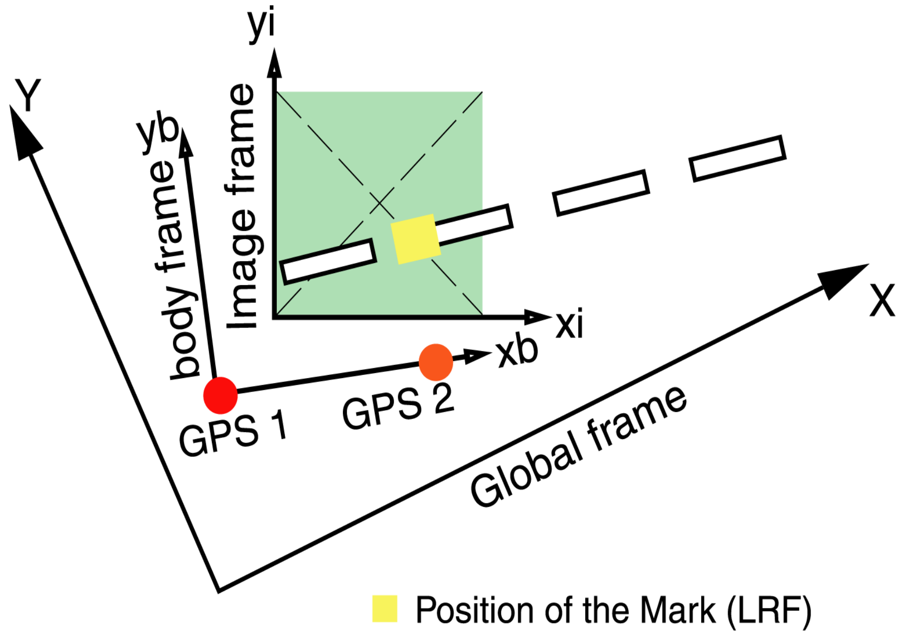


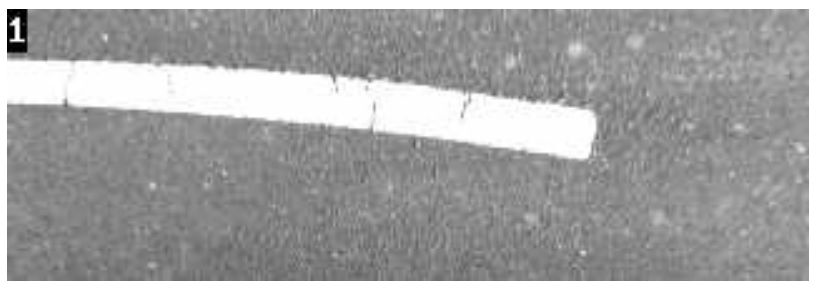
GPS1, GPS2 -> azimuth + pitch

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

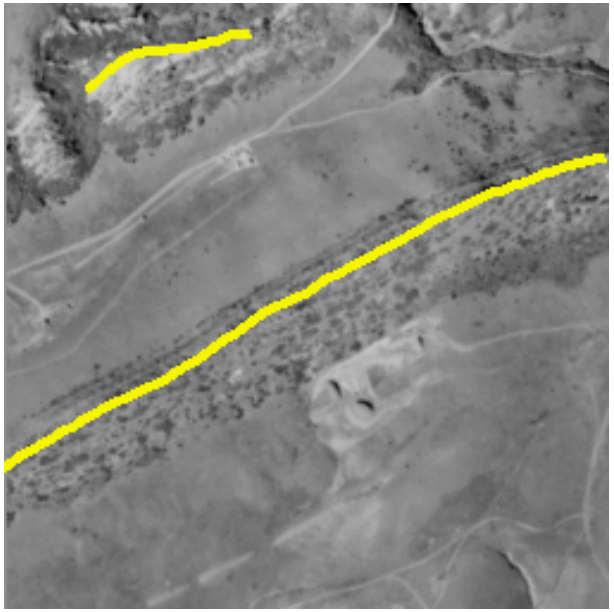
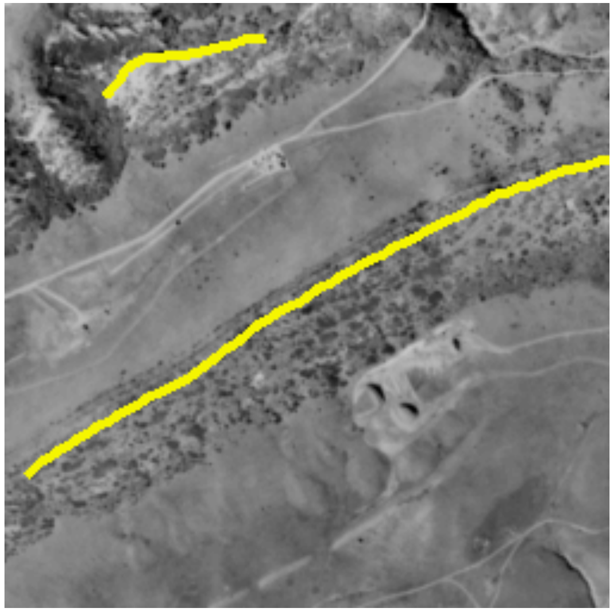
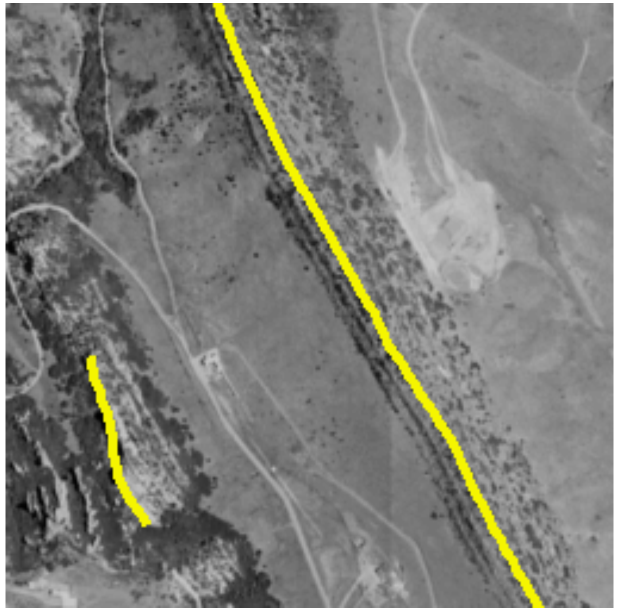
ROAD MARKINGS

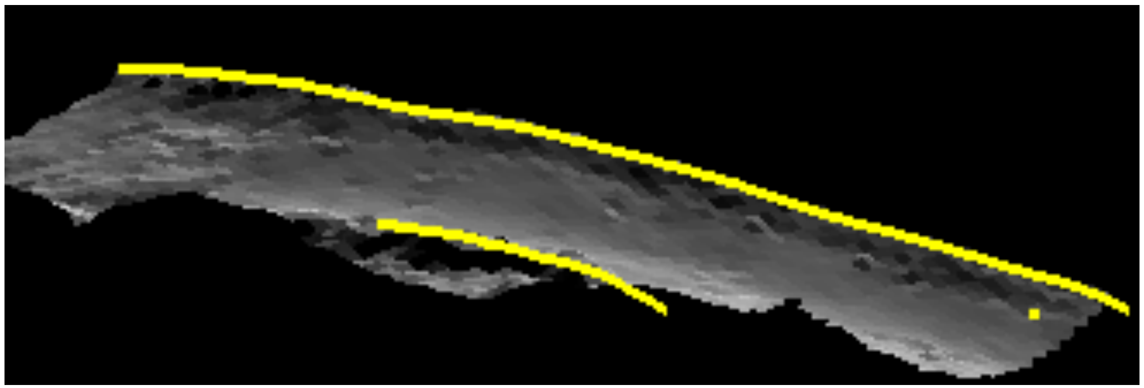
- Real-time feature extraction.
- Store only object coordinates.





RIDGE LINES

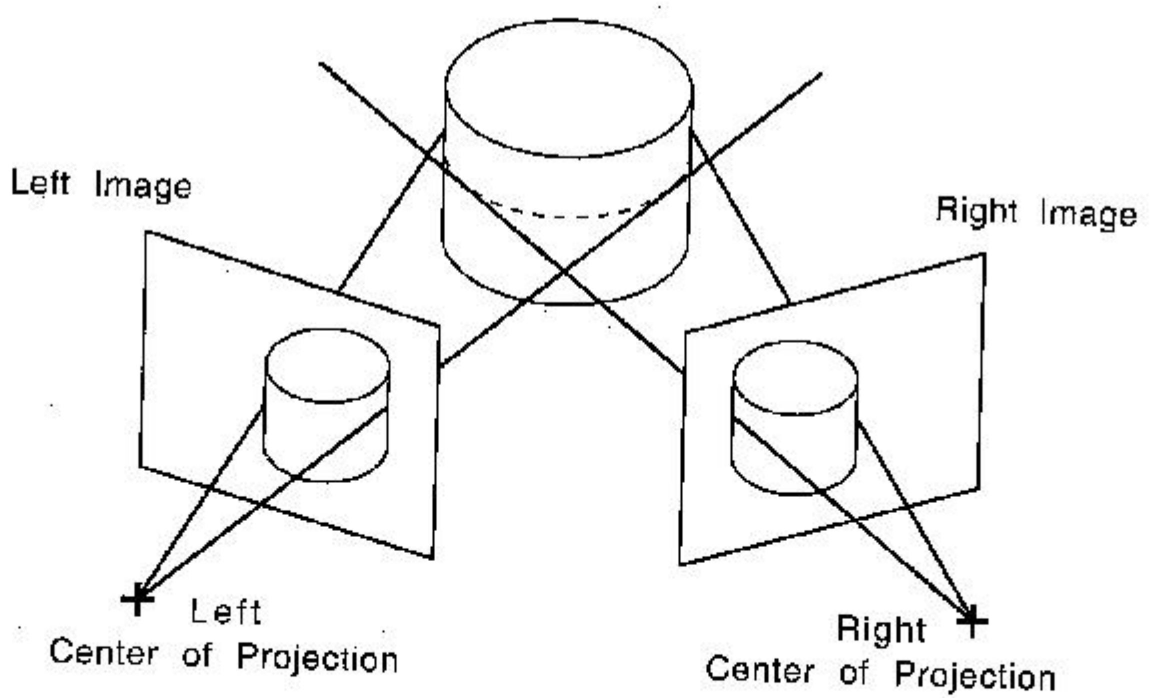


BUILDINGS

The deformable model encodes the endpoints of the segments.

RACING SPINNAKER

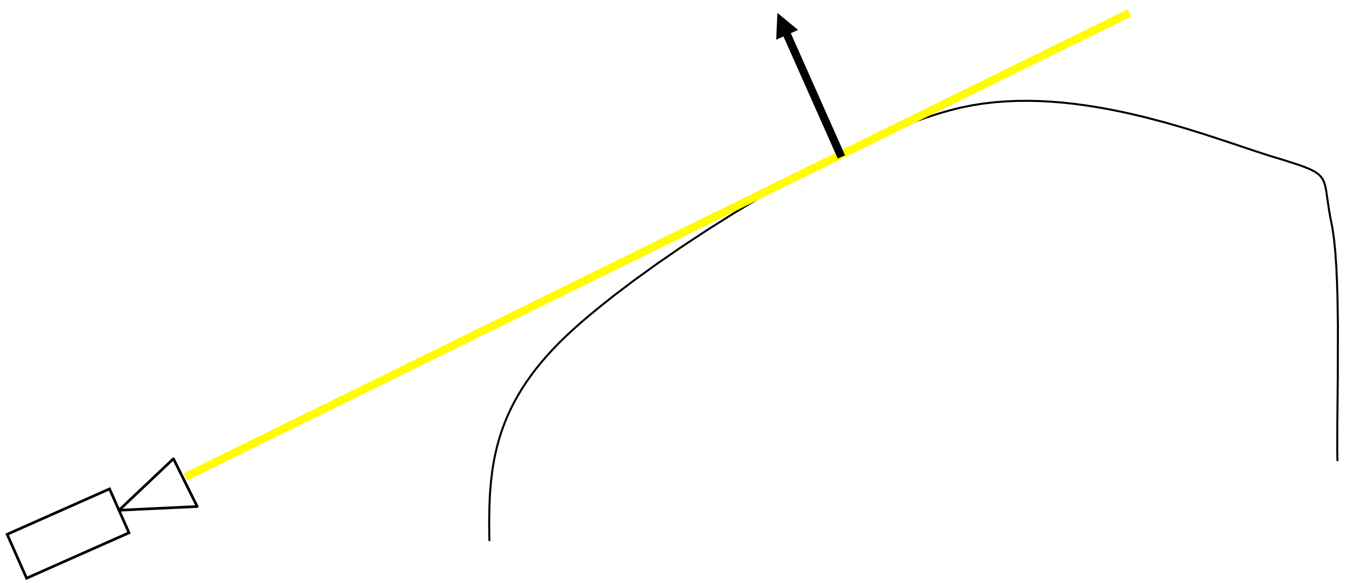
OCCLUDING CONTOURS



Silhouettes let us carve the space:

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

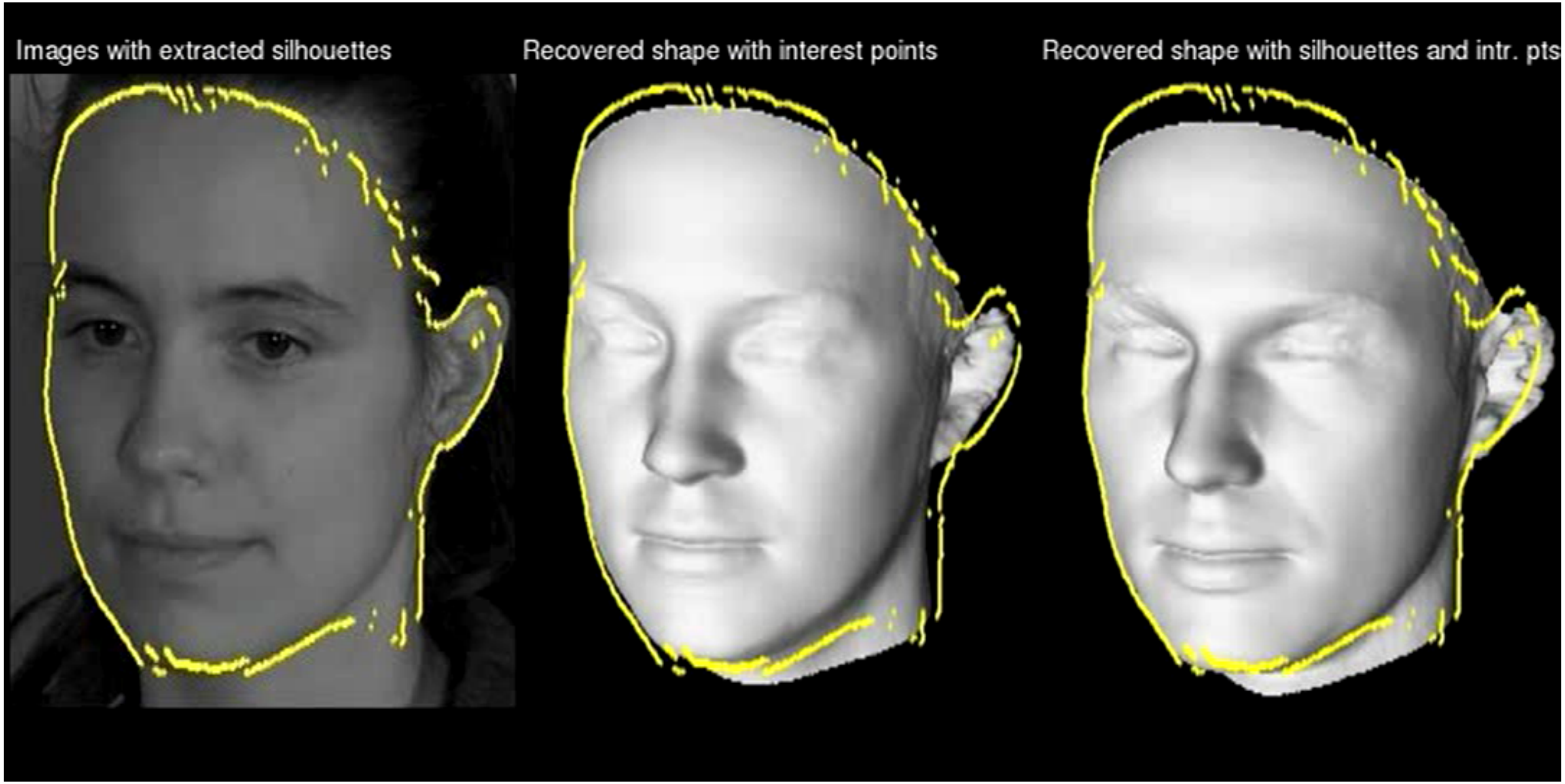
LINE OF SIGHT



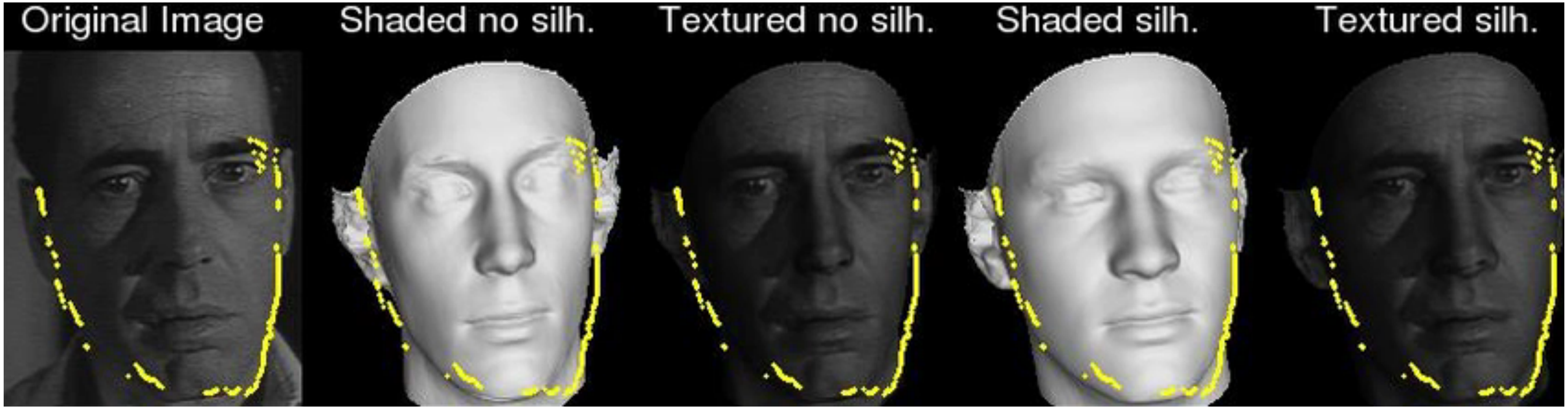
The line of sight is tangent to the surface. In at least one point:

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

COMBINING STEREO AND SILHOUETTES

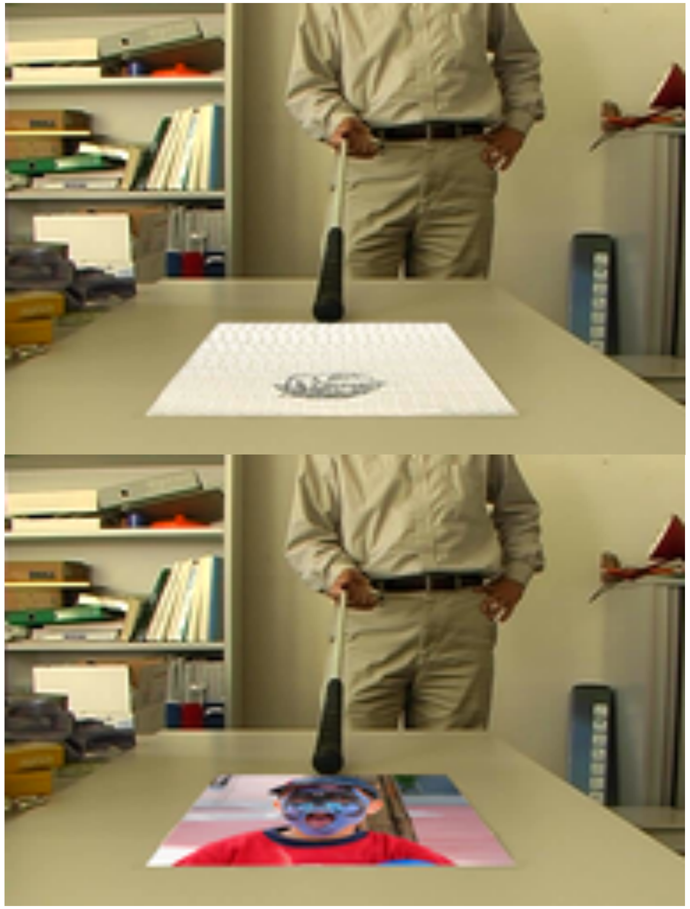


COMBINING STEREO AND SILHOUETTES

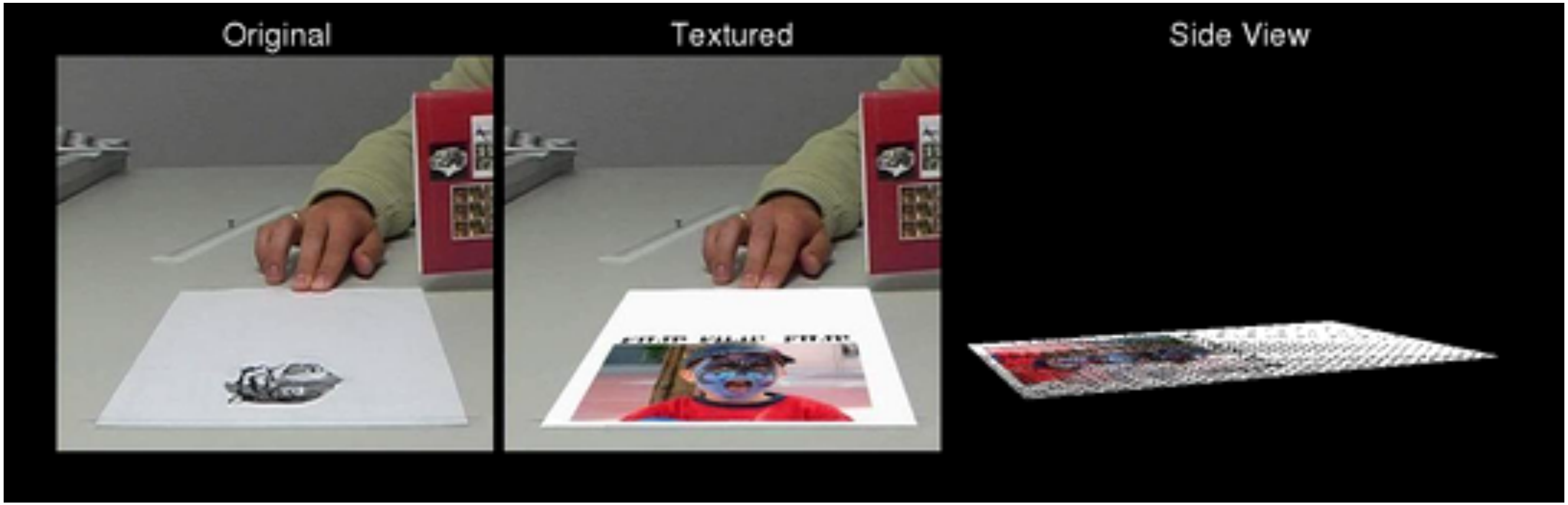


TRACKING A DEFORMABLE PIECE OF PAPER

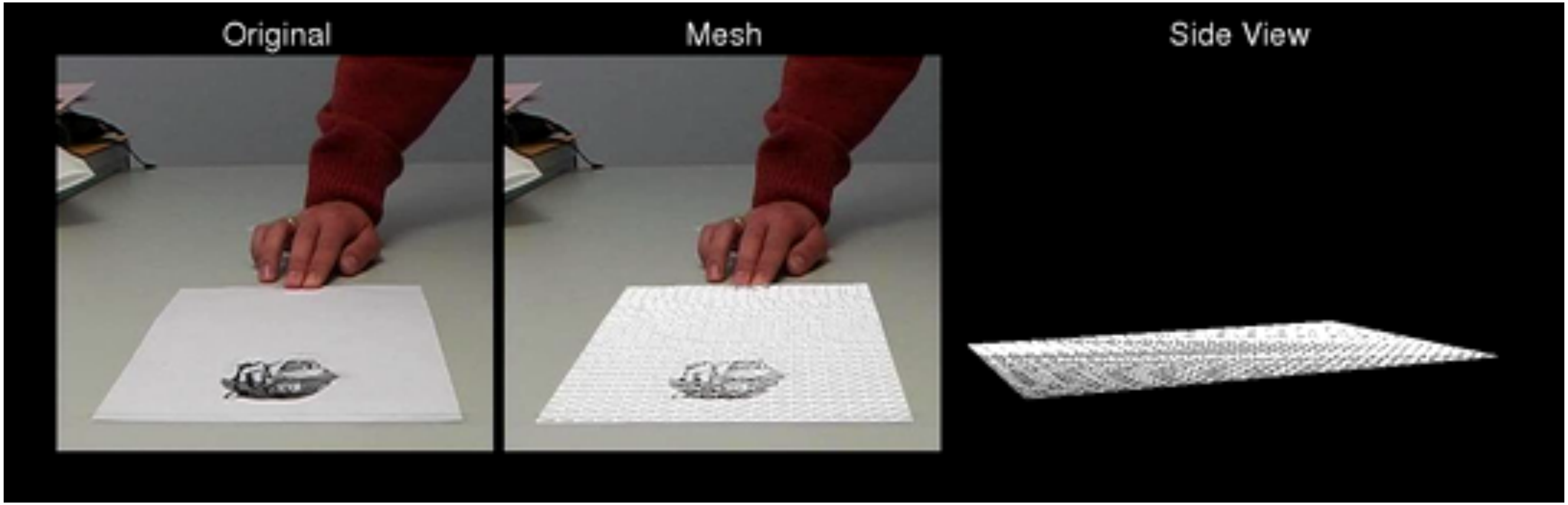
- Track feature points on page
- Fit page boundary
- Detect and use silhouettes when they appear.



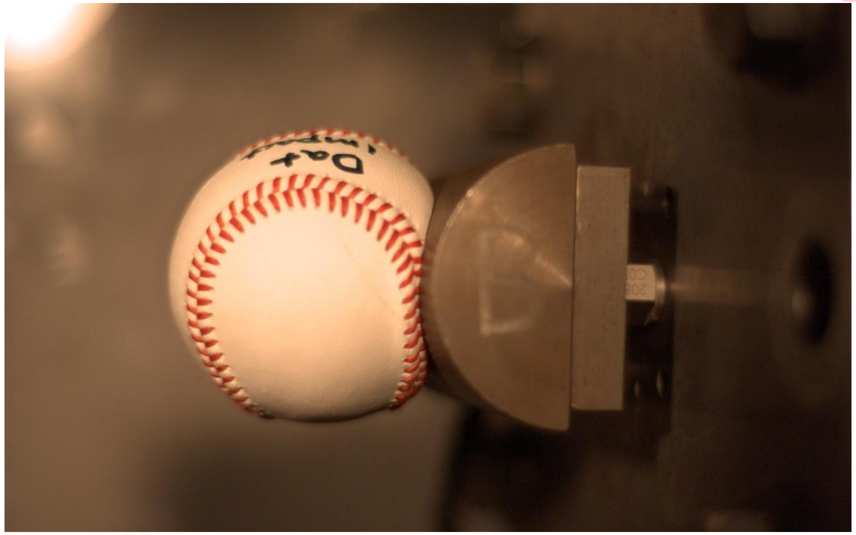
CHANGING BACKGROUND

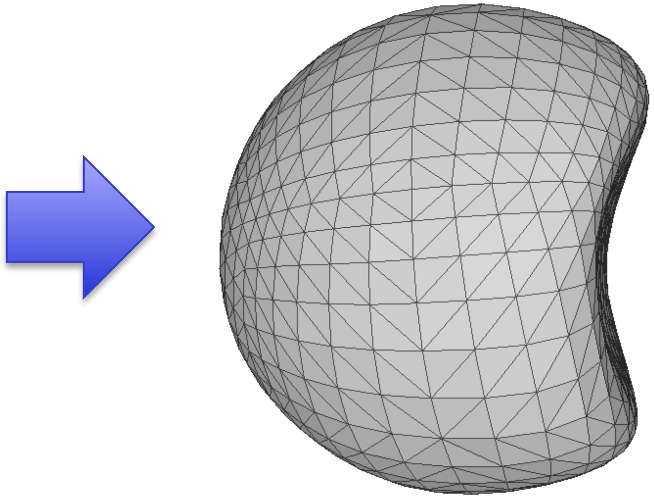


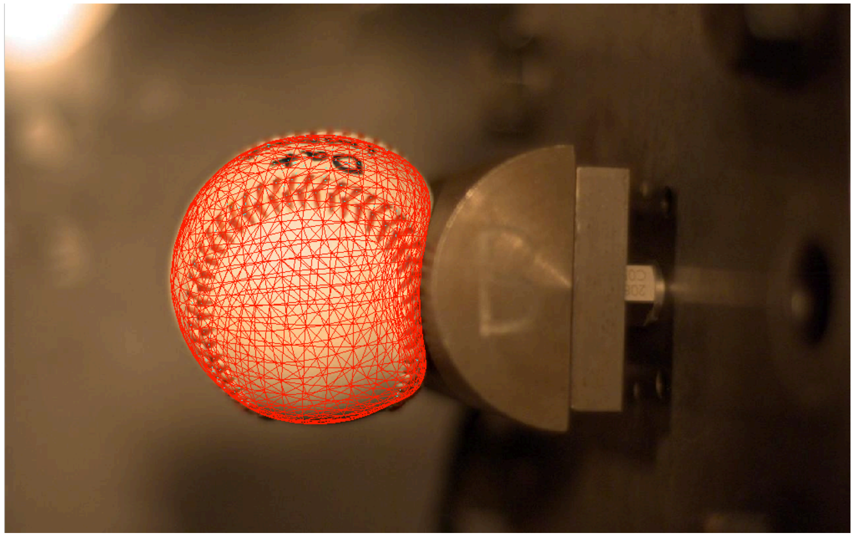
HANDLING OCCLUSIONS

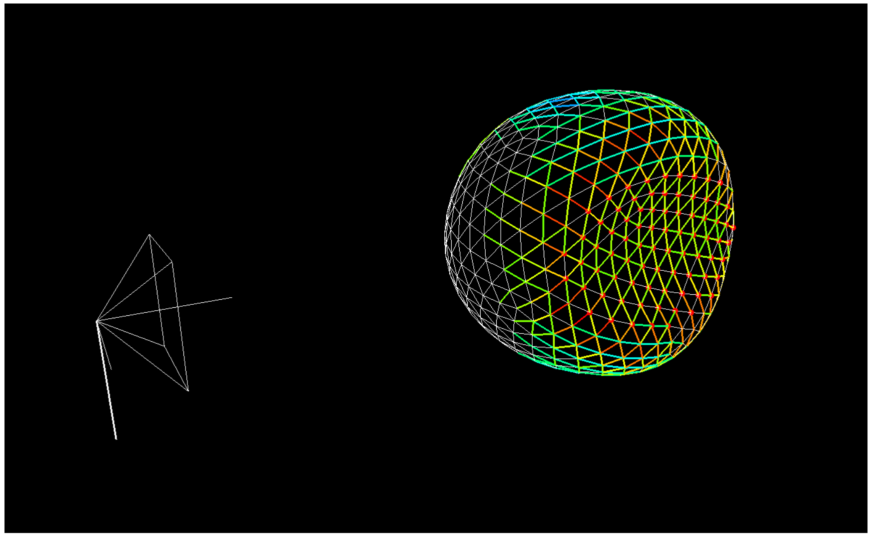


BASEBALL AND BAT

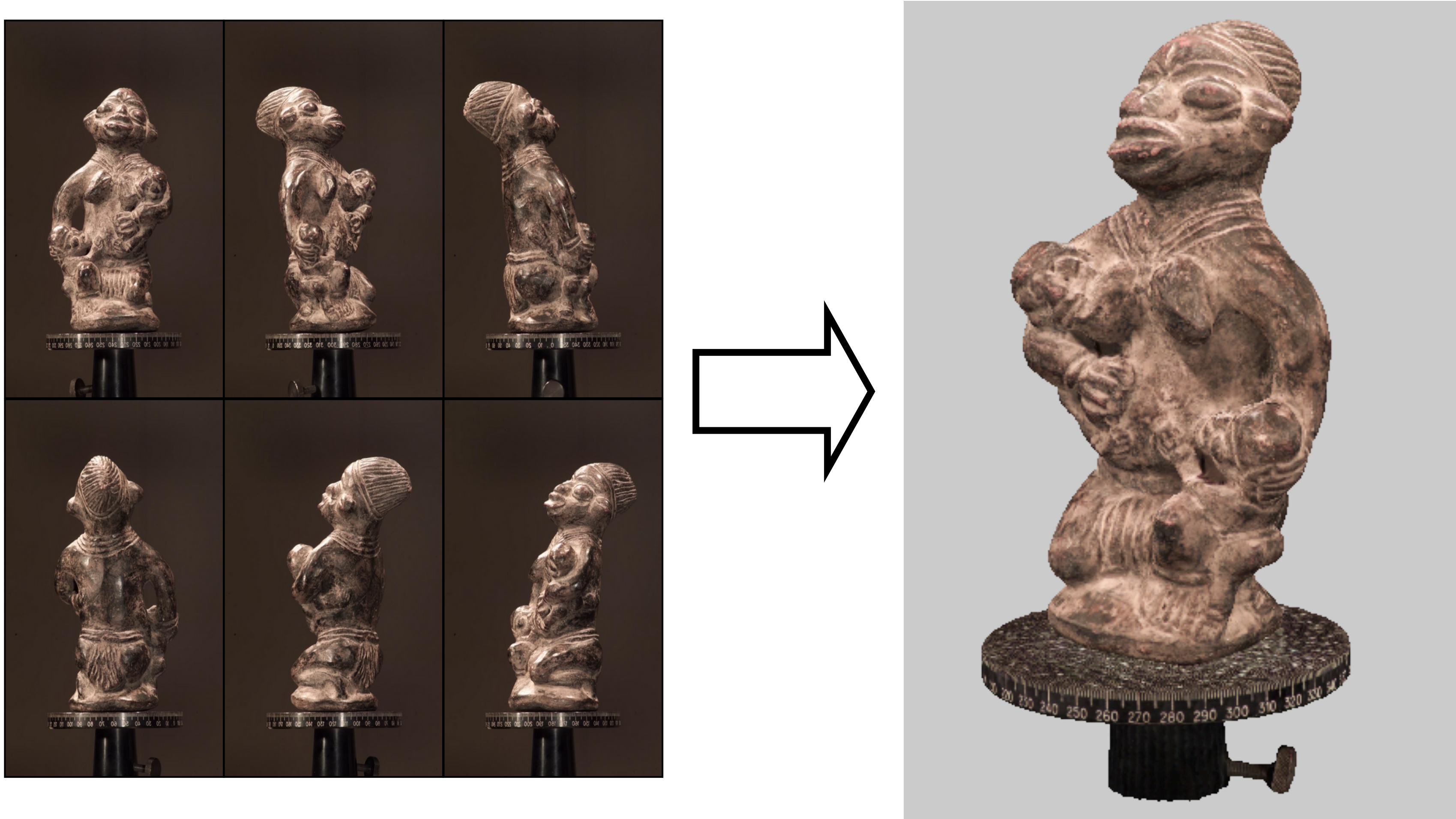






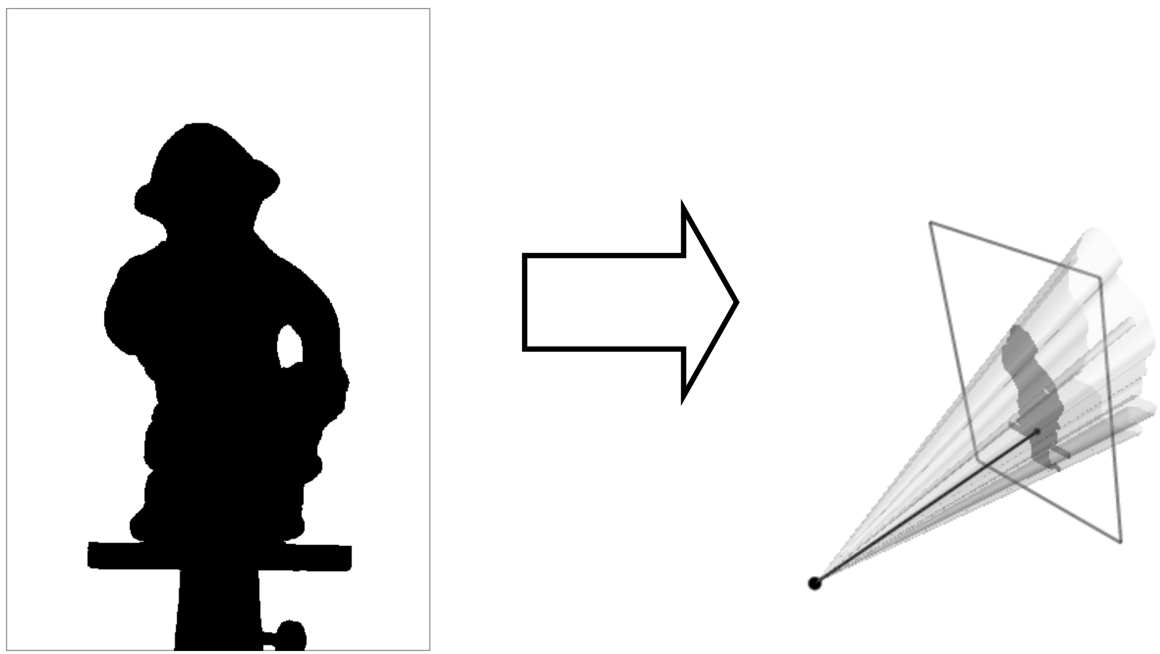


MODELING FROM MANY PHOTOGRAPHS

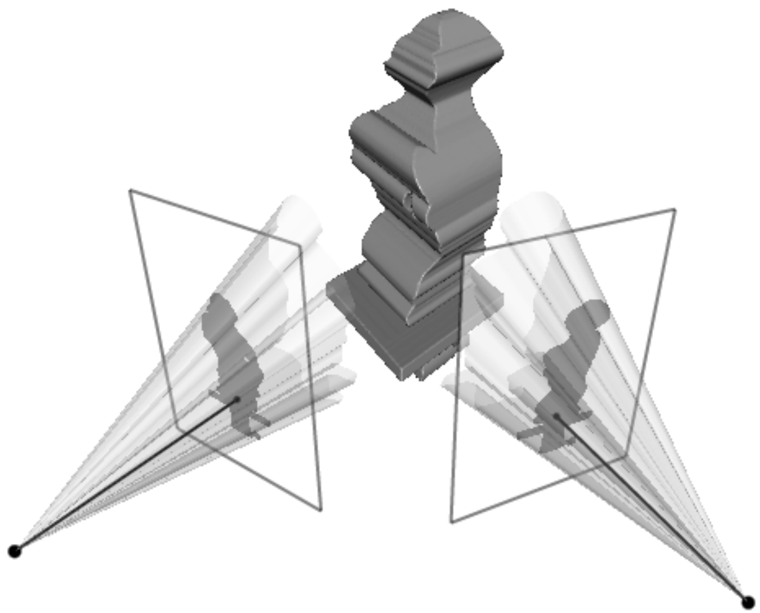


C. Hernandez, PhD ENST, 2004

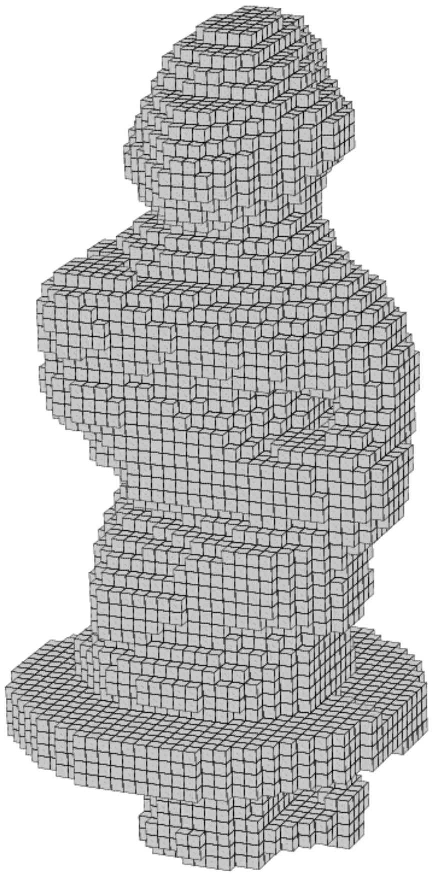
VISUAL HULL ONE IMAGE



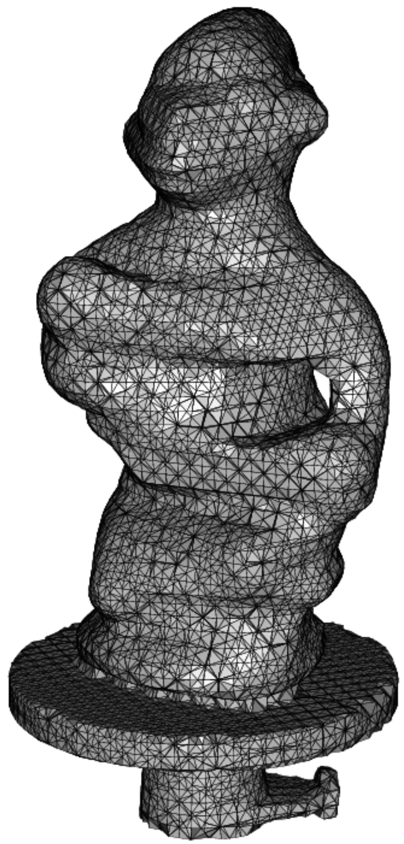
VISUAL HULL
TWO IMAGES



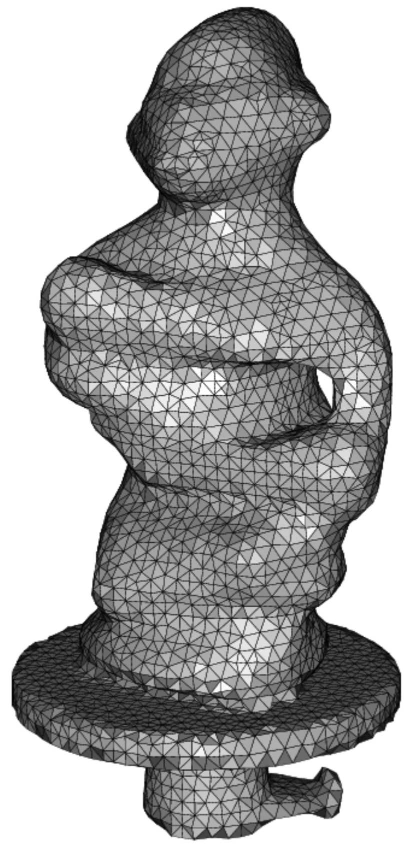
VISUAL HULL MANY IMAGES



Octree volume



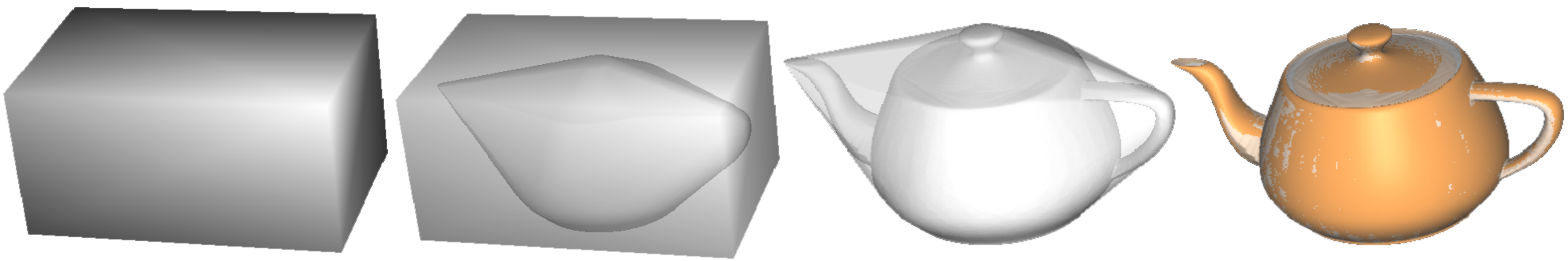
Mesh



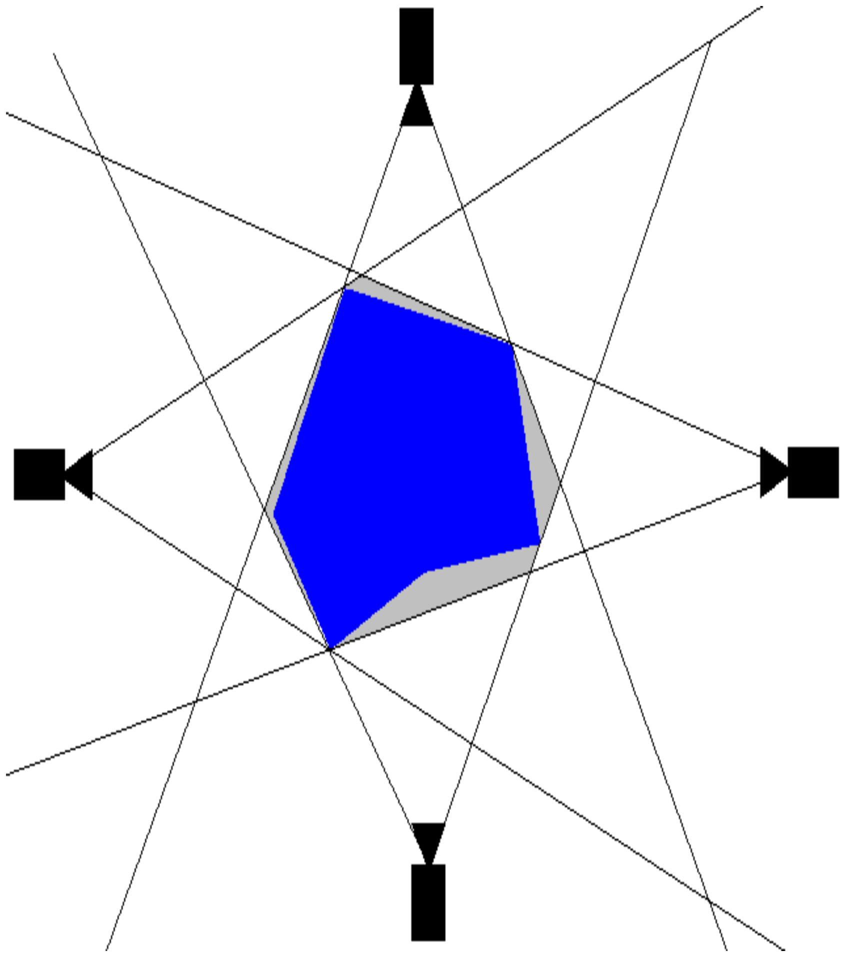
Simplified mesh

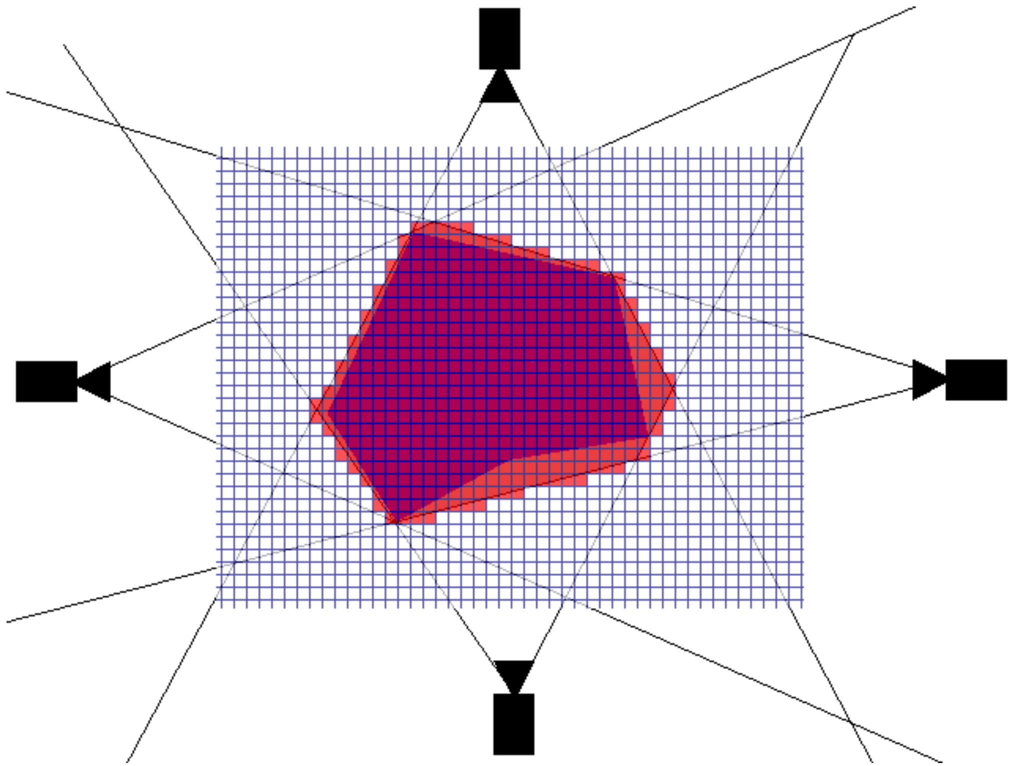
LEVELS OF DETAIL

Bounding box | Convex Hull | Visual Hull | Real Object



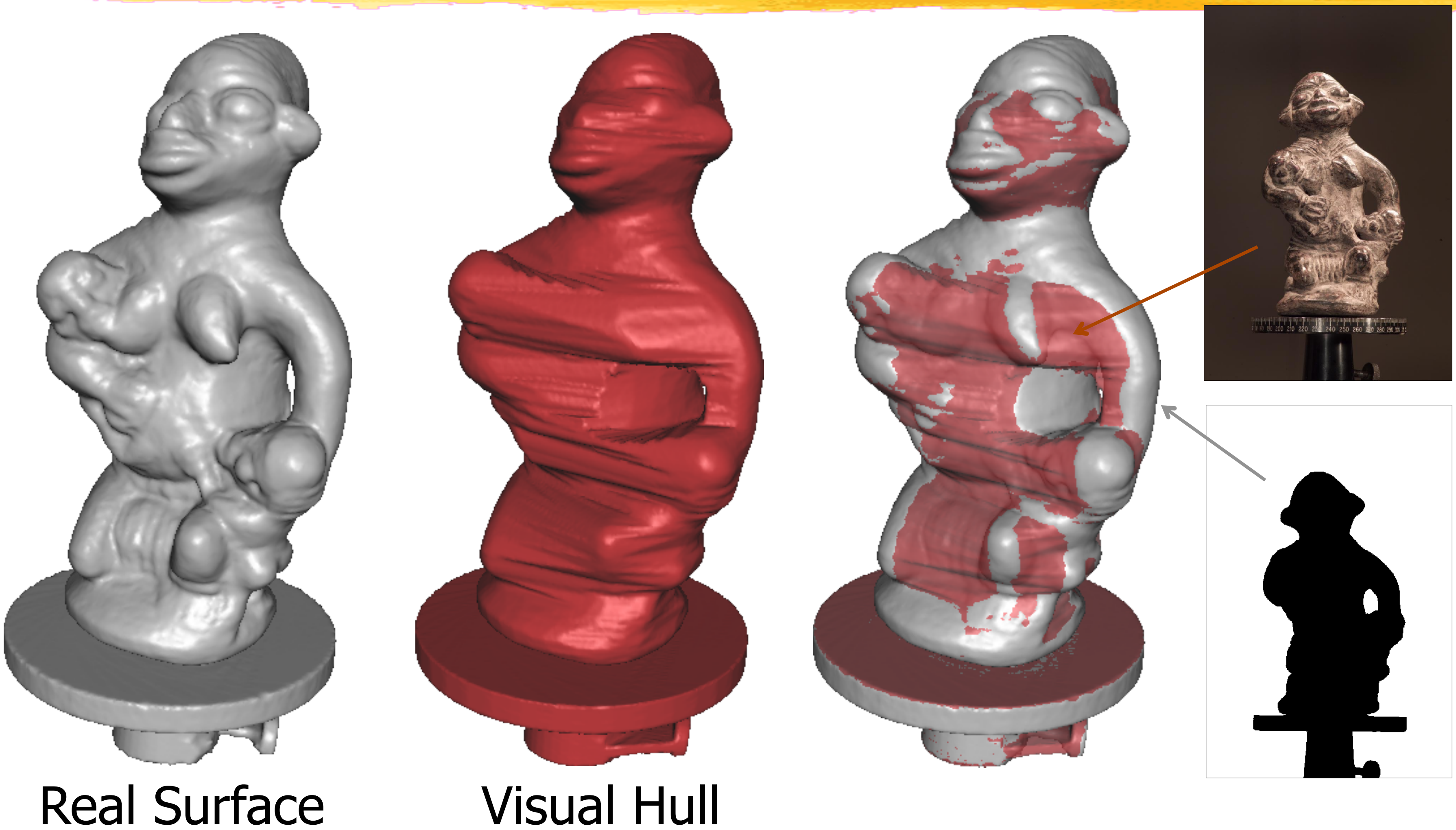
VISUAL HULL IN 2D





Concavities are lost

COMBINING STEREO AND SILHOUETTES



MODELING PROCESS

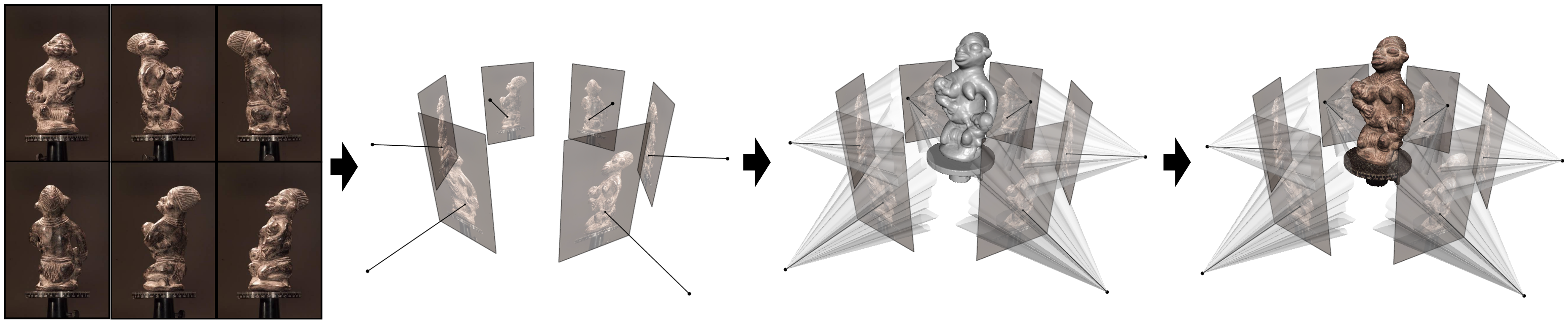


Image Acquisition | Camera Calibration | 3—D Reconstruction | Texture Mapping

IMAGE ACQUISITION

Objects → **Calibration Grid**

Image Acquisition

Calibration of the camera and turntable

Image Sequence

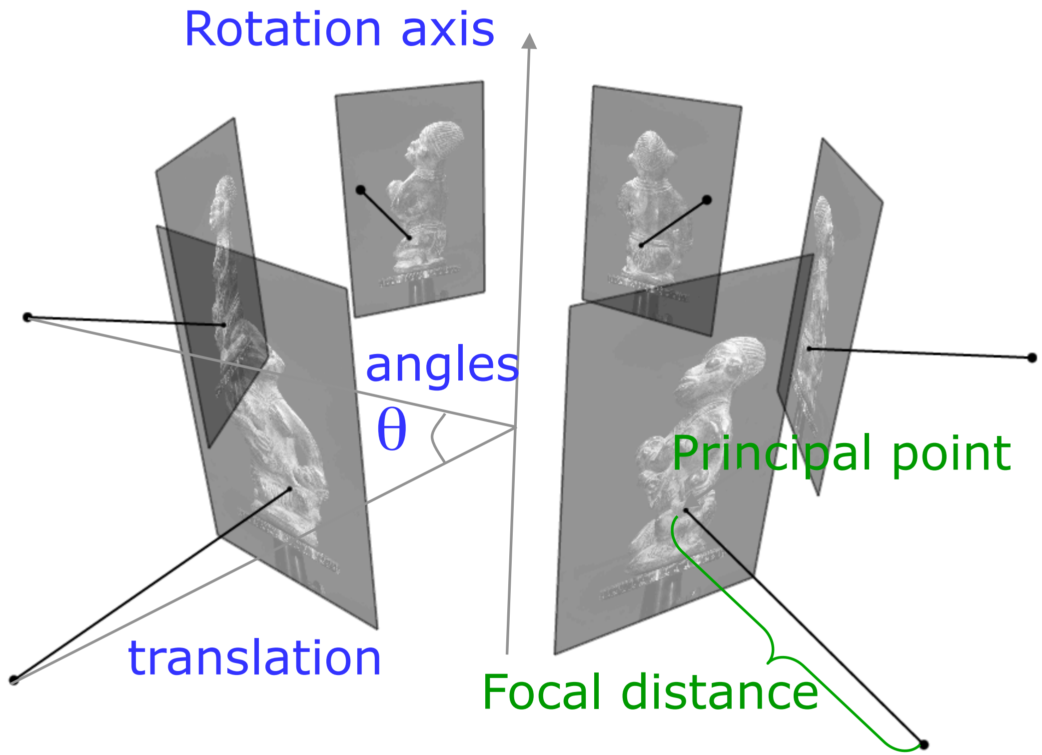
Camera Parameters

IMAGE ACQUISTION

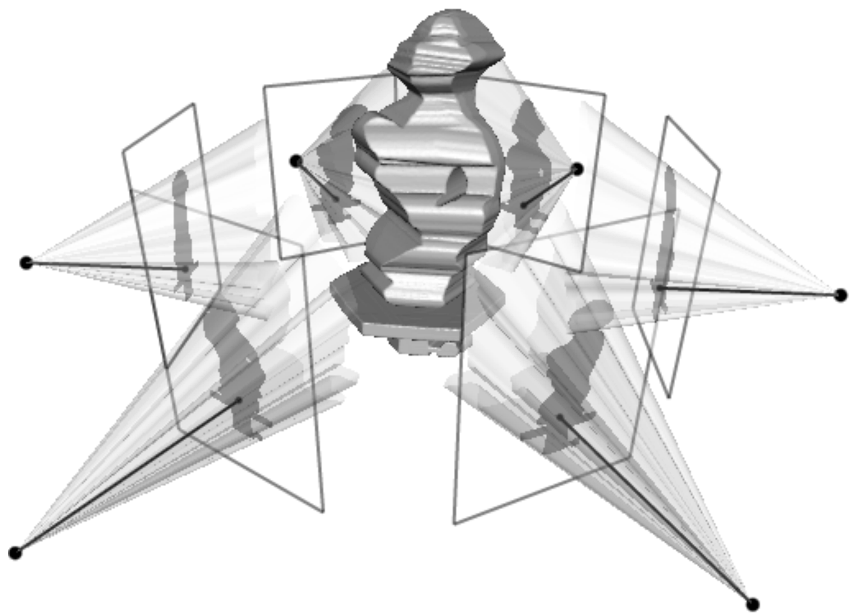
CIRCULAR CAMERA MOTION CALIBRATION

Parameters to be estimated:

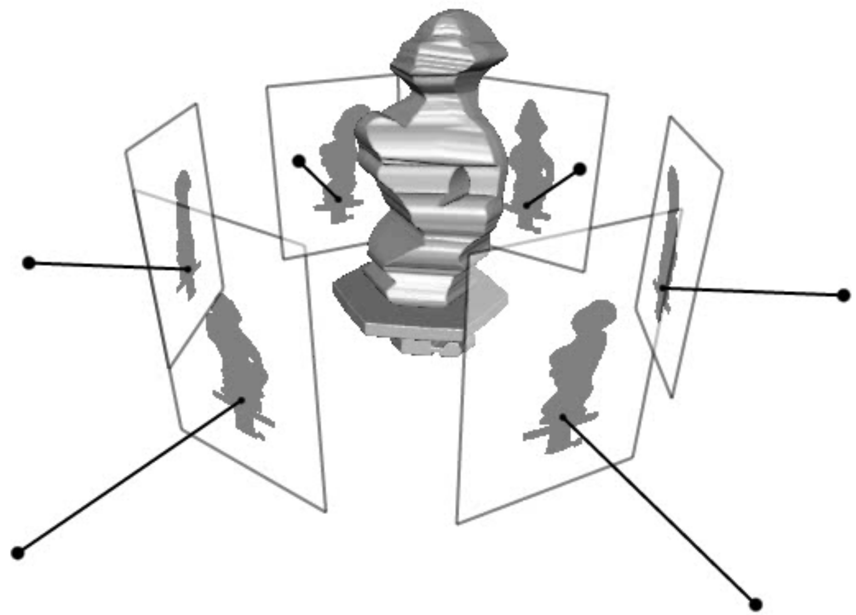
- Rotation axis
- Translation
- Rotation angles
- Focal distance
- Principal point



VISUAL HULL
N IMAGES



Correct Calibration



Decalibrating

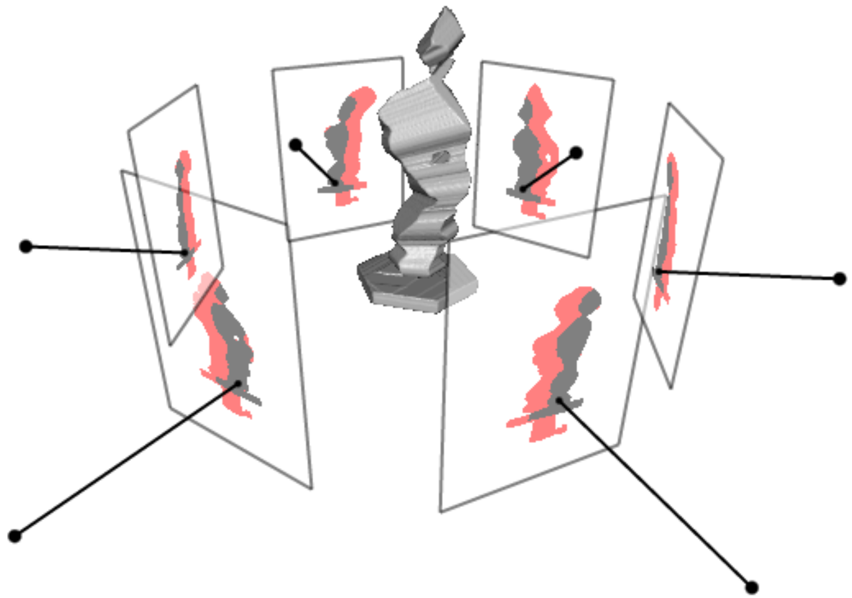
VISUAL HULL REPROJECTION

In theory:

Silhouettes of Visual Hull $\subseteq$ Original Silhouettes

In practice:

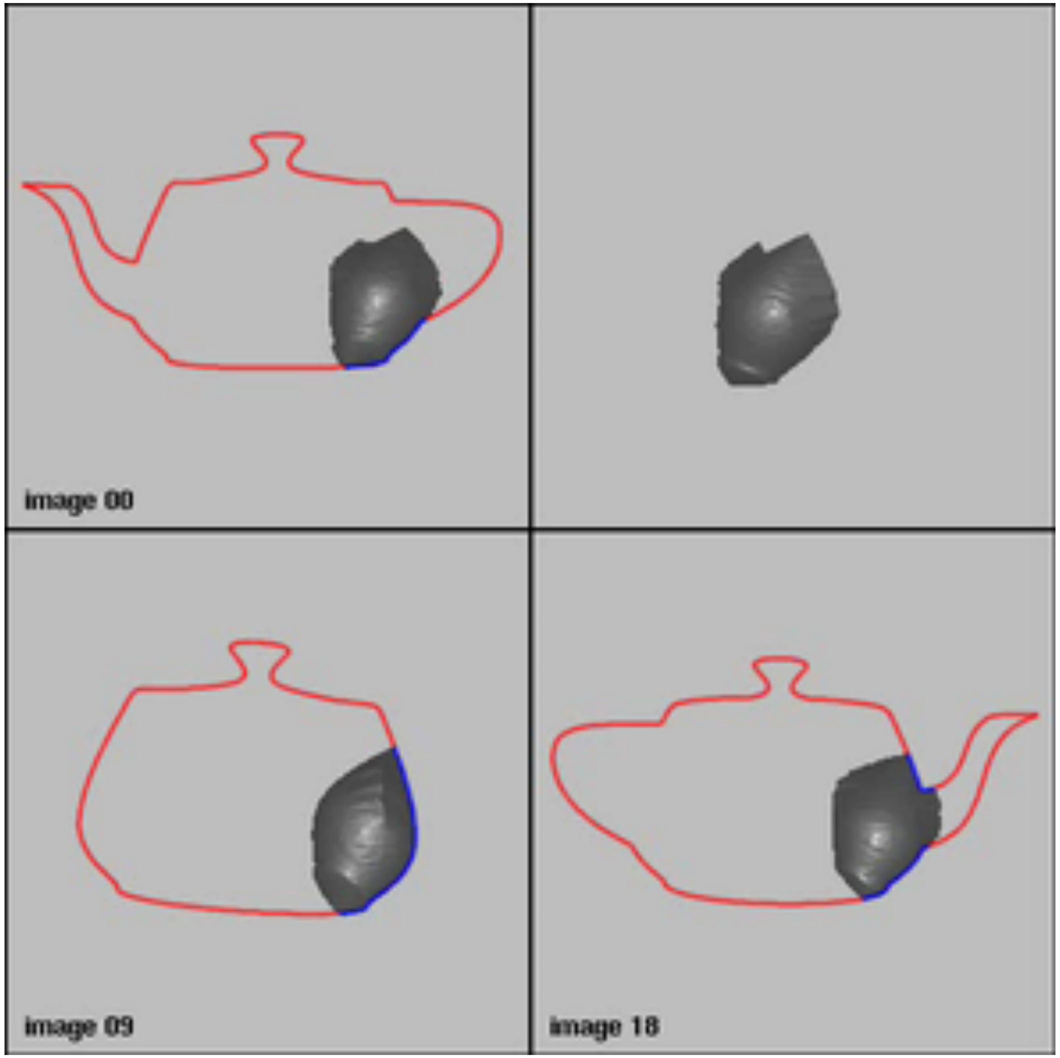
Silhouettes of Visual Hull $\subset$ Original Silhouettes



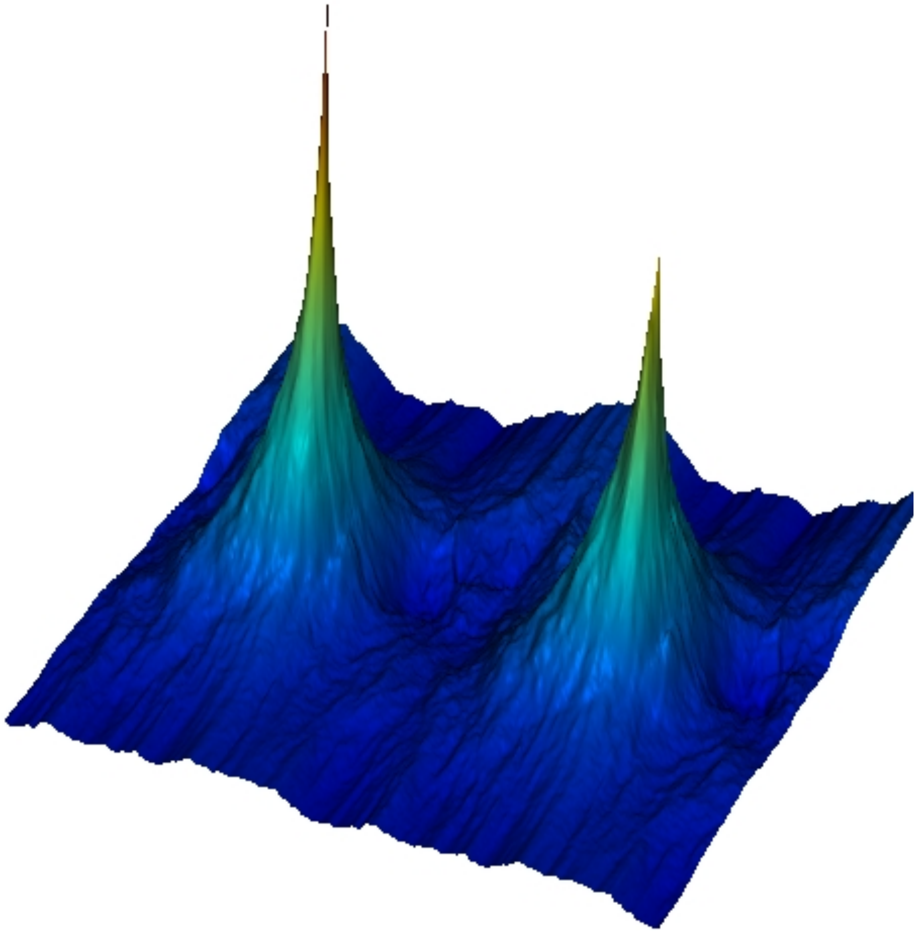
→ **Calibration heuristic:**

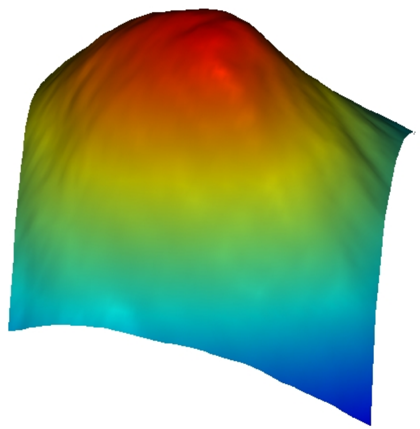
Maximize overlap of re-projected visual hull and silhouettes

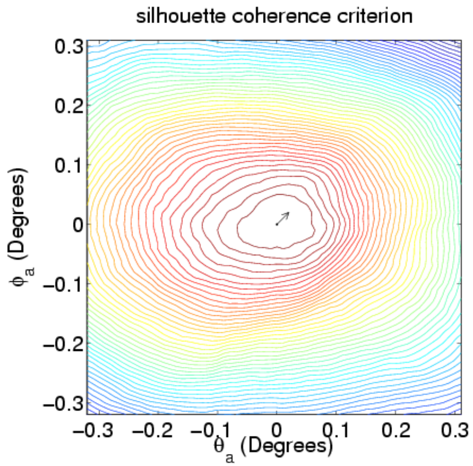
CONSISTENCY MAXIMIZATION



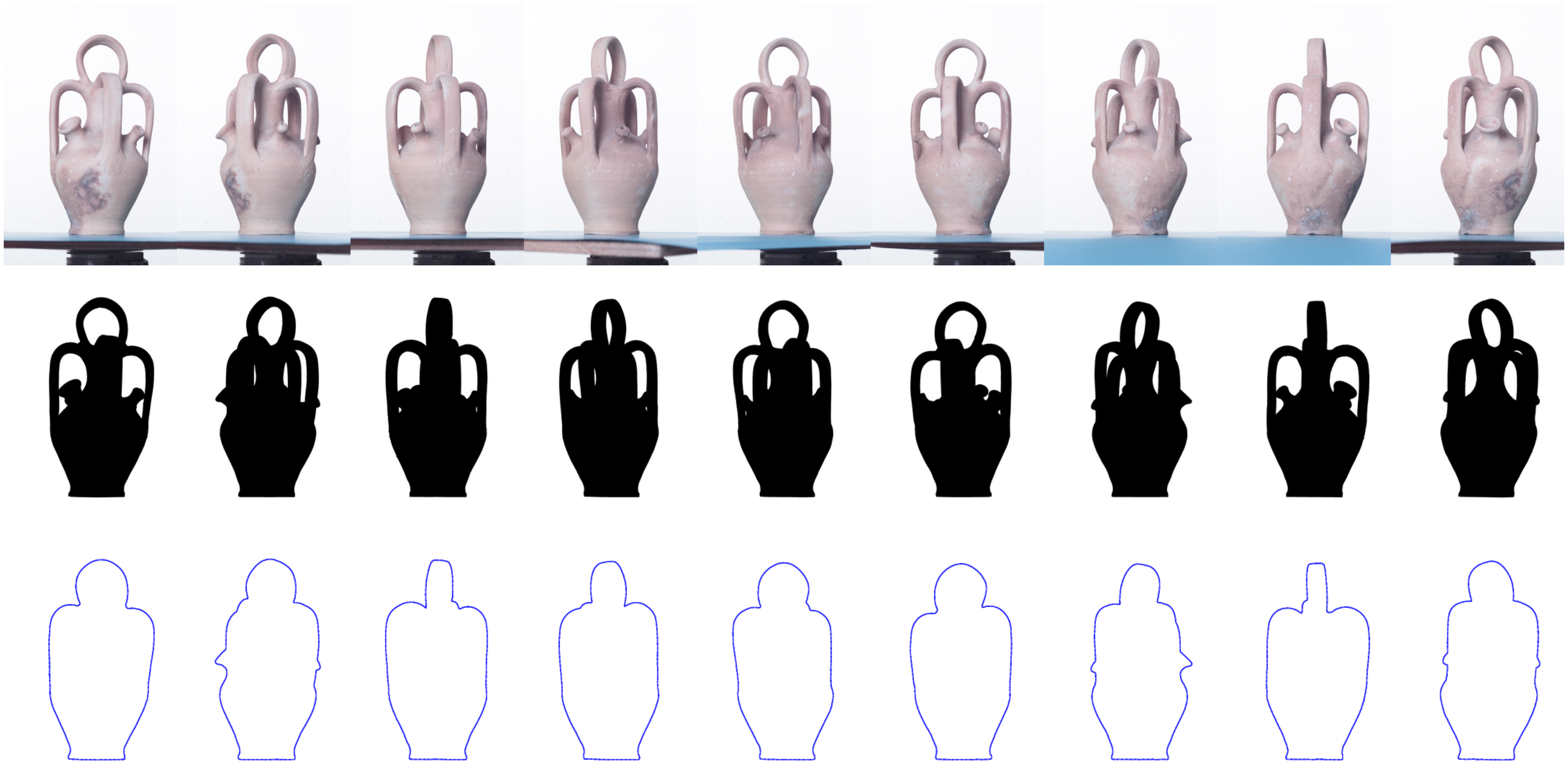
CONSISTENCY AS A FUNCTION OF THE ROTATION AXIS



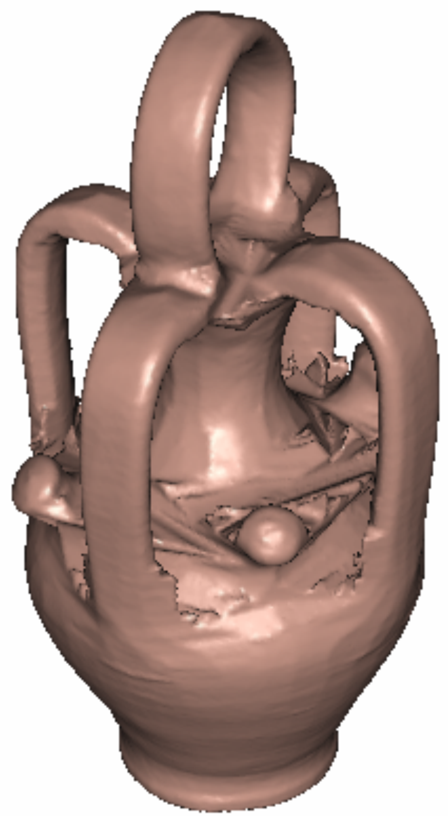




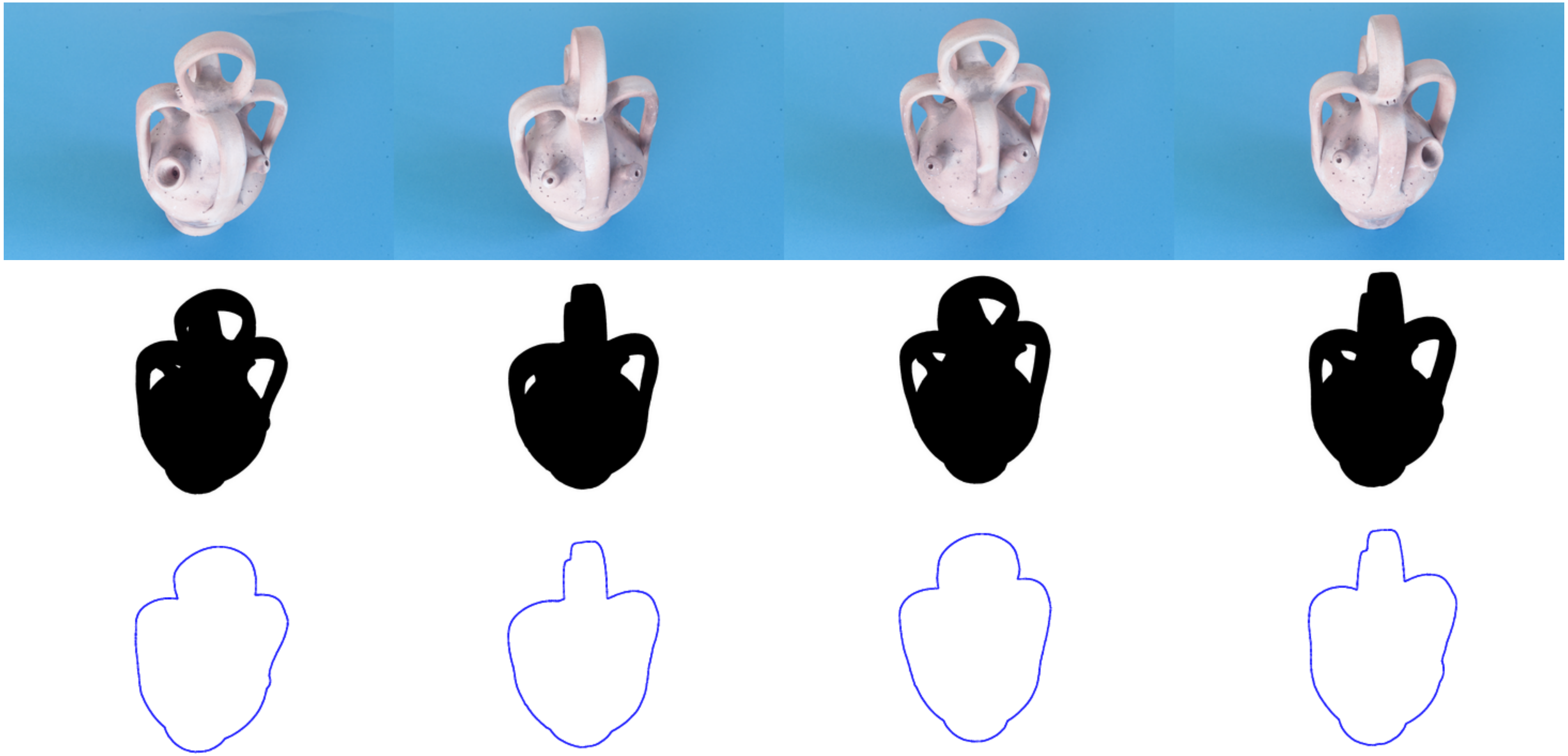
ROTATING SEQUENCE



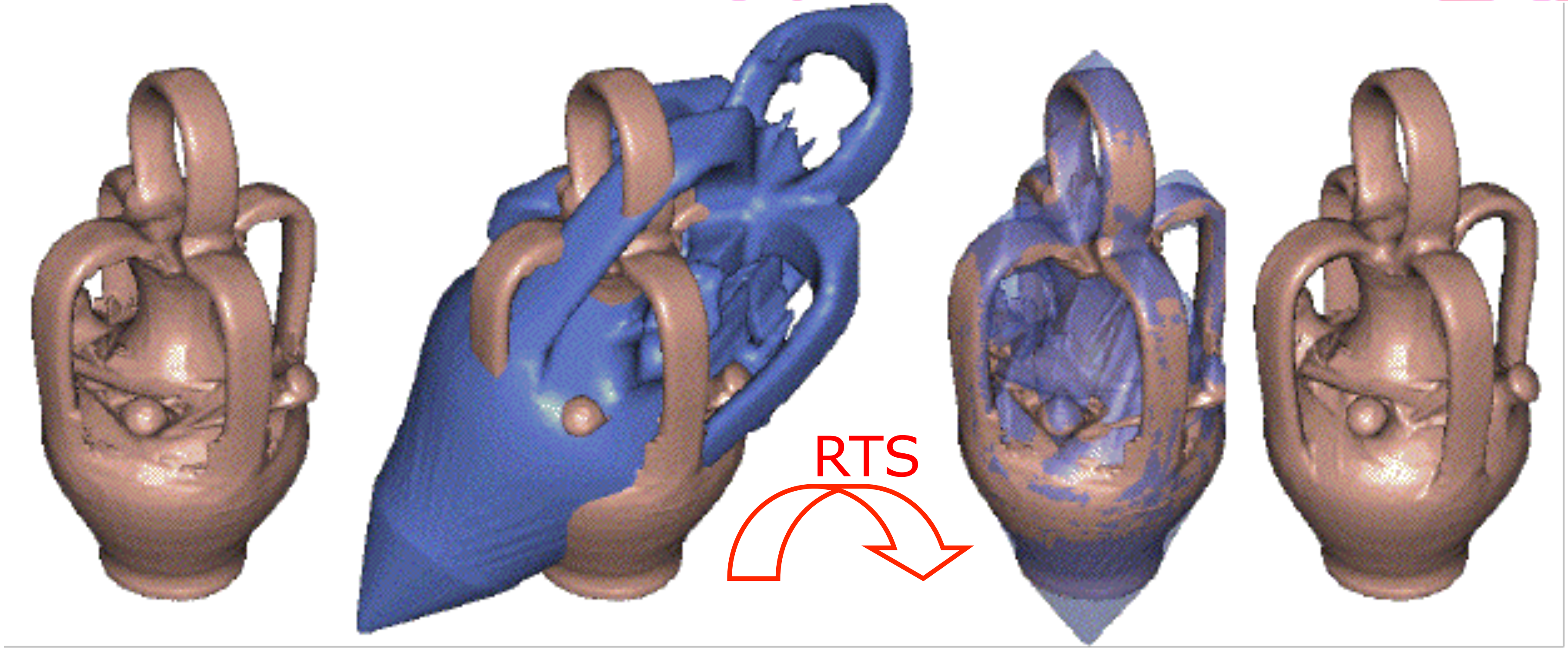
VISUAL HULL



SECOND ROTATING SEQUENCE



COMBINING THE SEQUENCES



Rigid motion + Scaling

MODELING PROCESS

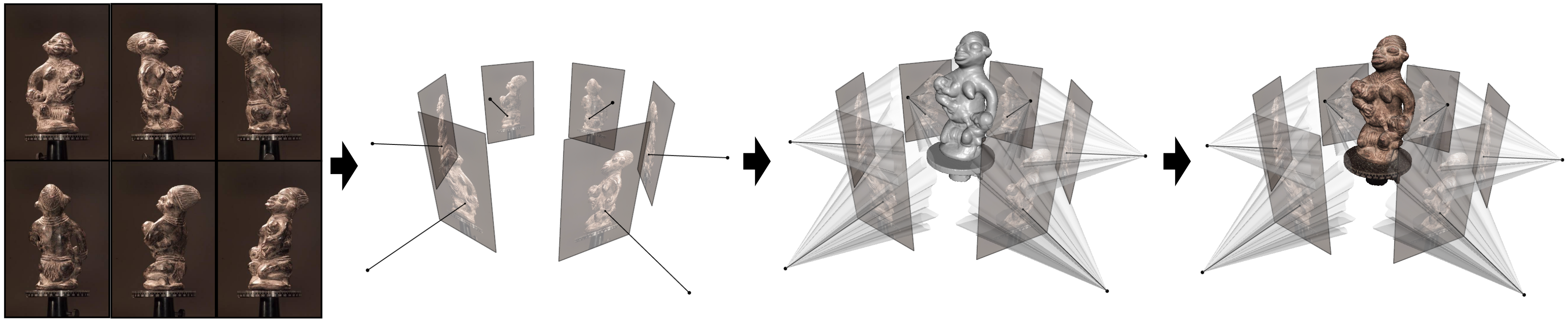


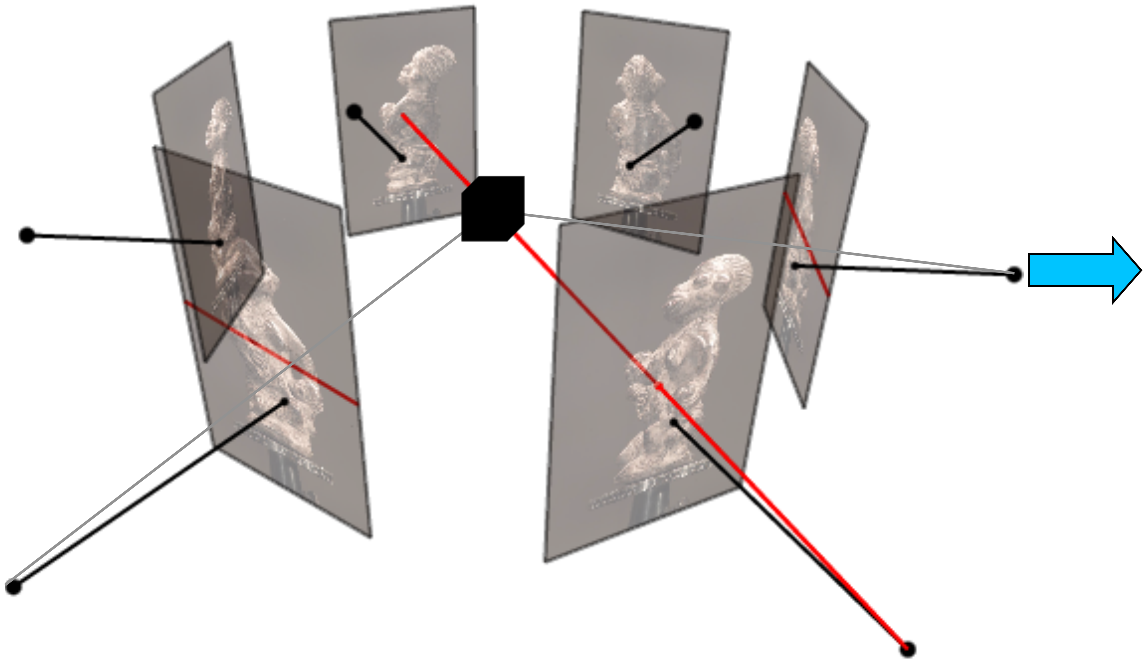
Image Acquisition → Camera Calibration → **3—D Reconstruction** → Texture Mapping

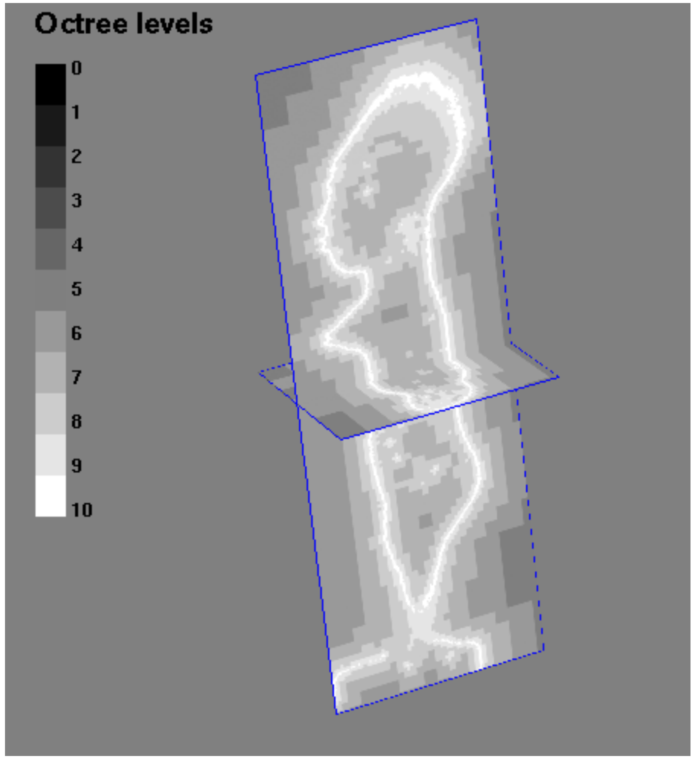
3-D DEFORMABLE MODEL

1. Initialization of the model

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

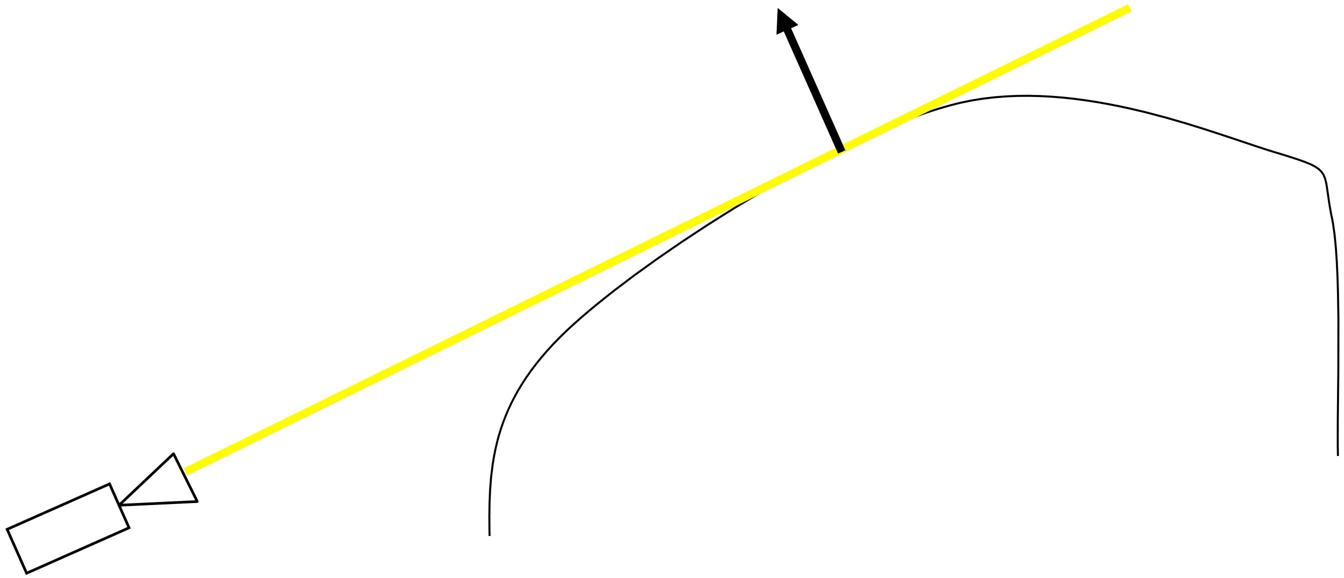
TEXTURE ENERGY





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.

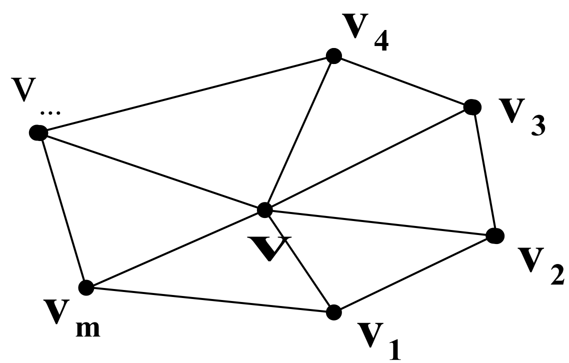
DEFORMATION ENERGY

Laplacian

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

Biharmonic

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



OPTIMIZATION

$$v_i^{k+1} = v_i^k + \Delta t(F_{tex}(v_i^k) + \beta F_{sil}(v_i'^k) + \gamma F_{\text{int}}(v_i^k))$$

F : Derivative of Energy

β : Silhouette Weight

γ : Regularization weight

RECONSTRUCTION

83241 vertices, 166482 triangles

MODELING PROCESS

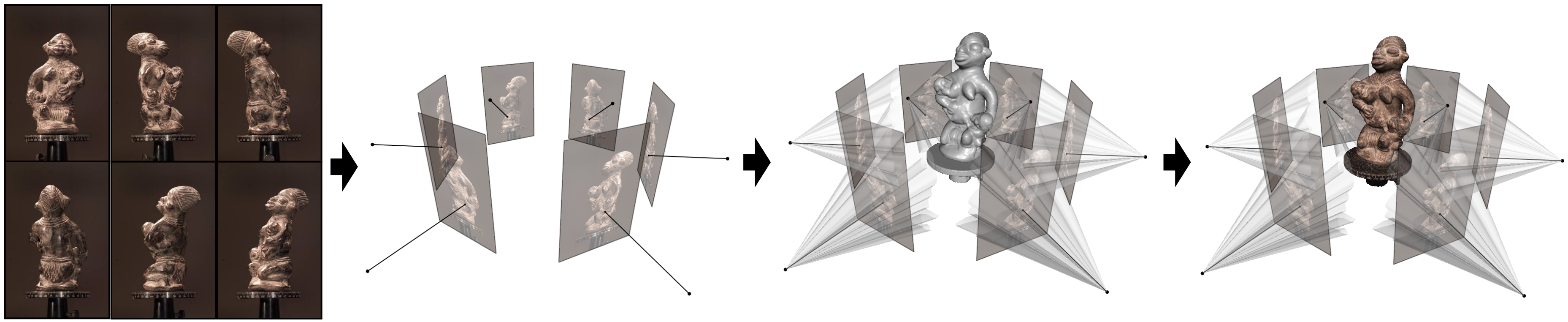
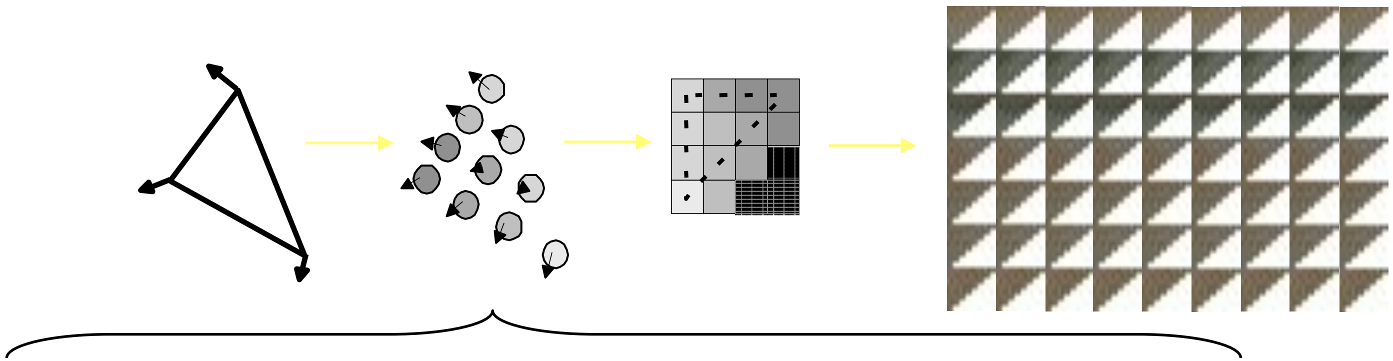
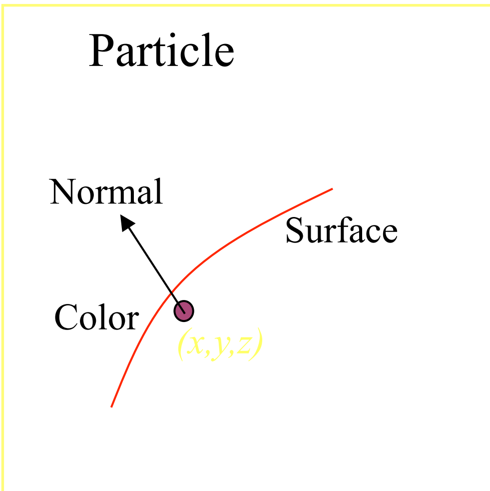
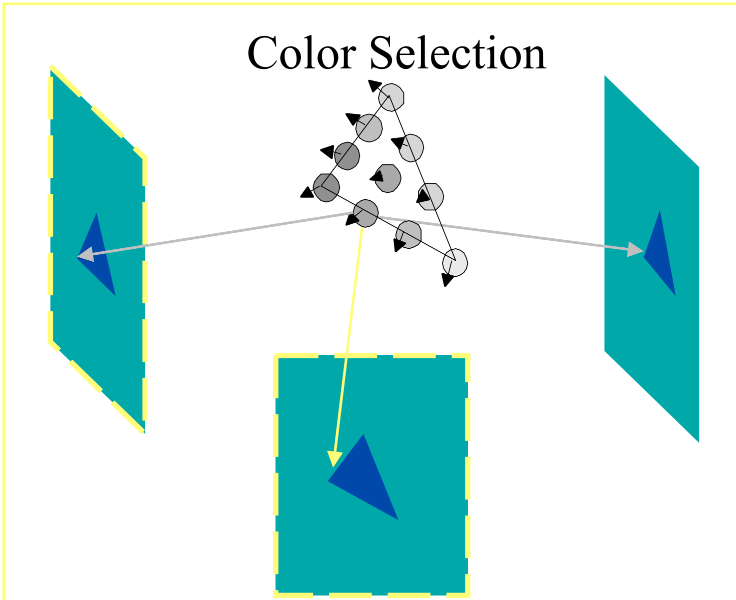


Image Acquisition | Camera Calibration | 3—D Reconstruction | **Texture Mapping**

TEXTURE MAP





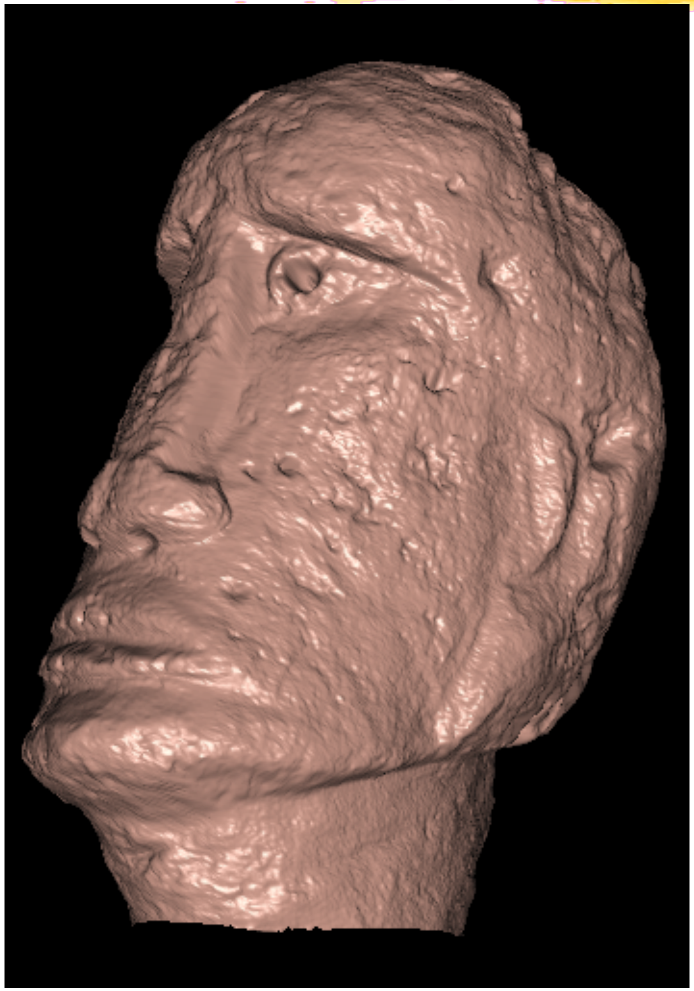


RECONSTRUCTION

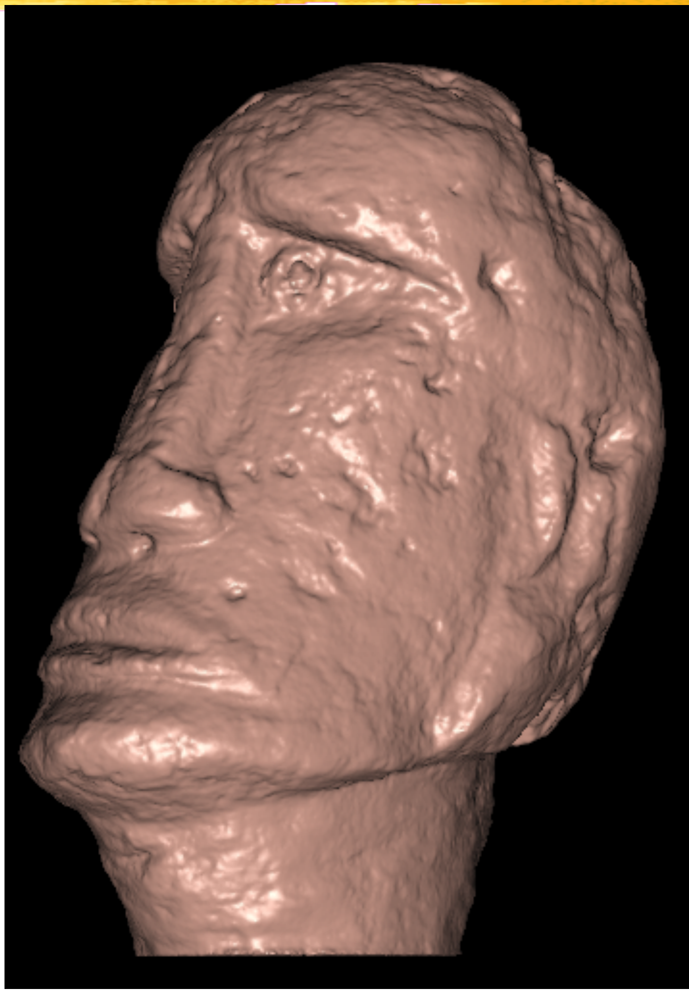
57639 vertices, 115282 triangles

LASER vs IMAGES

Minolta
Laser
Scanner



385355 vertices
770209 triangles



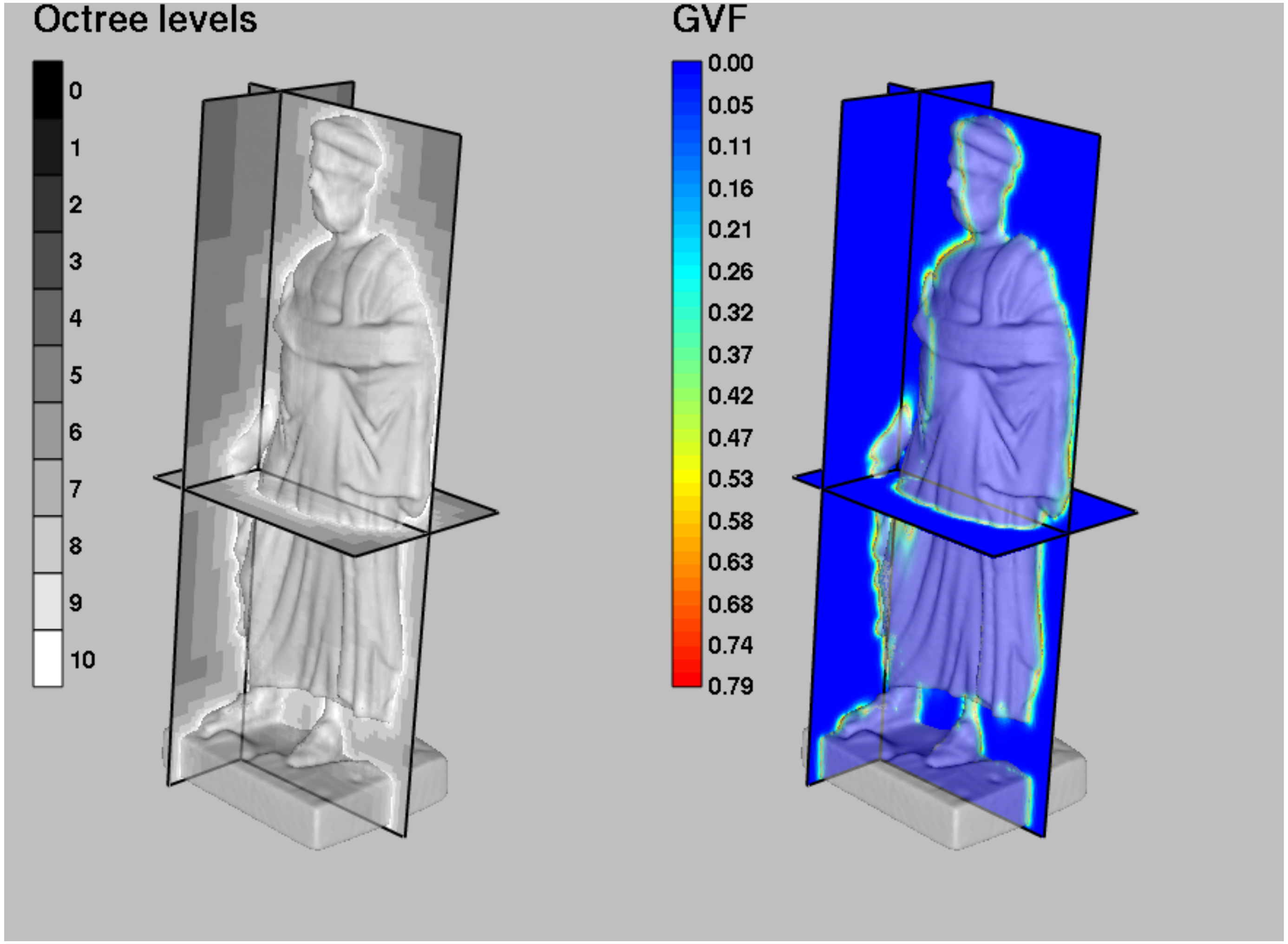
Silhouettes

233262 vertices
466520 triangles

RECONSTRUCTION

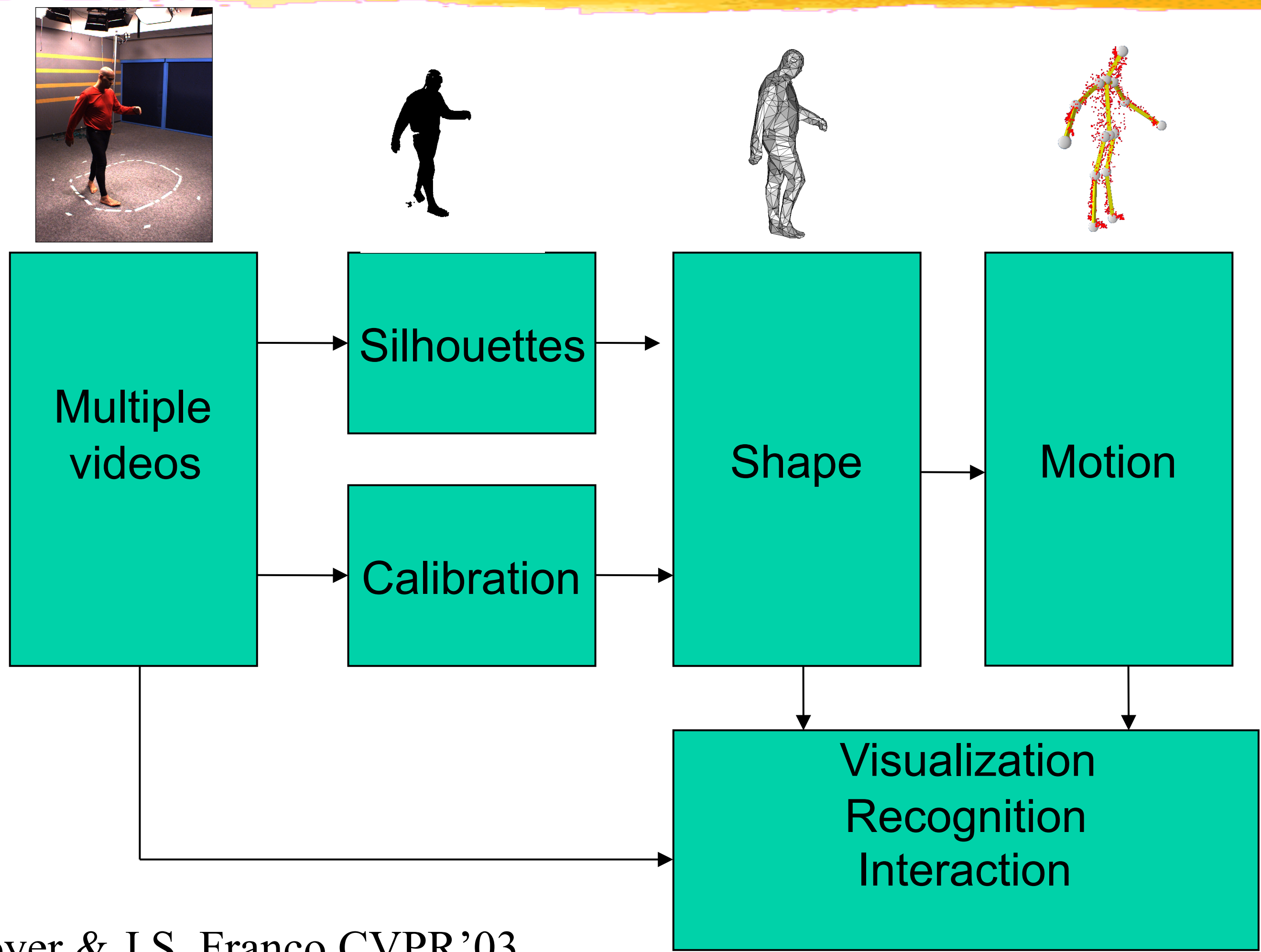
47159 vertices, 94322 triangles

TEXTURE ENERGY



RECONSTRUCTION

3D MODELING OF DYNAMIC SCENES FROM MULTIPLE VIEWS



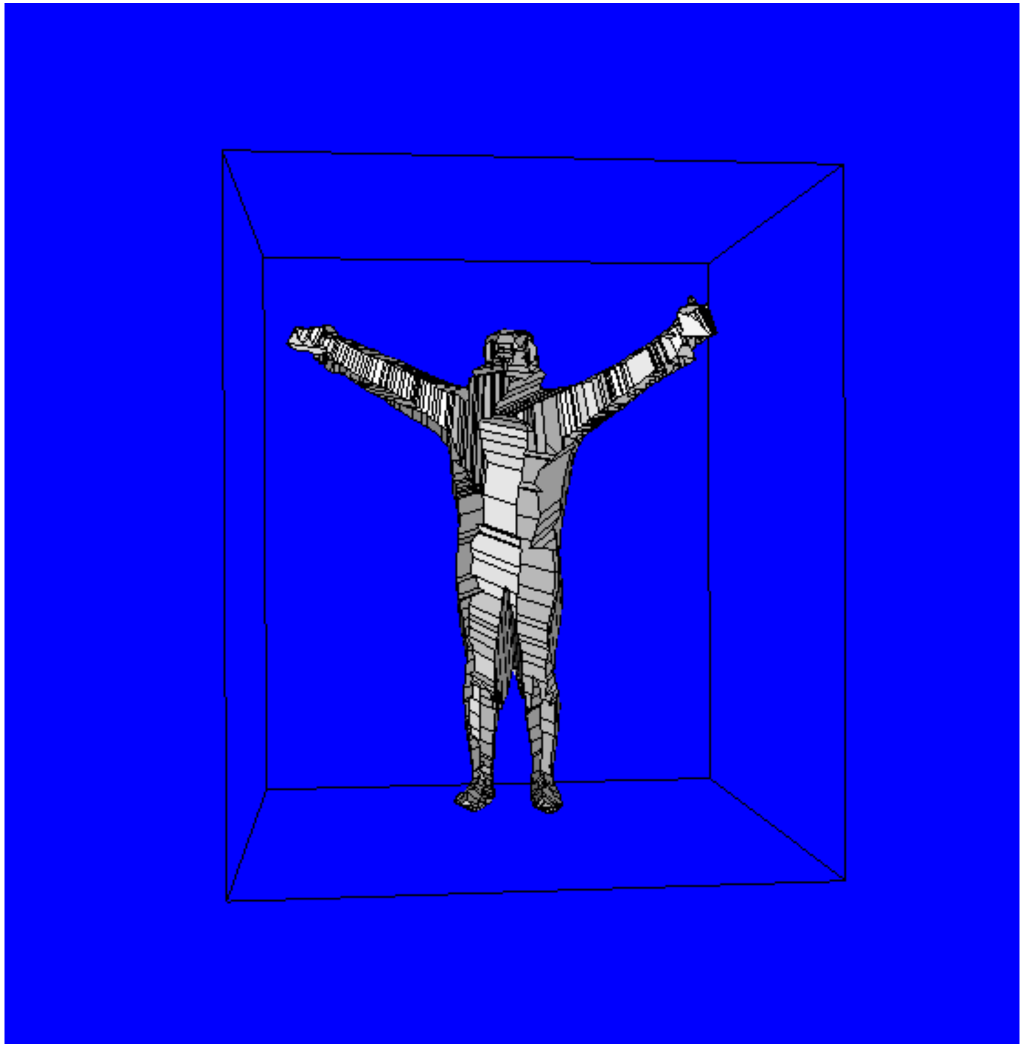
E. Boyer & J.S. Franco CVPR'03

M. Niskanen & E. Boyer & R. Horaud BMVC'05

MOVI - INRIA

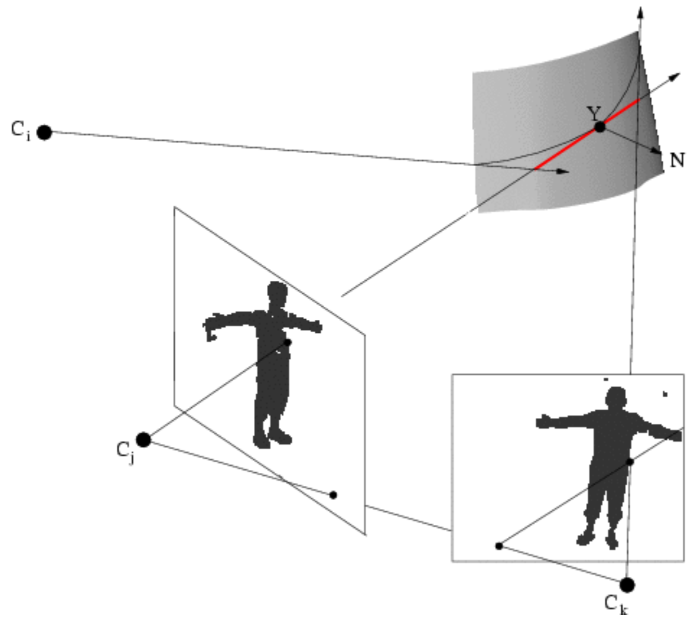
BACKGROUND SUBTRACTION

VISUAL HULL



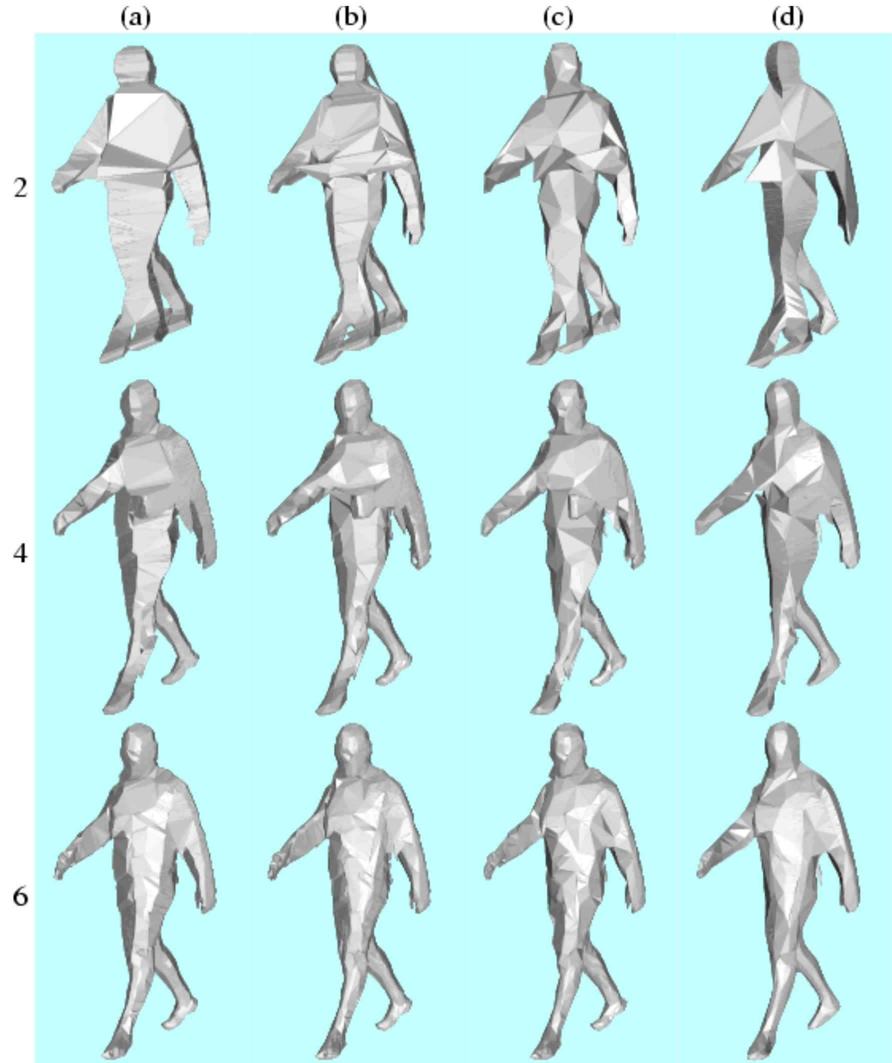
VISUAL SHAPES

- Shapes inside the visual hull and such that the VH surface is tangent along viewing edges.
- Better approximation of the observed object shape.

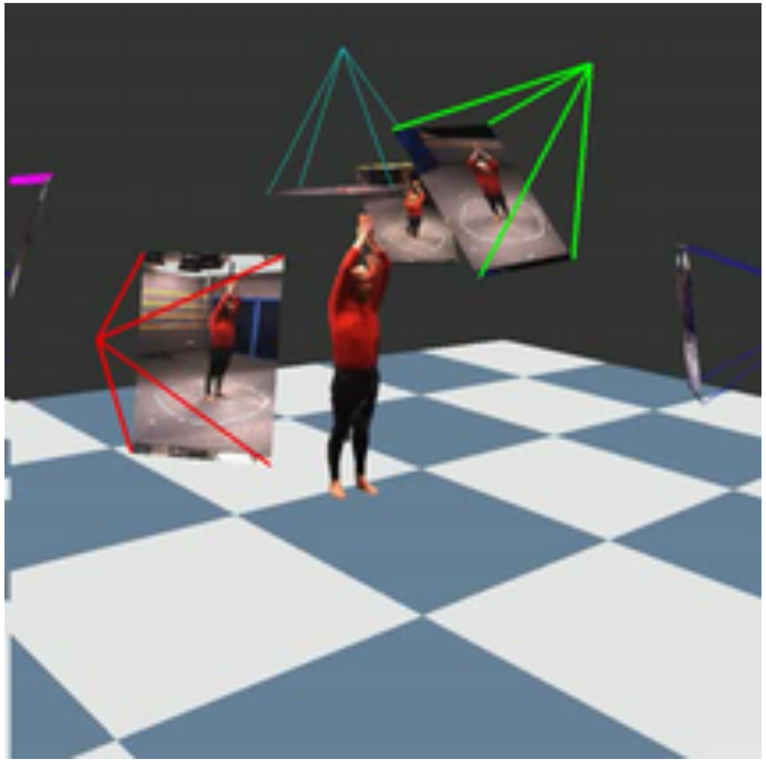


2 images 3 4 5 6

VISUAL SHAPES



TEXTURE MAPPING



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.