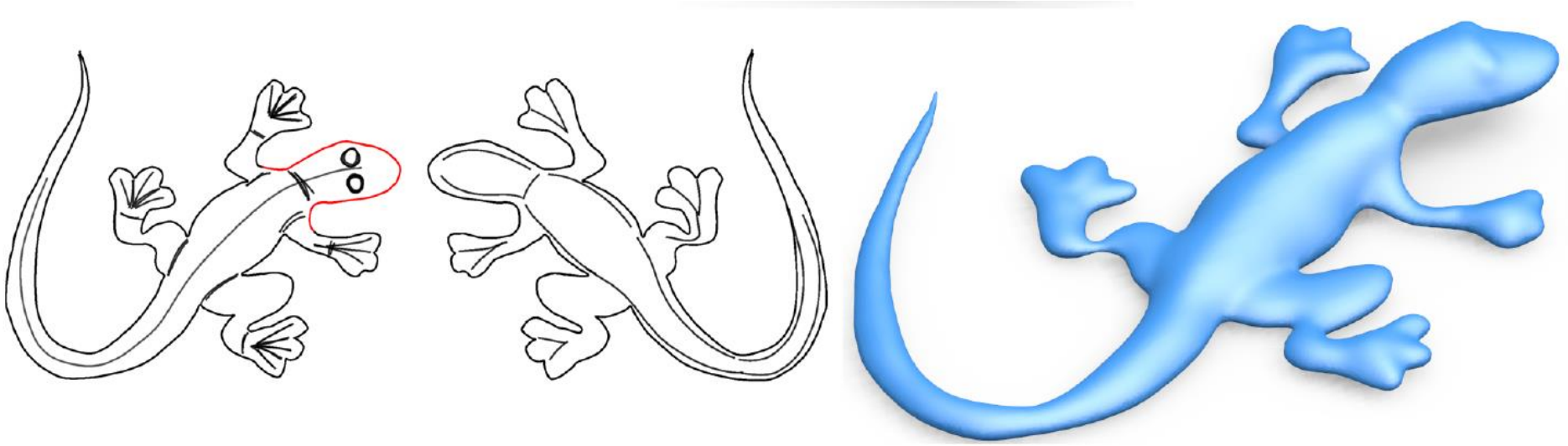
IFT 6113
SKETCH-BASED MODELING

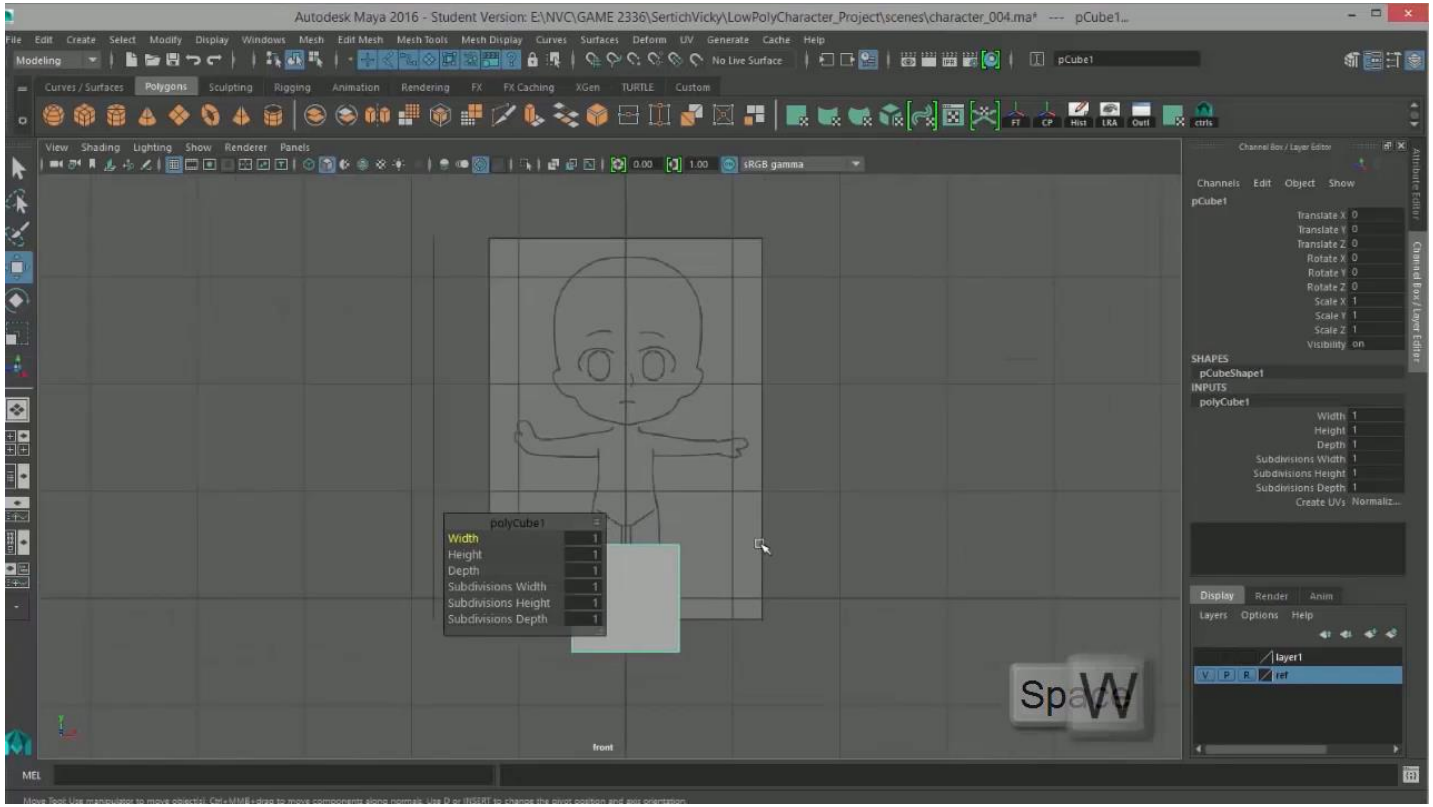
tiny.cc/6113



Robust Flow-Guided Neural Prediction for Sketch-Based Freeform Surface Modeling by Li et al., SIGGRAPH ASIA 2018

Mikhail Bessmeltsev

Motivation



30x speed

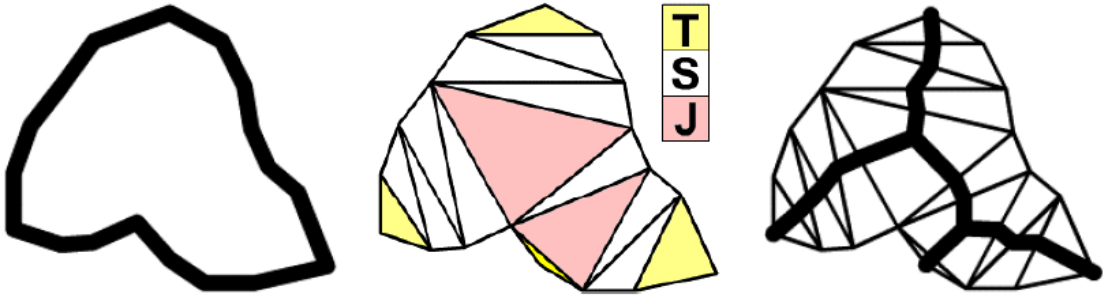
Applications

- Modeling
  - Natural shapes
  - CAD-models
  - Buildings
  - Trees
- Animating
  - Characters
  - Liquids
  - Etc.

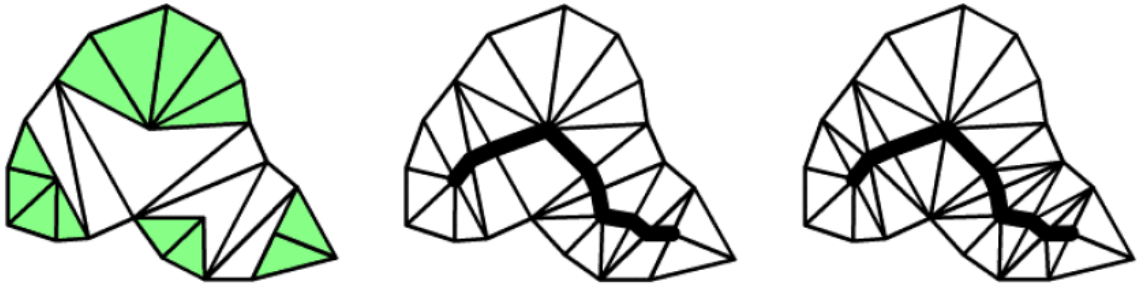
Teddy


Takeo Igarashi
Hidehiko Tanaka
University of Tokyo
Satoshi Matsuoka
Tokyo Institute of Technology
Teddy:
A Sketching
Interface for 3D
Freeform Design

Teddy



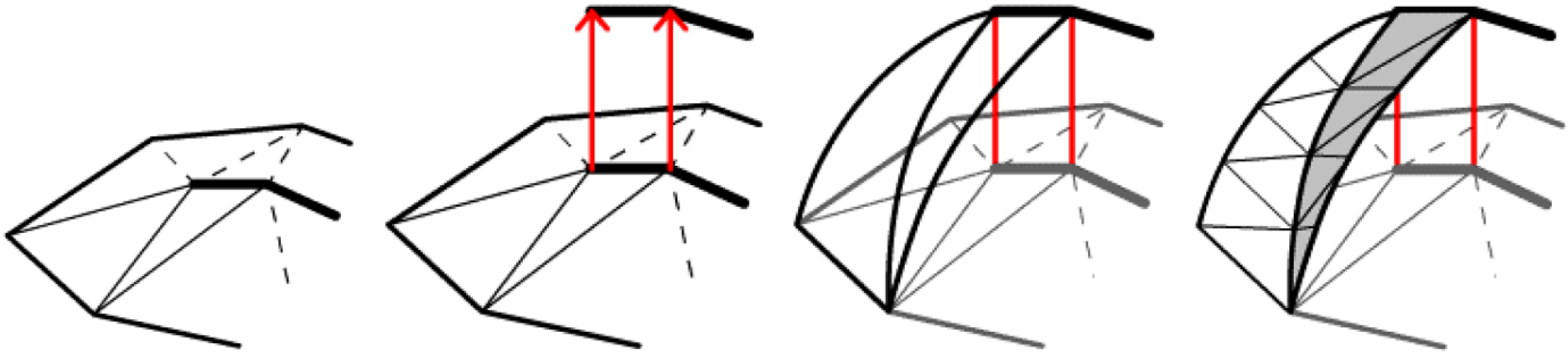
a) initial 2D polygon b) result of CDT c) chordal axis



d) fan triangles e) resulting spine f) final triangulation

Teddy

- Skeleton -> 3D:
  - Depth proportional to distance to the outer contour
- Assume every ‘fan’ edge is a part of an ellipse:



a) before b) elevate spines c) elevate edges d) sew elevated edges

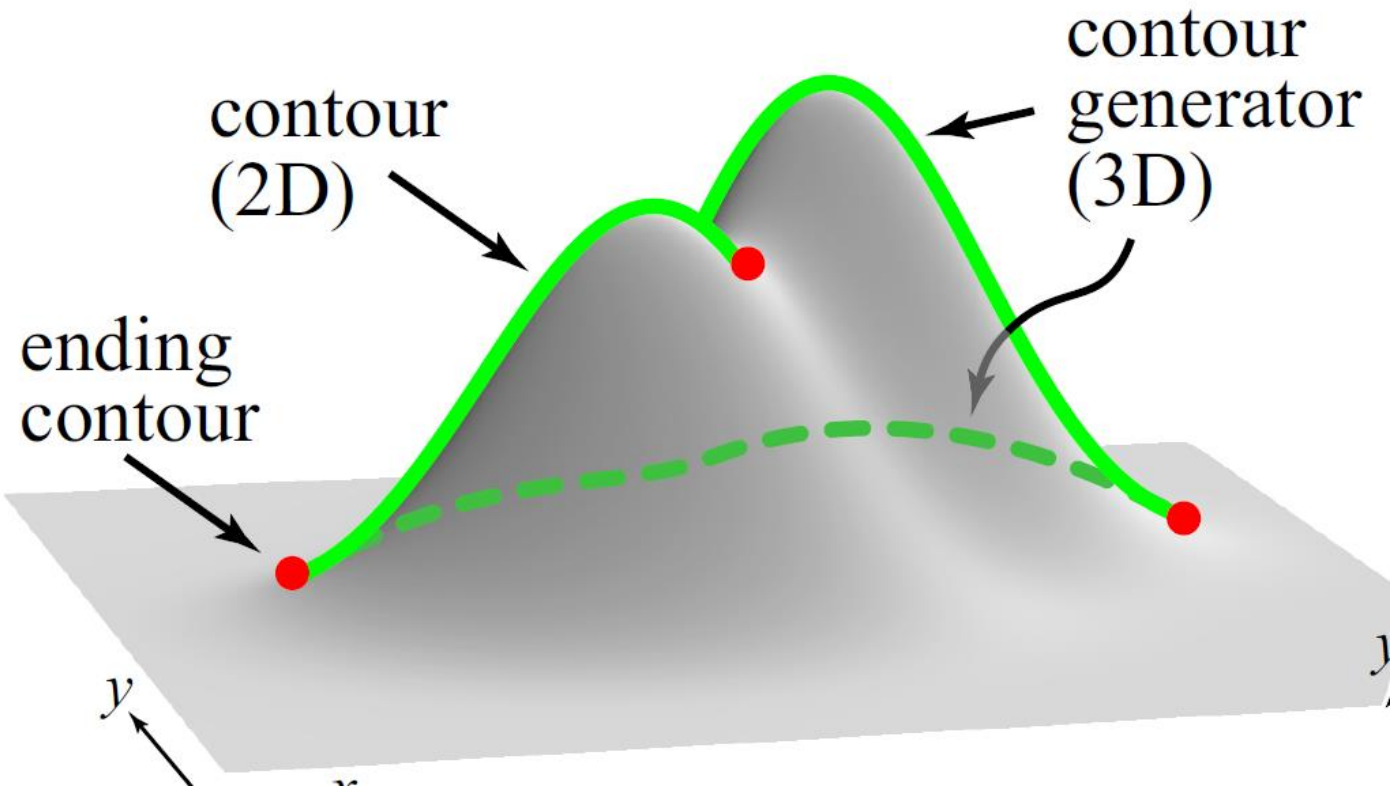
Can we interpret
natural drawings?

What lines do we draw?

What lines should we render?

Occlusion contours

$$n \cdot (p - O_{camera}) = 0$$



What lines should we render?

Occlusion contours

$$n \cdot (p - O_{camera}) = 0$$

Demo

What lines should we render?

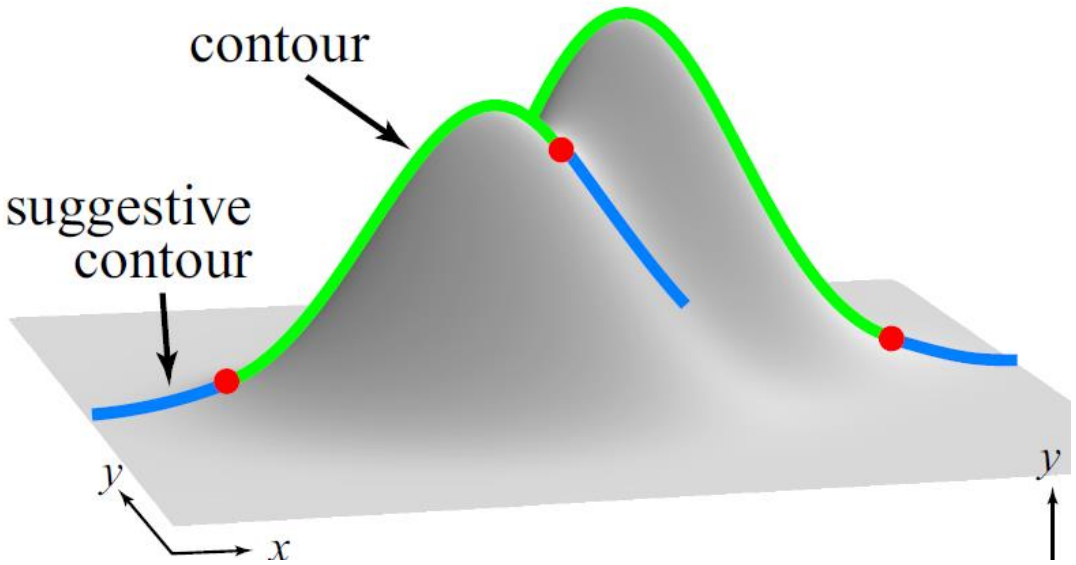
Occlusion contours

$n \cdot (p - O_{camera}) = 0$

How to find contours in the nearby views?

Suggestive contours

- Extend the occlusion contours



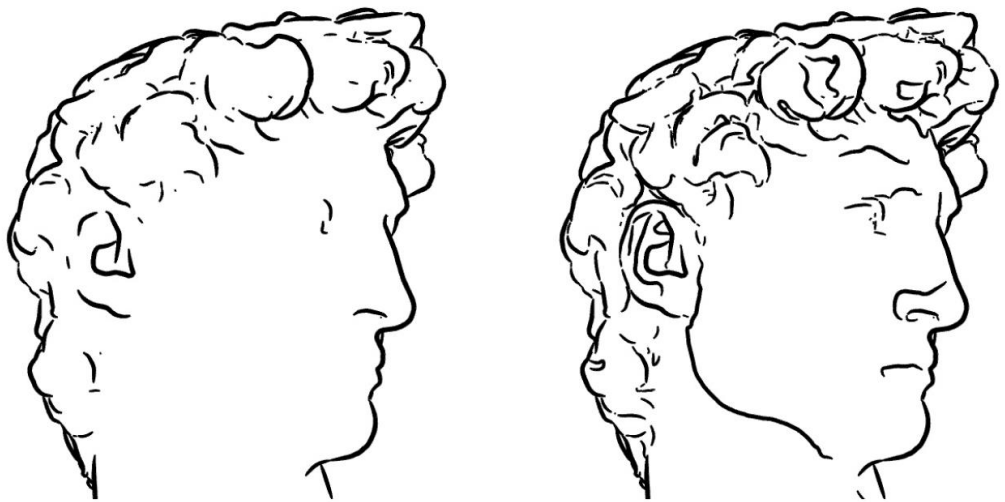
What lines should we render?

- Occlusion contours

$$n \cdot (p - O_{camera}) = 0$$

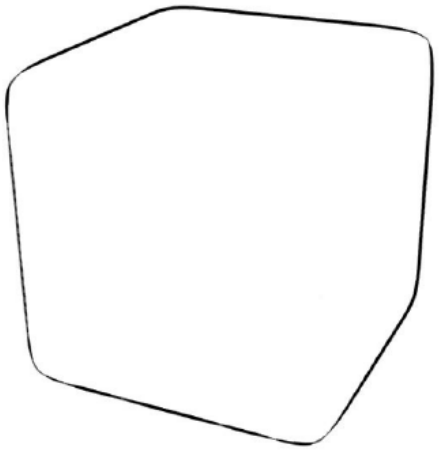
- Suggestive contours

$$\min_{p} n \cdot (p - O_{camera})$$



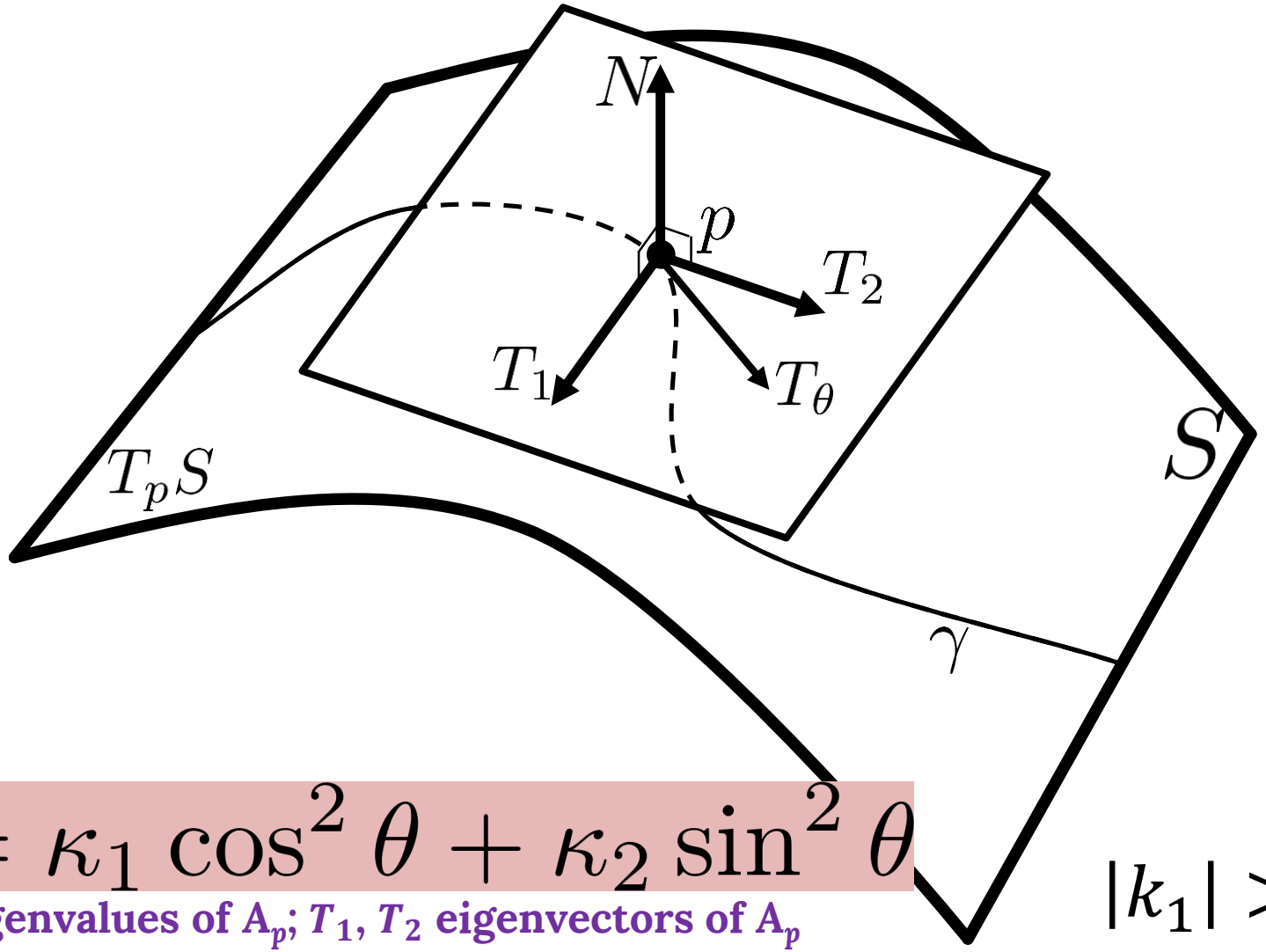
Not a universal tool

Objects without concavities don’t have suggestive contours



Recall:

Principal Directions and Curvatures



$$\kappa_\theta = \kappa_1 \cos^2\theta + \kappa_2 \sin^2\theta$$

κ_1, κ_2 eigenvalues of A_p; T_1, T_2 eigenvectors of A_p

$$|k_1| > |k_2|$$

Ridges and valleys

Extrema of principal curvature

$$\frac{\partial k_1}{\partial T_1} = 0$$

Ridges and valleys

Local max of $k_1 > 0$ **ridge**

Local min of $k_1 < 0$ **valley**

Recall:

Second Fundamental Form

$$DN_p : T_pS \to T_pS$$

$$A_p(V, W) := -\langle DN_p(V), W \rangle$$

"Shape operator"

Apparent Ridges

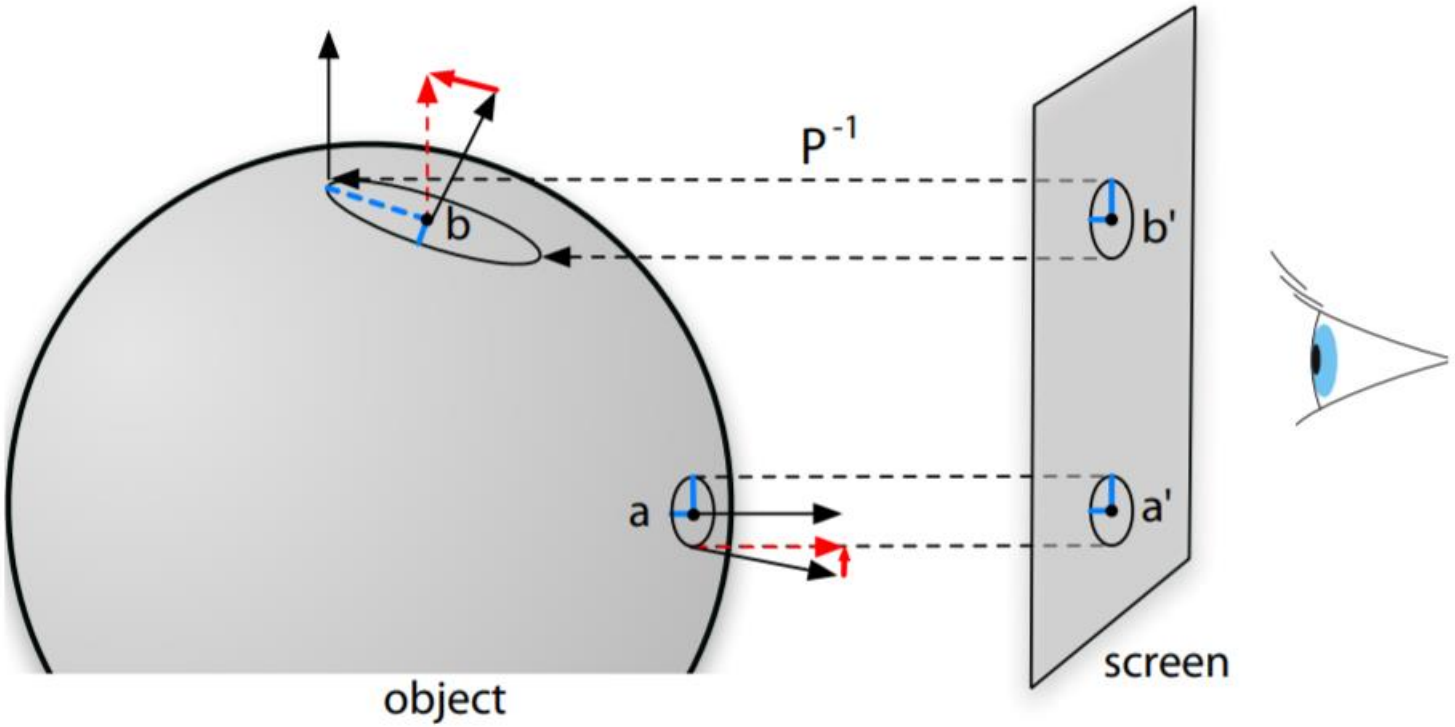


Figure 4: *The maximum view-dependent curvature at b' is much larger than at a' uniquely because of projection.*

Apparent Ridges

$$A'_{p(V,W)} = -\langle proj_{screen} DN_p(V), W \rangle$$

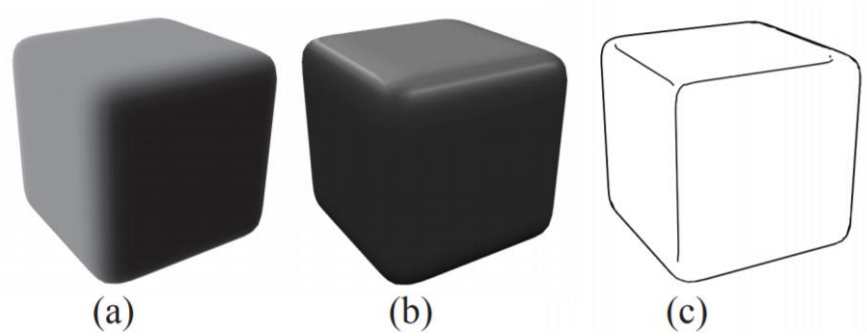


Figure 2: *Depiction of a cube with traditional computer graphics shading and with line drawing (using our apparent ridges).*

What lines do we draw?

Where Do People Draw Lines?

Forrester Cole, Aleksey Golovinskiy, Alex Limpaecher, Heather Stoddart Barros,
Adam Finkelstein, Thomas Funkhouser, and Szymon Rusinkiewicz

Princeton University

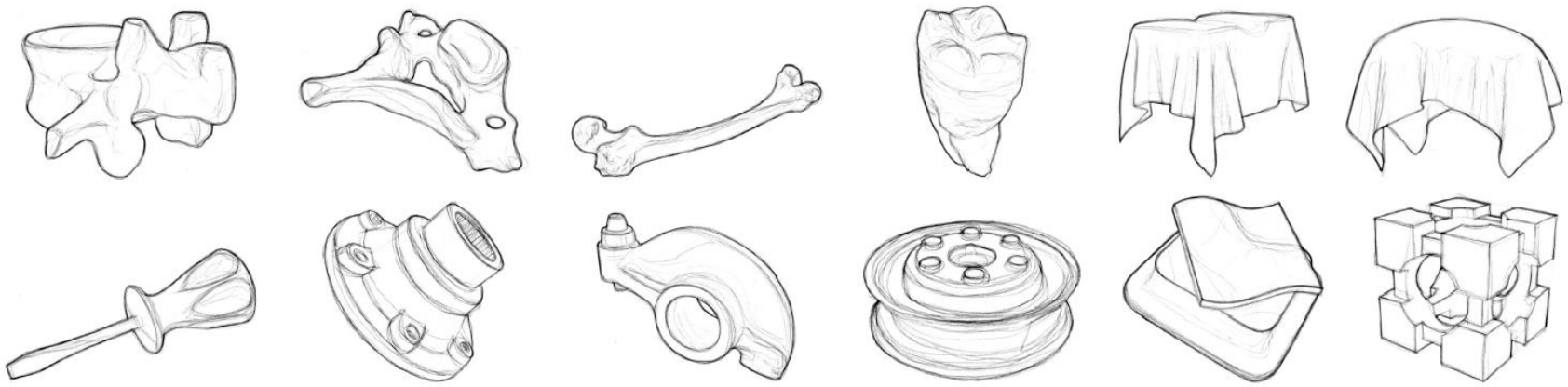
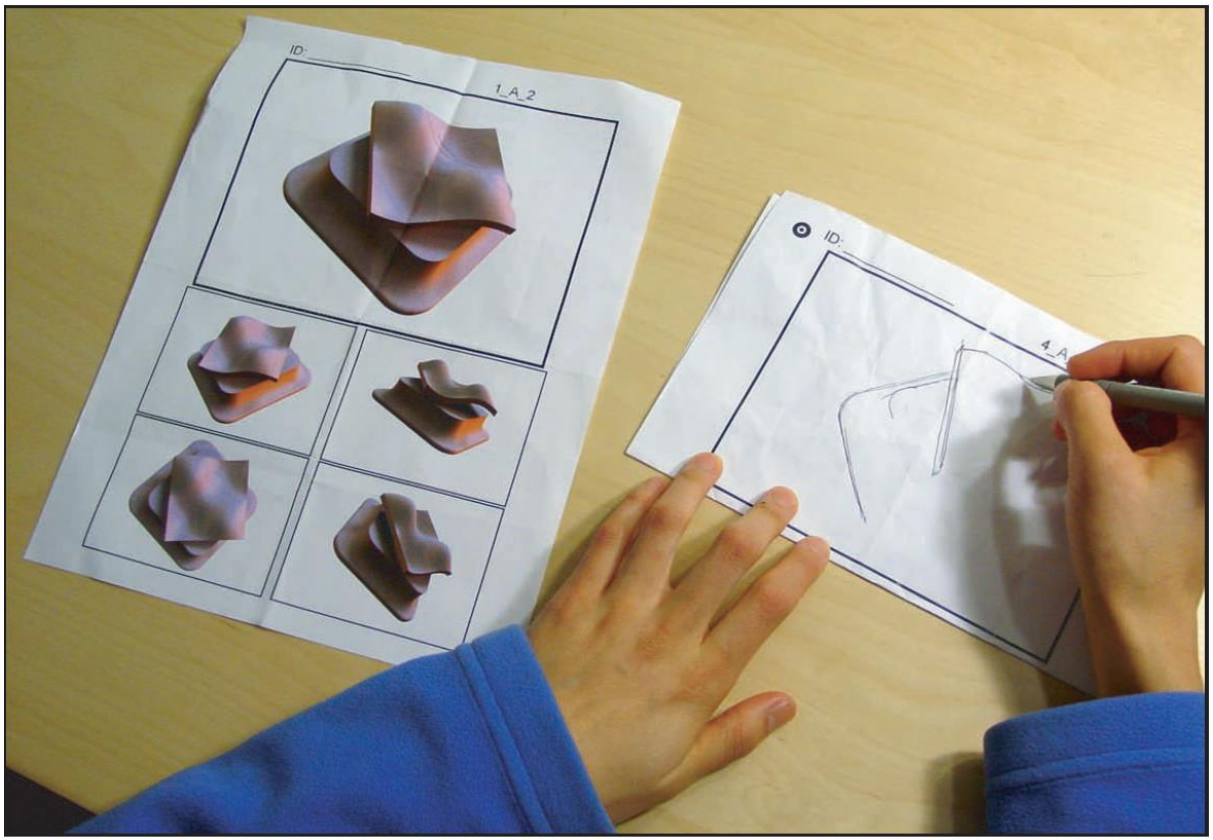
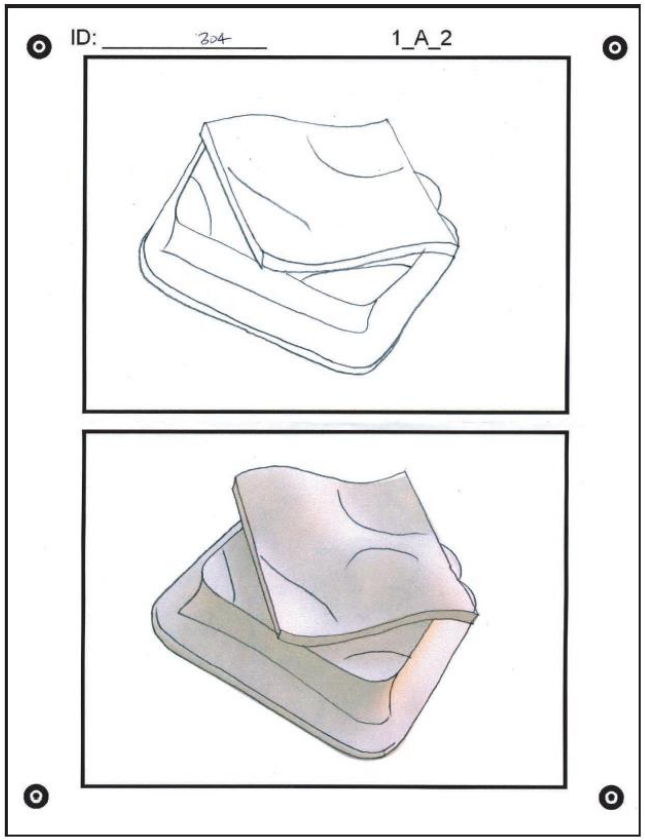


Figure 1: *Where people draw lines.* Average images composed of 107 drawings show where artists most commonly drew lines in our study.

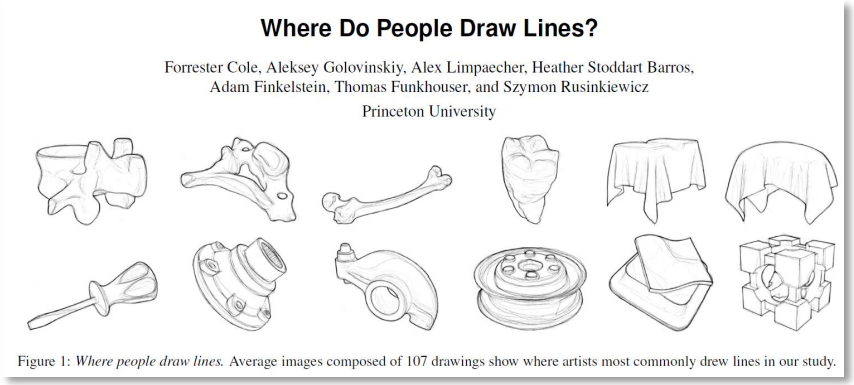
What lines do we draw?





What lines do we draw?

- Occlusion contours
- Suggestive contours
- Ridges and valleys
- Apparent ridges
- Feature lines



Where Do People Draw Lines?

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Princeton University

Figure 1: *Where people draw lines.* Average images composed of 107 drawings show where artists most commonly drew lines in our study.

Can you classify these lines?

Stats

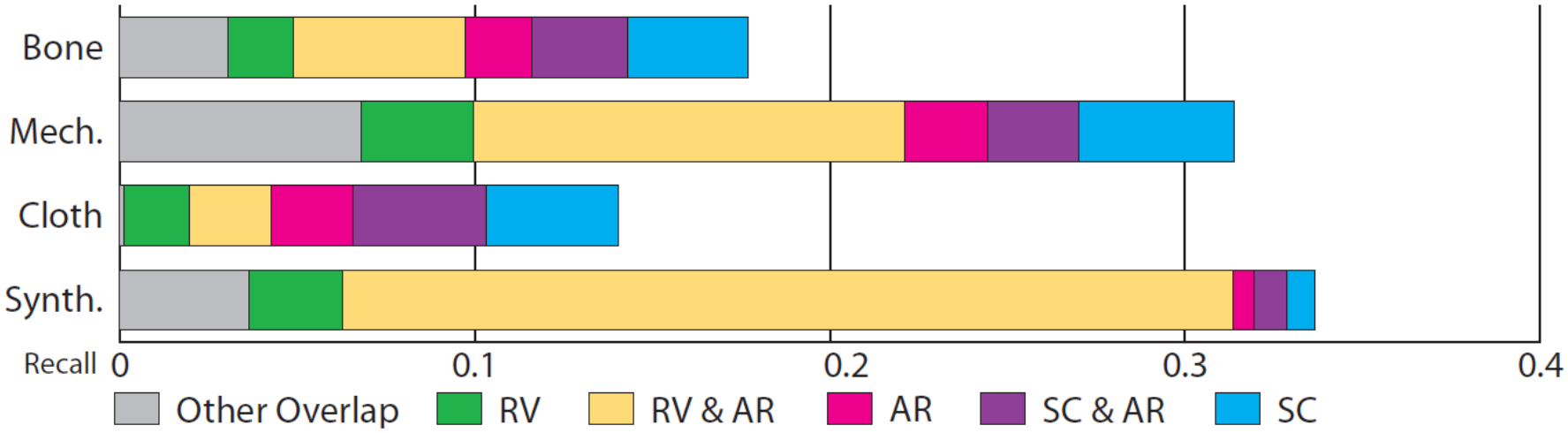


Figure 9: *Non-contour lines.* Categorization of artists' lines that are not exterior or interior occluding contours: geometric ridges and valleys (RV), apparent ridges (AR), suggestive contours (SC), and combinations.

If we can label the lines, can we reconstruct 3D?

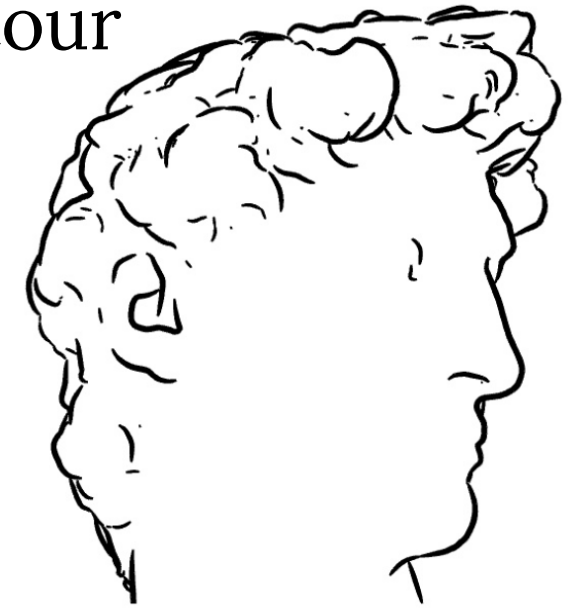
Issues

- Infinite # of 3D surfaces have the same 2D
- Drawings are approximate

Occlusion contours

$$n \cdot (p - O_{camera}) = 0$$

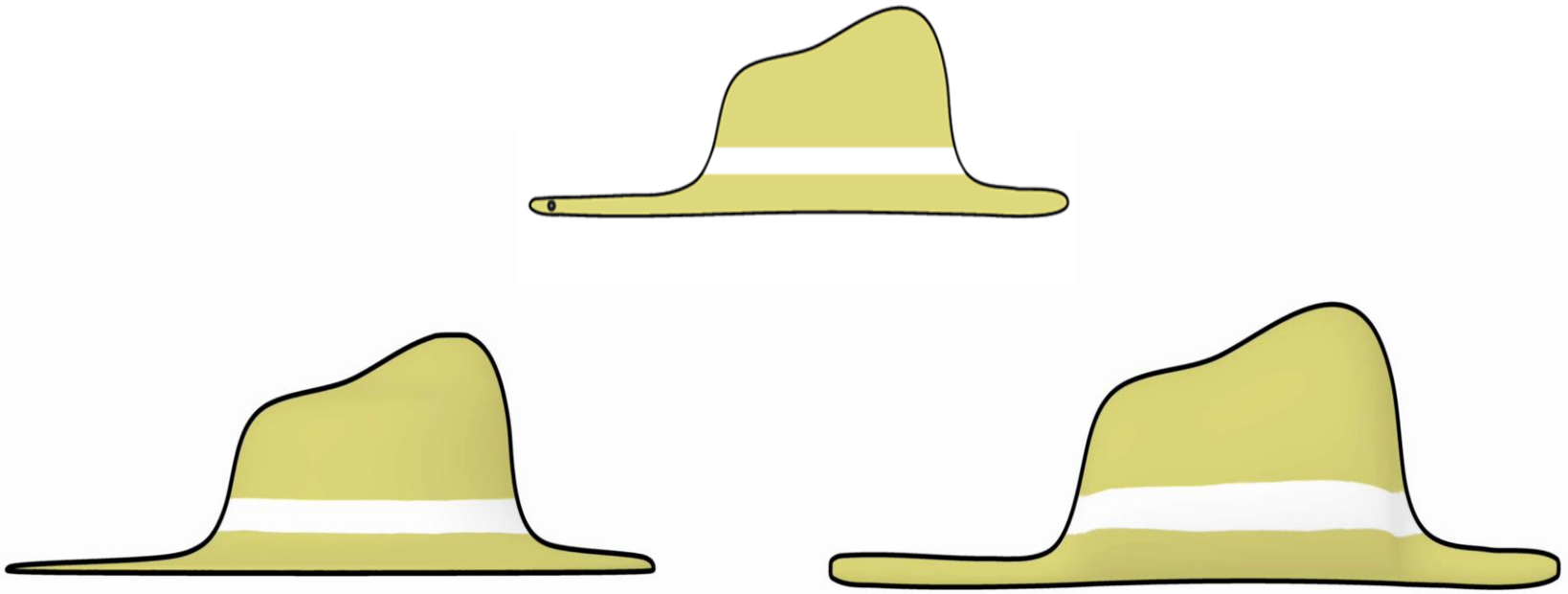
- *Contour generators* not parallel to the screen
- Sign of contour curvature = sign of Gaussian curvature
- Gaussian curvature around contour generators' endpoints < 0
- Depth discontinuities!



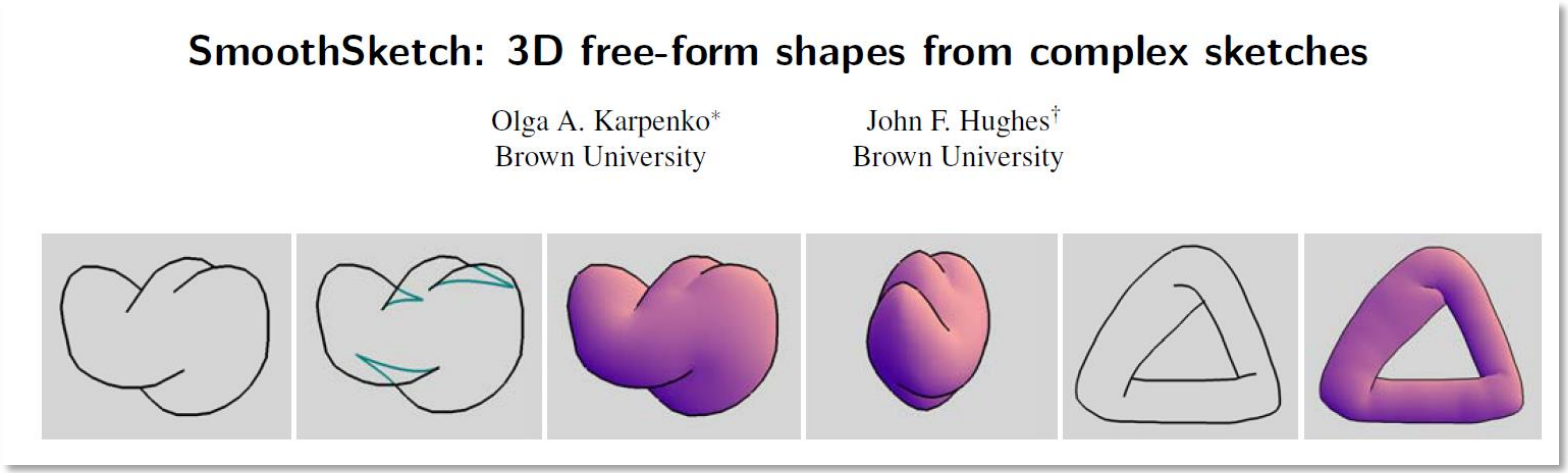
Occlusion contours

$$n \cdot (p - O_{camera}) = 0$$

Necessary, but not sufficient for shape recognition



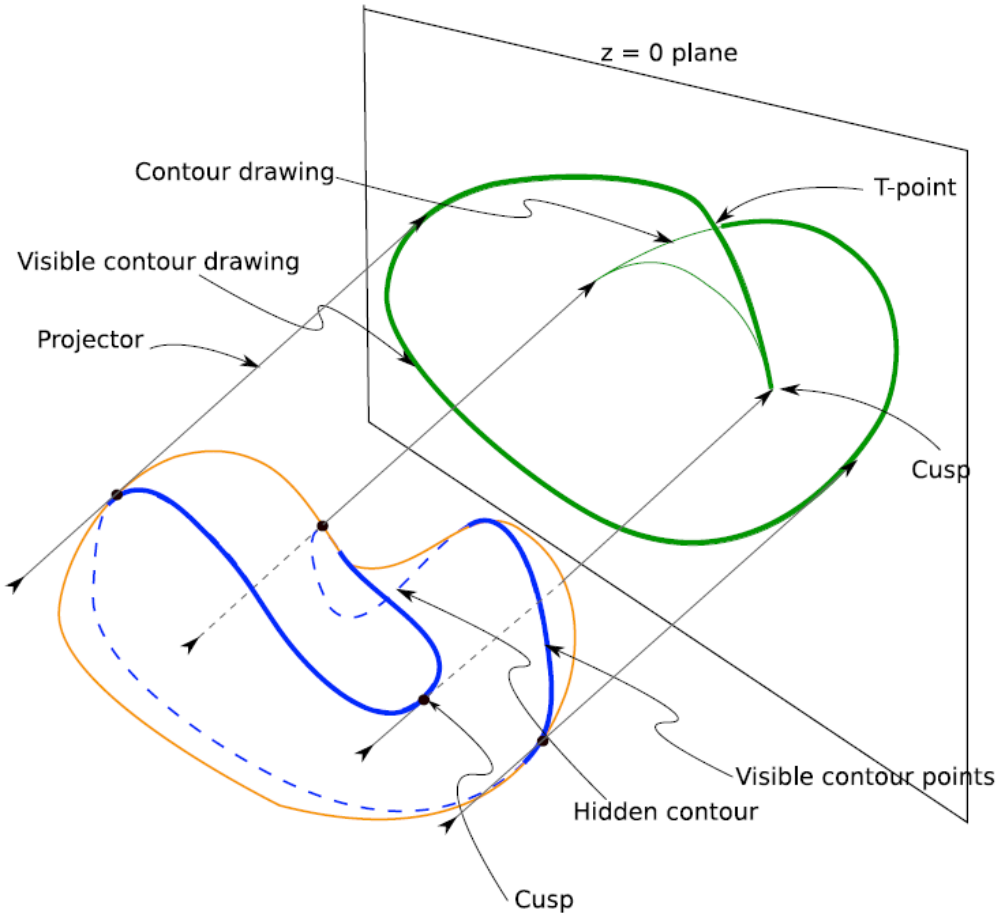
Completing Contours



We only see *visible* contours

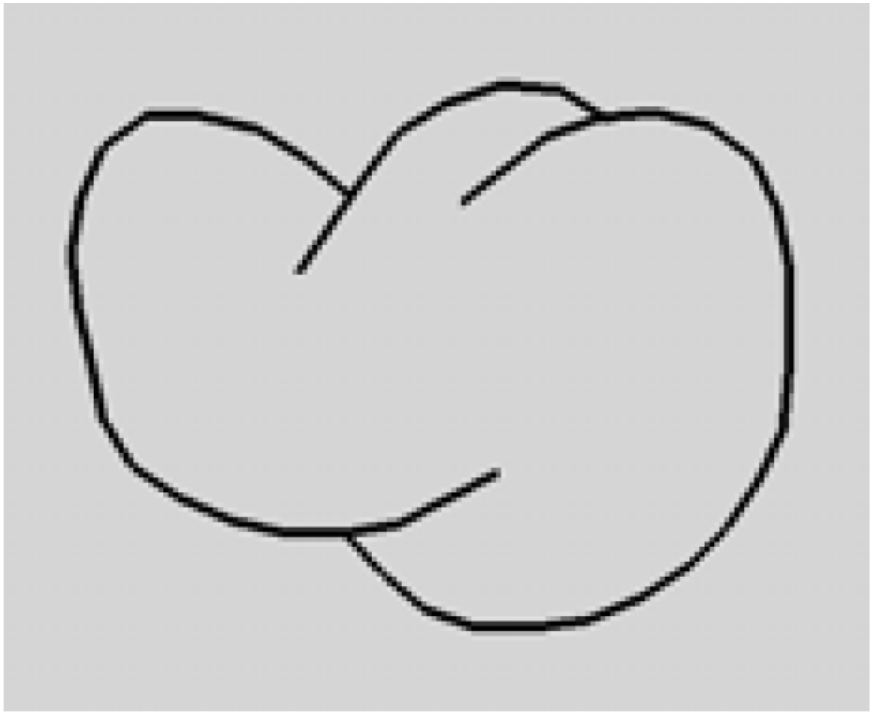
Complete into loops and inflate!

Completing Contours



Completing Contours

- Heuristics:
  - Measure some energy of Bézier curve



Completing Contours

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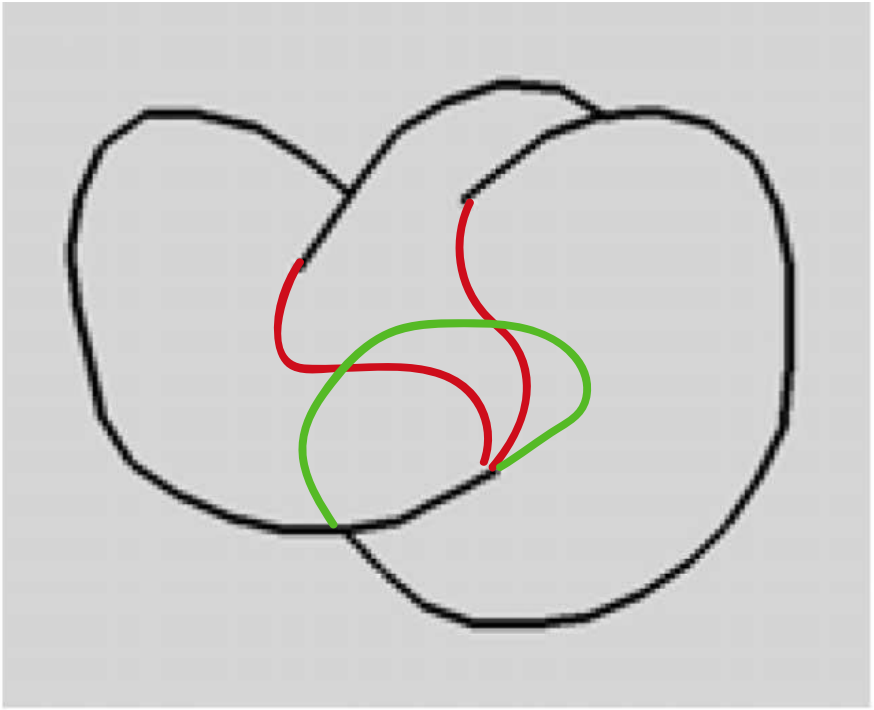
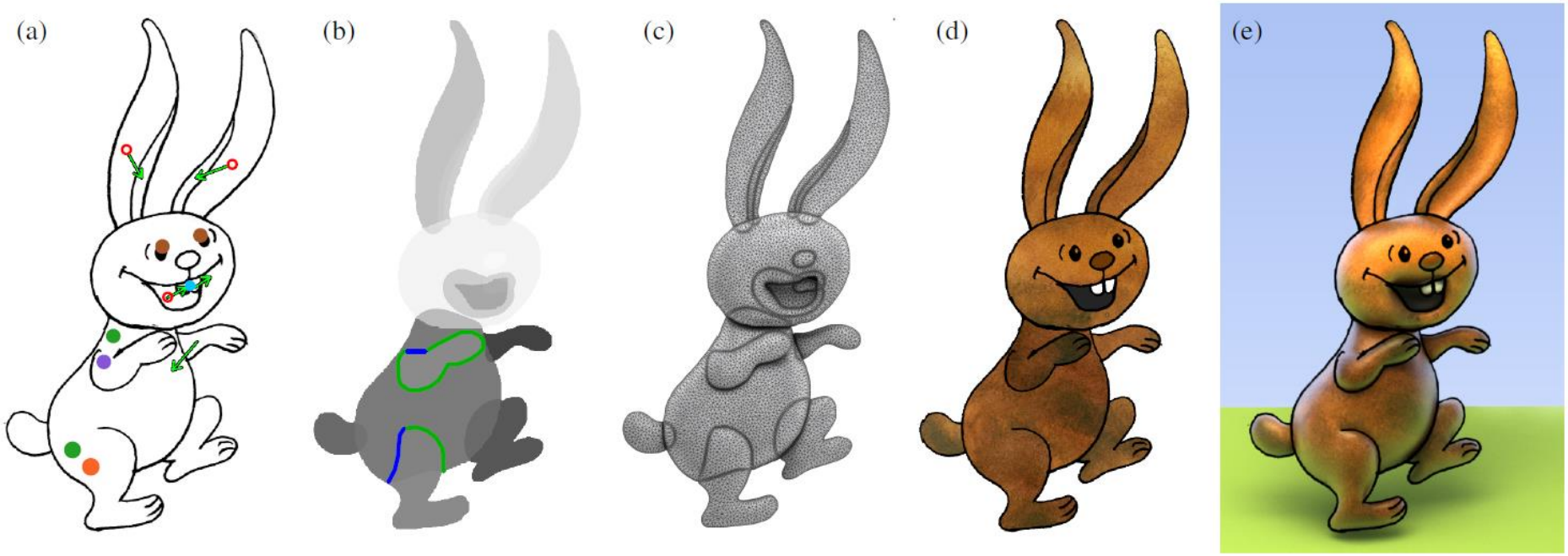


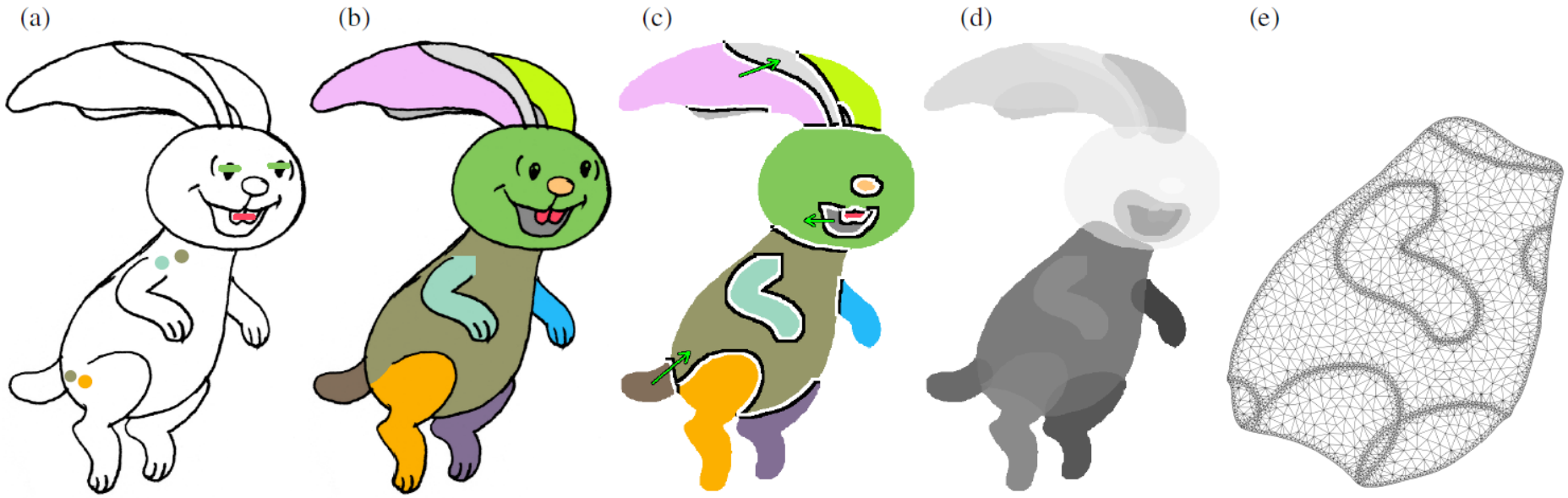
A simpler problem: illumination effects

A simpler problem: illumination effects

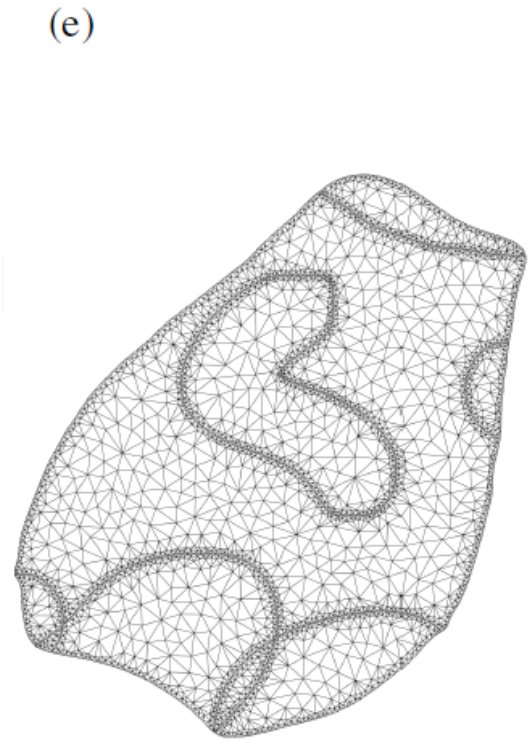


Preprocessing

- Complete all regions
- Find/ask user to specify depth order
- Constrained Delaunay Triangulation (CDT)



How to lift to 3D?



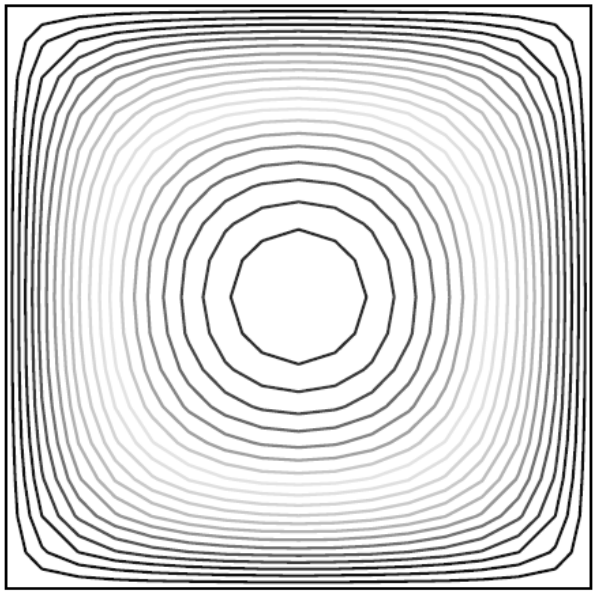
Idea

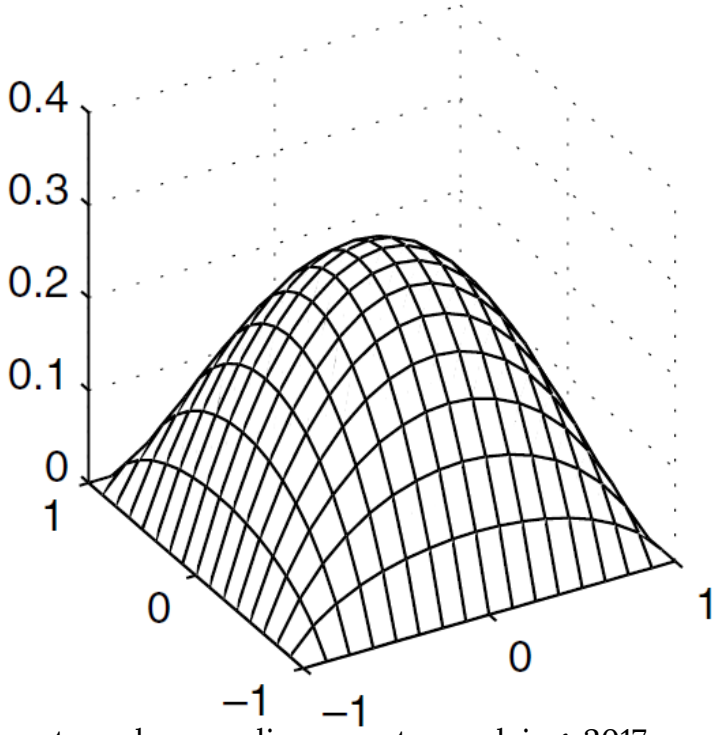
Steady-state heat equation
(with a heat source)

$$\Delta z_0 = a$$

$$z_0 \Big|_{\partial\Gamma} = 0$$

$a \in \mathbb{R}$

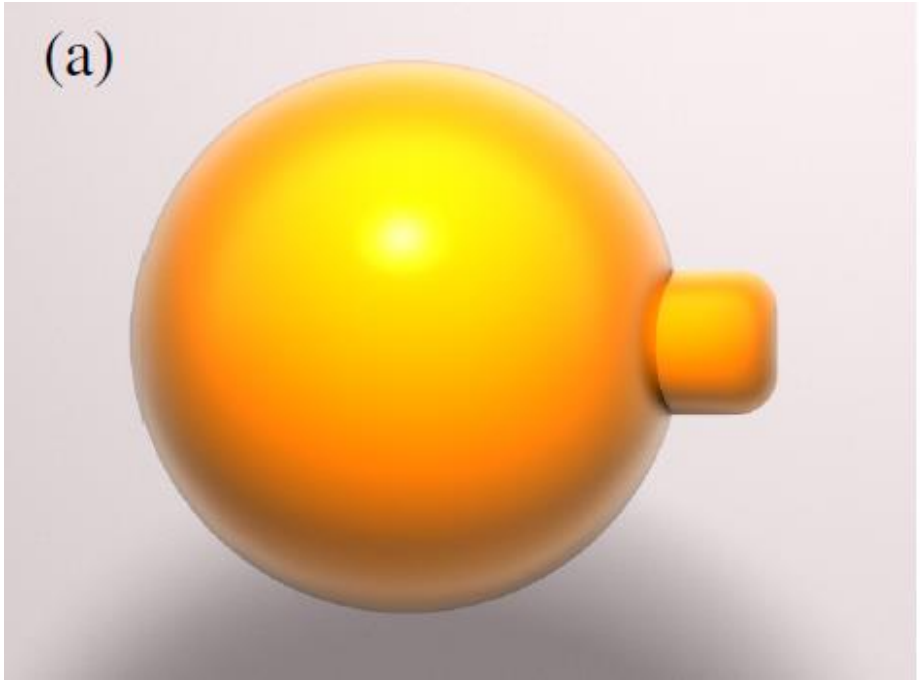




Prof. Dr. Peter Arbenz, Introduction to finite elements and sparse linear system solving, 2017

After inflation

- Each piece is centered around $z = 0$
- Need to use z-order! $z_1 < z_2$
- Need a smooth model



After inflation

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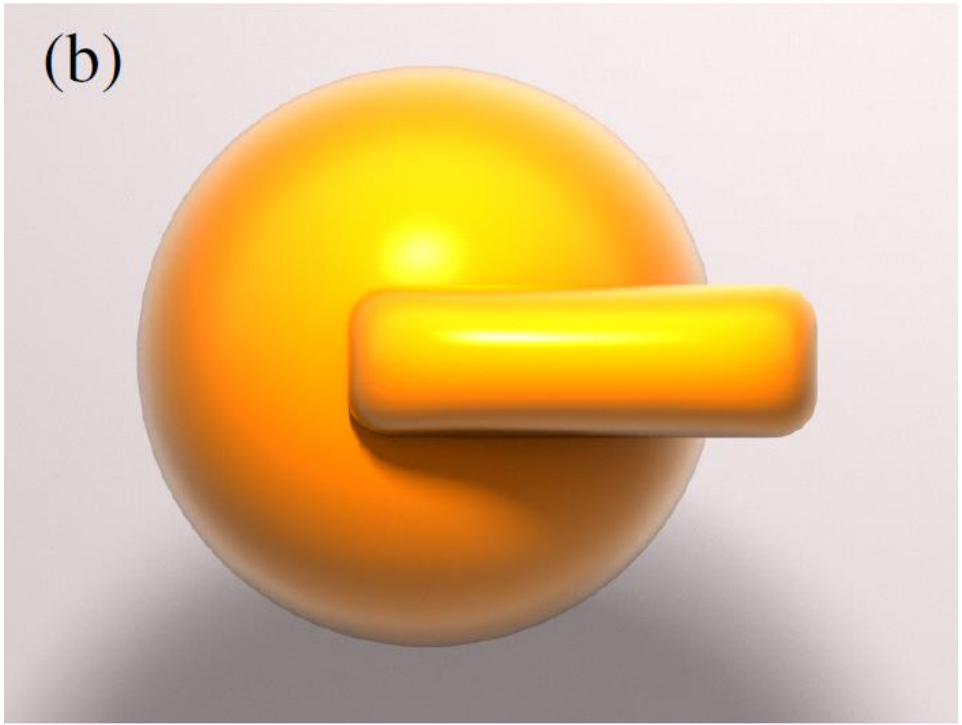
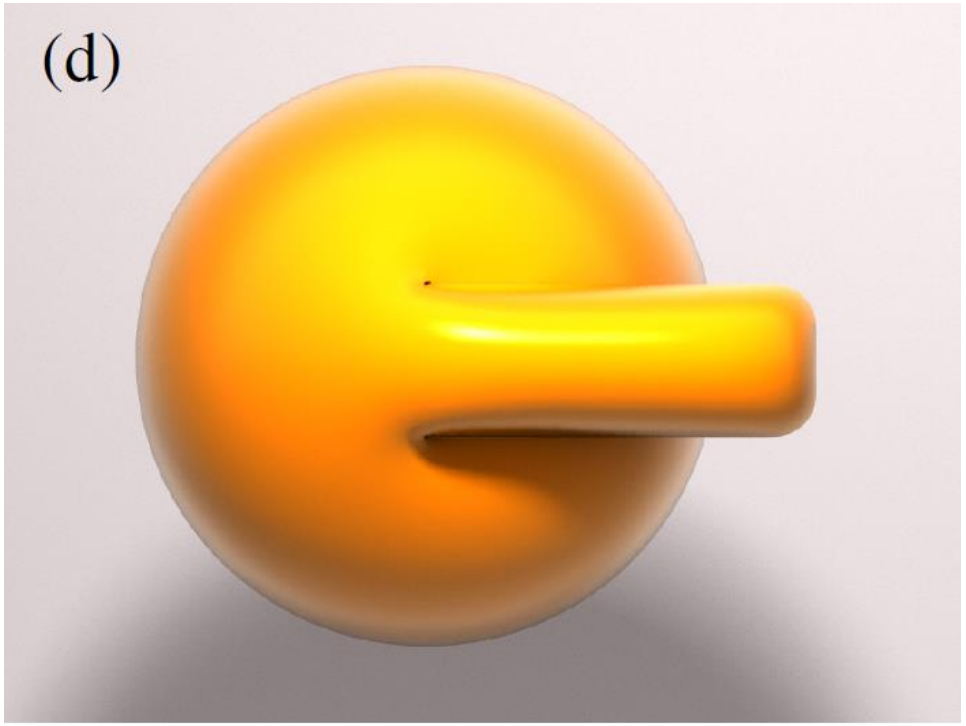


Smooth function?

$$z^i = z_0^i + g^i(x)$$

$$\min \int_\Omega \|\nabla g_i\|^2 dx$$

$$\text{s.t. } z_i < z_j$$



Cross-sections

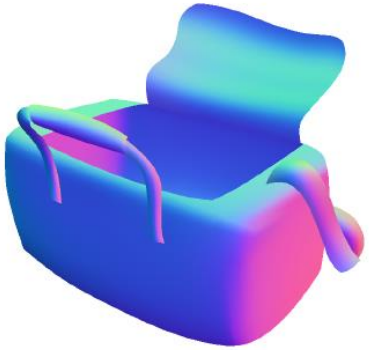
- Lines of curvature
- At intersections:
  - Orthogonal
  - Define a tangent plane
  - (often) belong to perpendicular planes

A simpler problem: shade?

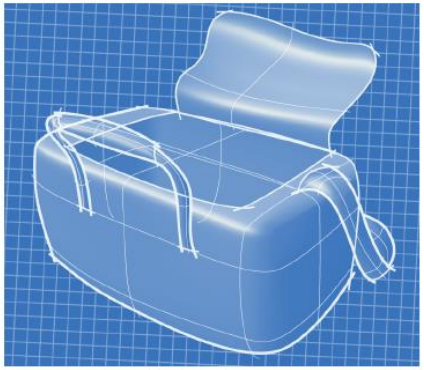
CrossShade: Shading Concept Sketches Using Cross-Section Curves

Cloud Shao[1*] Adrien Bousseau[2*] Alla Sheffer[3] Karan Singh[1]
[1] University of Toronto [2] REVES - INRIA Sophia Antipolis [3] University of British Columbia

(a) Input curves



(b) Estimated normals



(c) Shading

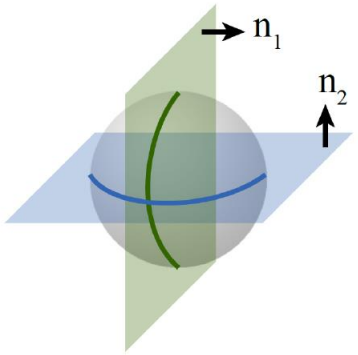
CrossShade

Find a normal field over the drawing

n_i: tangent plane normals

t_{ij}: tangents

$$\mathbf{n}_1 \cdot \mathbf{n}_2 = 0$$



CrossShade

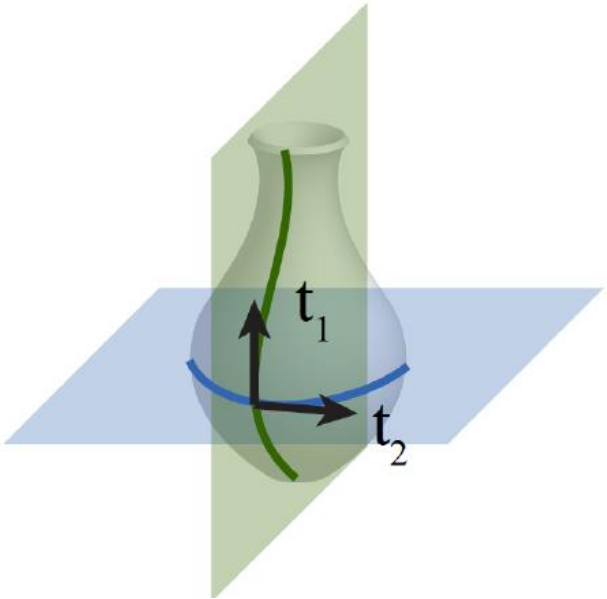
Find a normal field over the drawing

n_i: tangent plane normals

t_{ij}: tangents

$$\mathbf{n}_1 \cdot \mathbf{n}_2 = 0$$

$$\mathbf{t}_1 \cdot \mathbf{t}_2 = 0$$



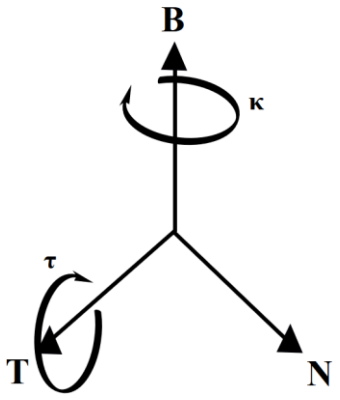
Cross-sections as curvature lines

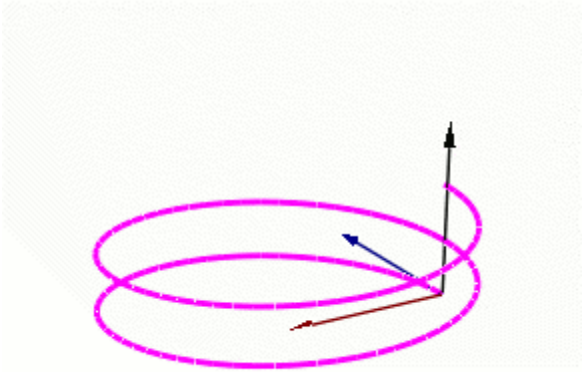
Recall:

Frenet Frame: Curves in $\mathbb{R}^3$

$$\frac{d}{ds}\begin{pmatrix} T \\ N \\ B \end{pmatrix} = \begin{pmatrix} 0 & \kappa & 0 \\ -\kappa & 0 & \tau \\ 0 & -\tau & 0 \end{pmatrix}\begin{pmatrix} T \\ N \\ B \end{pmatrix}$$

- **Binormal:** $\boldsymbol{T \times N}$
- **Curvature:** In-plane motion
- **Torsion:** Out-of-plane motion





Recall:

Intuition

$$\text{proj}_{T_{\gamma(s)}S}\left[\gamma''(s)\right] = 0$$

- **The only acceleration is out of the surface**
  - **No steering wheel!**

CrossShade

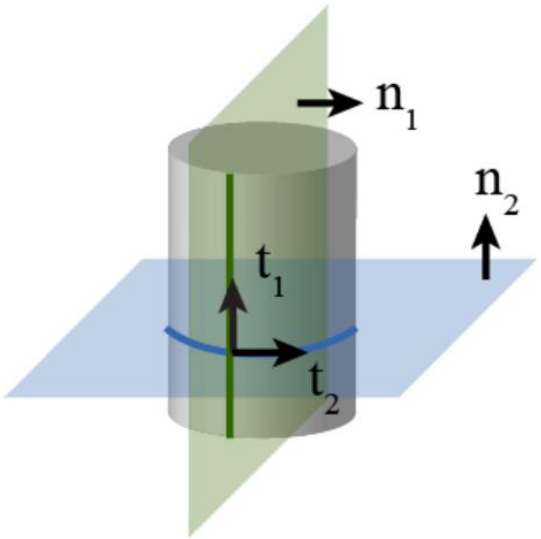
Find a normal field over the drawing

n_i: tangent plane normals

t_{ij}: tangents

$$t_1 \times n_2 = 0$$

$$t_2 \times n_1 = 0$$



Geodesics?

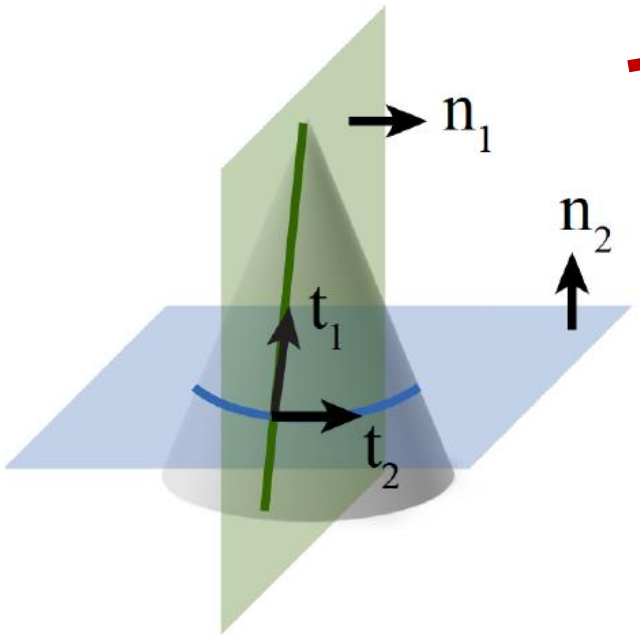
"humans perceive intersecting cross-section curves as geodesics"

CrossShade

Find a normal field over the drawing

n_i: tangent plane normals

t_{ij}: tangents

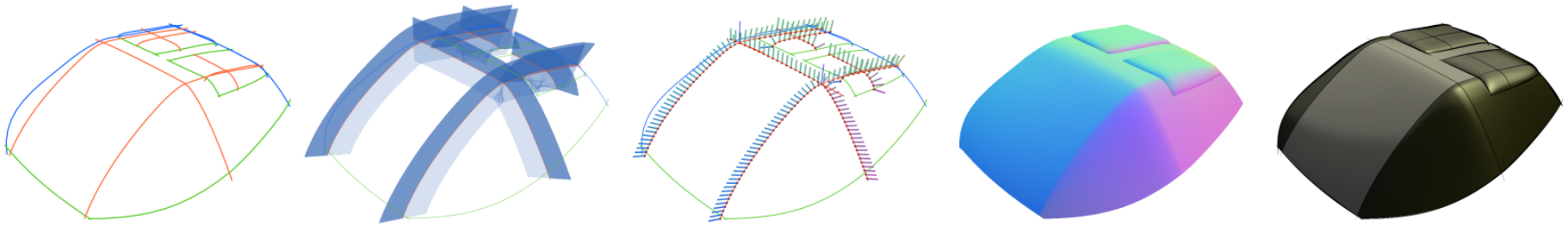


~~$t_1 \times n_2 = 0$~~

$t_2 \times n_1 = 0$

At least one is
a geodesic

CrossShade: overview

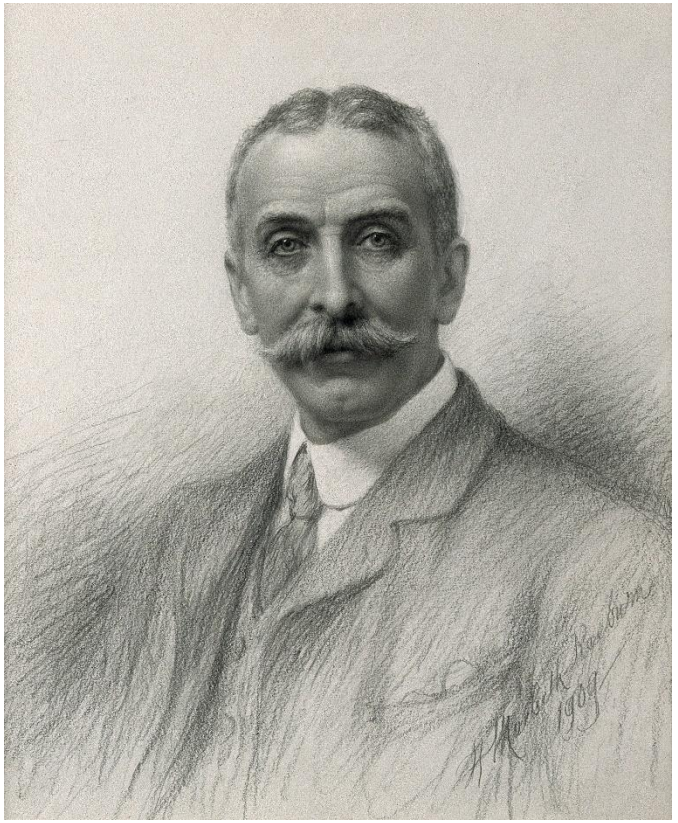


(a) Input curves (b) Estimated curve planes (c) Normals along curves (d) Normals over the sketch (e) Resulting shading

Figure 4: *Our algorithm takes as input an annotated sketch (a). Orange curves denote cross-sections, blue curves represent smooth silhouettes, and green curves correspond to other object boundaries. We first optimize for the supporting plane of each cross-section and compute the 3C cross-sections based on those (b). We use the resulting 3D curves to compute 3D normals at each intersection and interpolate normals along the curves (c). We finally generate a normal field in between the curves using Coons' interpolation (d).*

Shading/Hatching

- Approximates actual surface shading?
- Assume a shading model
  - E.g. Lambertian
- How to get illuminance per point?
- Shape from shading



Edward Law. Pencil drawing by H. M. Raeburn, 1909

Concave or convex?

M.C. Escher, "Concave and convex"

Shape priors

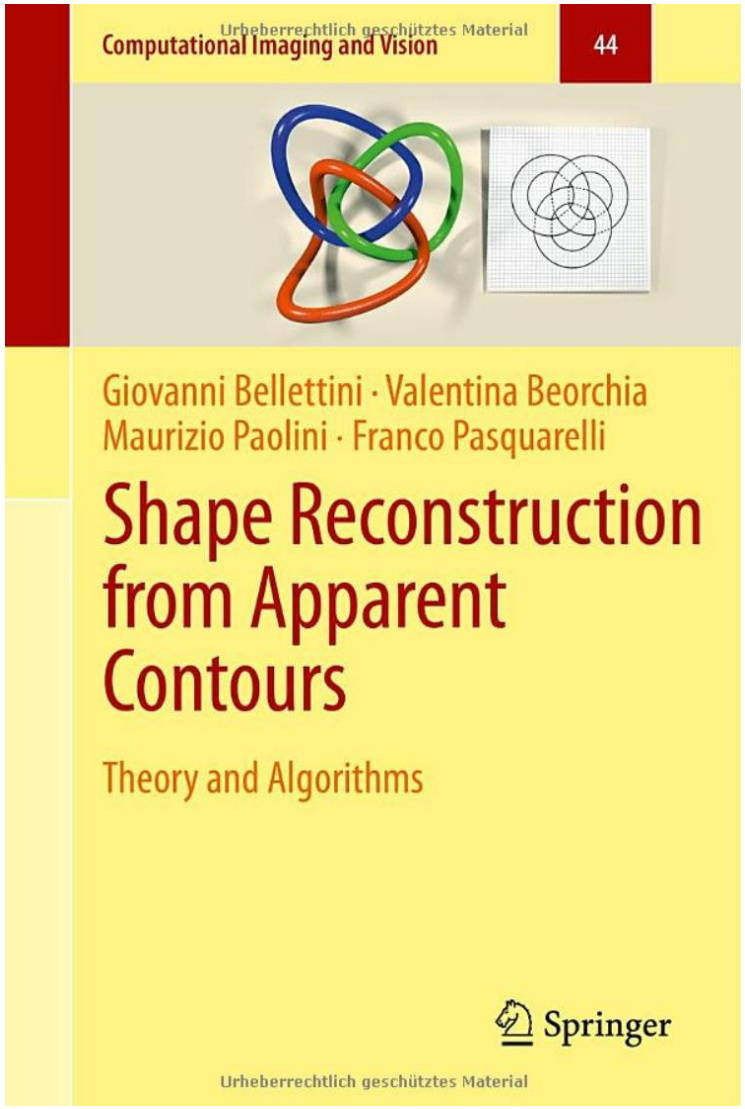
- Developability?
  - Garments
- Geometric primitives
  - Spheres, cylinders,...

Shape representations

- Meshes
- Generalized cylinders
- Bézier
- NURBS
- ...

A rigorous approach

Only for smooth shapes



Junctions

- Local depth depth order!

What to do with hidden parts?

- Use continuity
- Use symmetry
- Use anatomical priors?

Symmetry

Computers & Graphics 46 (2015) 221–230

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/cag

SMI 2014

Modeling 3D animals from a side-view sketch

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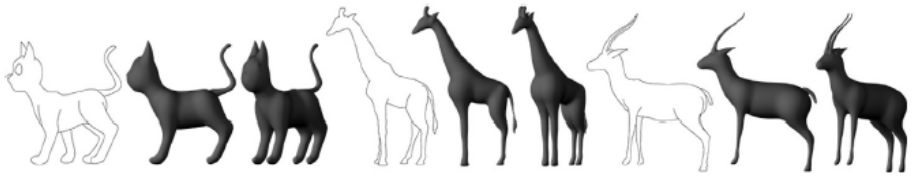
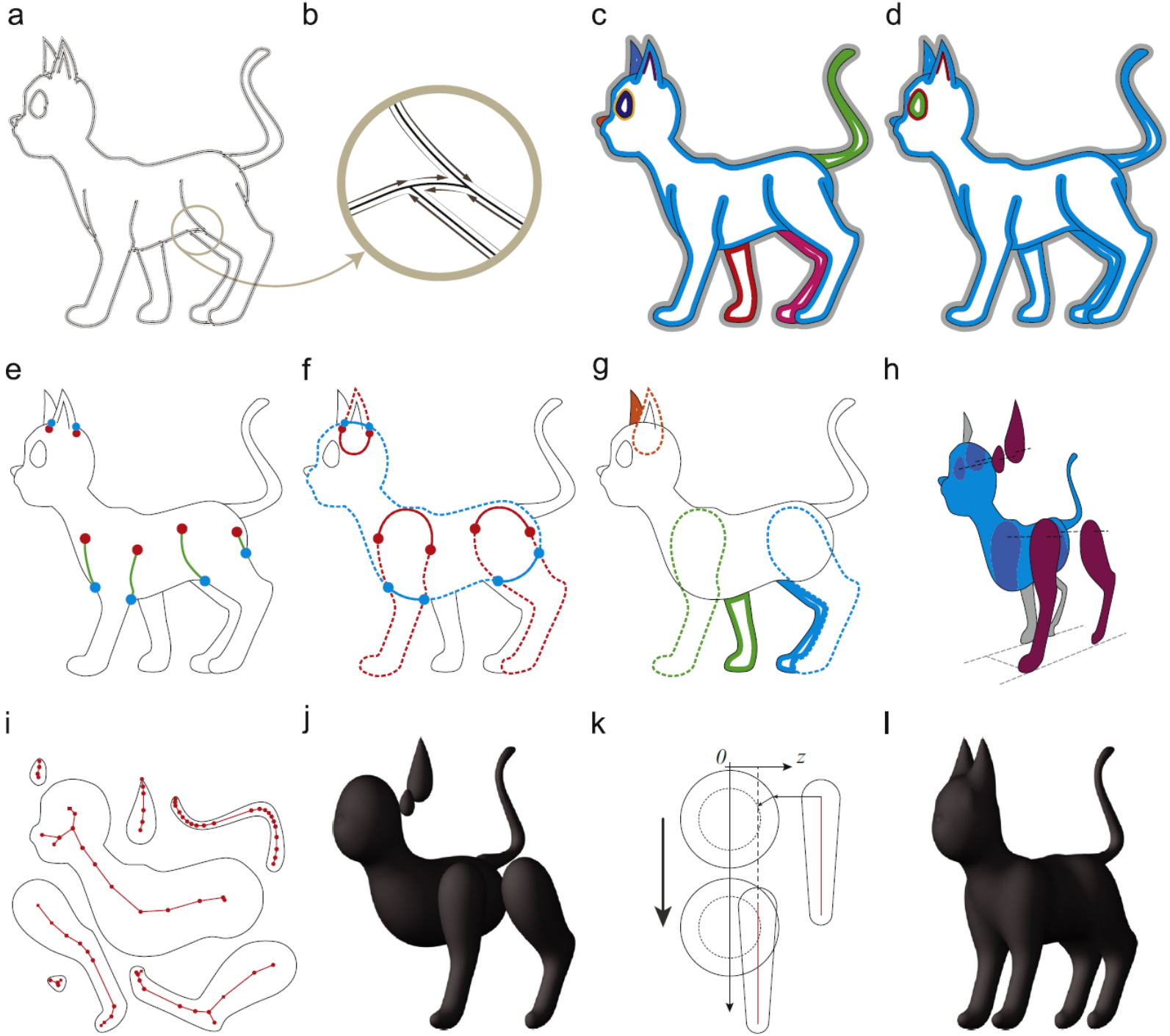
ABSTRACT

Using 2D contour sketches as input is an attractive solution for easing the creation of 3D models. This paper tackles the problem of creating 3D models of animals from a single, side-view sketch. We use the *a priori* assumptions of smoothness and structural symmetry of the animal about the sagittal plane to inform the 3D reconstruction. Our contributions include methods for identifying and inferring the contours of shape parts from the input sketch, a method for identifying the hierarchy of these structural parts including the detection of approximate symmetric pairs, and a hierarchical algorithm for positioning and blending these parts into a consistent 3D implicit-surface-based model. We validate this pipeline by showing that a number of plausible animal shapes can be automatically constructed from a single sketch.



Symmetry



Animation: Line of Action

The Line of Action: an Intuitive Interface for Expressive Character Posing

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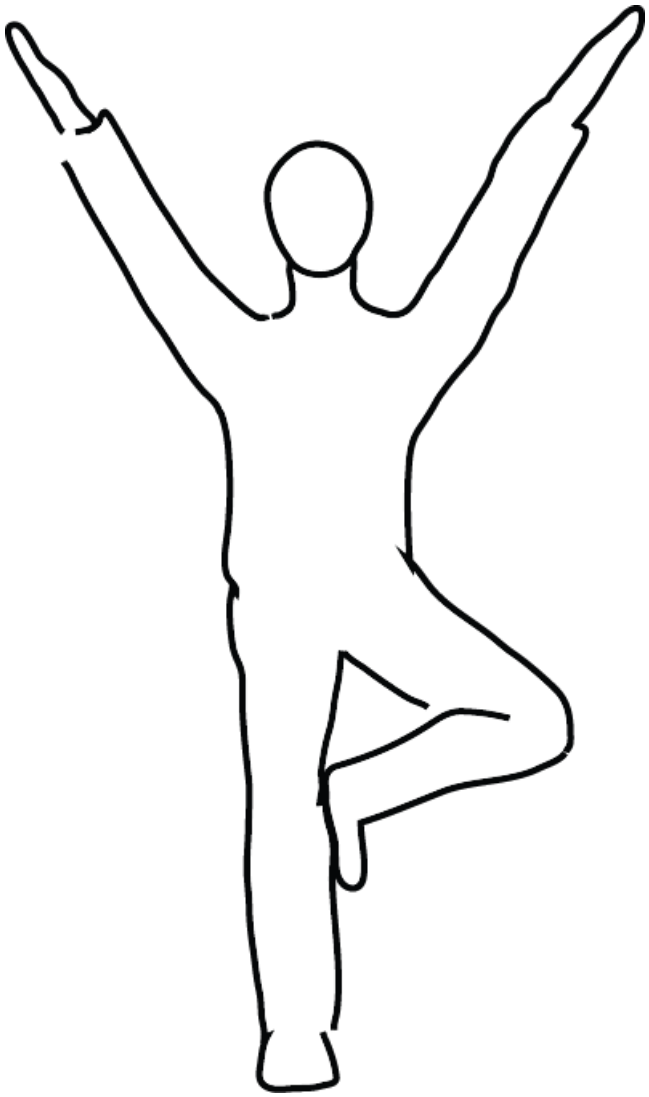
Figure 1: *Expressive character poses created in a few seconds each, by sketching intuitive lines of action.*

Animation: Line of Action

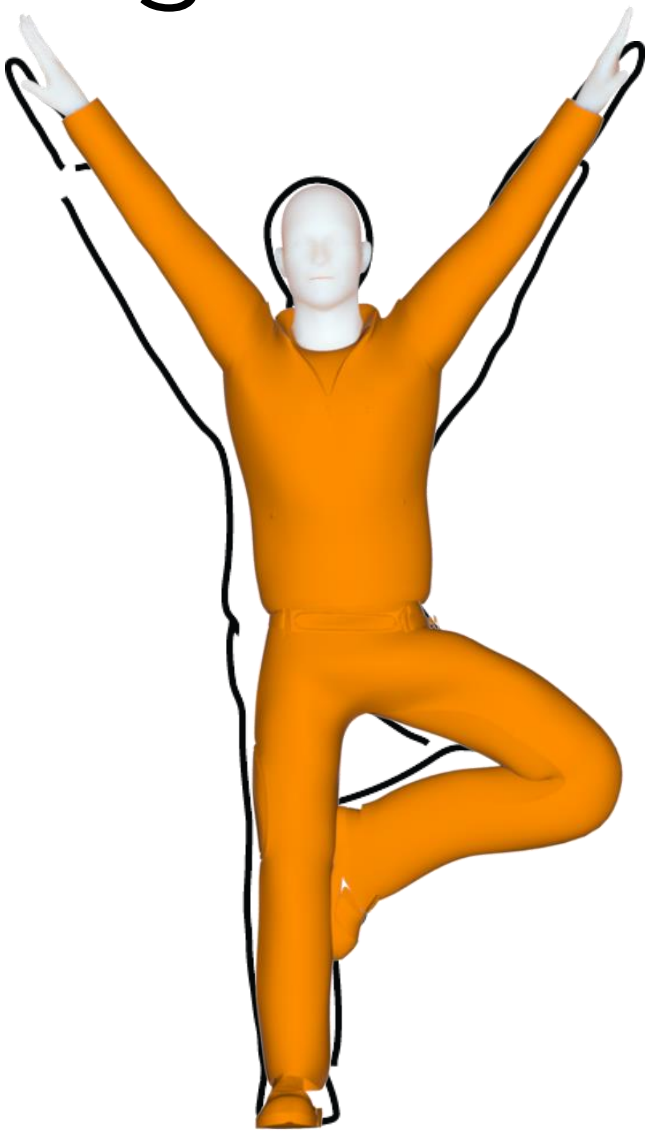
- Assume we know which bones
- Joint x, y positions should be along the LOA
  - Where along LOA?
- More importantly, bones should be parallel to LOA
- Need curve – bone chain correspondence!

Drawings are inexact



Bessmeltsev et al., Gesture 3D: Posing 3D Characters via Gesture Drawings, SIGGRAPH 2016

Drawings are inexact



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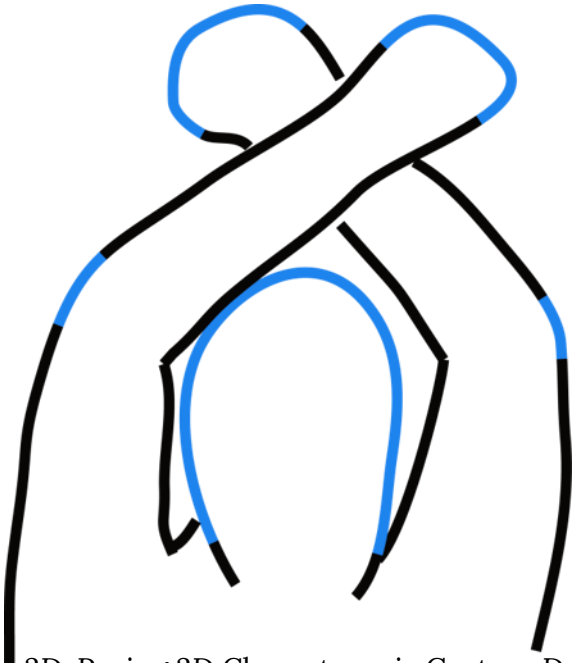
2D embedding

Low-curvature lines ~ body parts

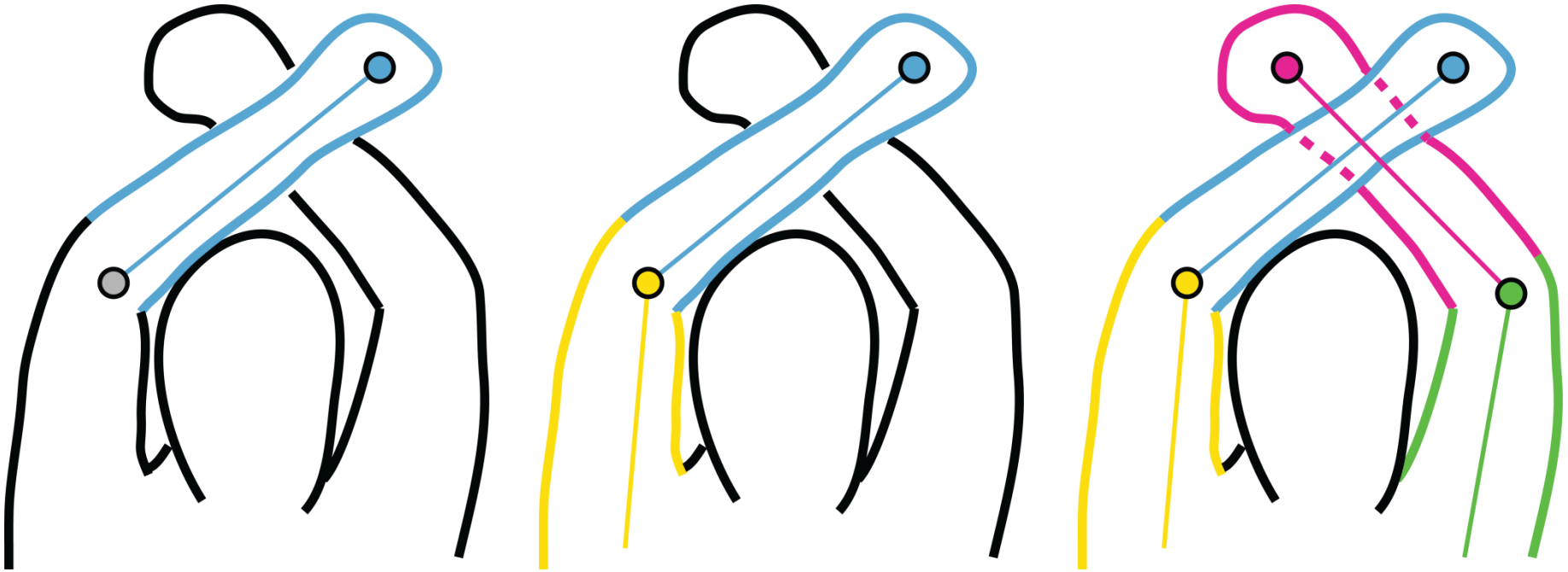
Circular contours ~ joints



Bessmeltsev et al., Gesture 3D: Posing 3D Characters via Gesture Drawings, SIGGRAPH 2016

2D embedding

Adjacencies



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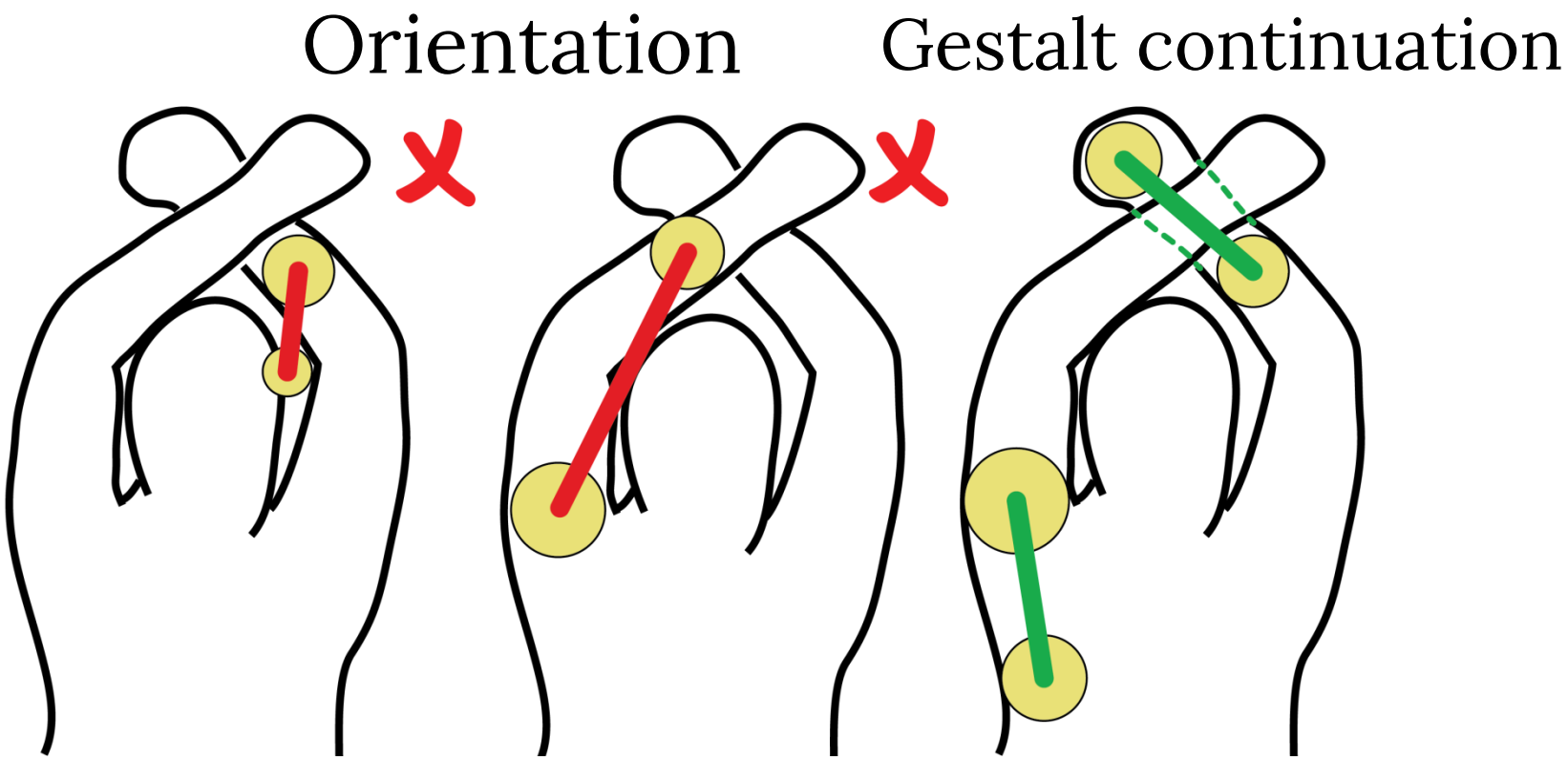
2D embedding



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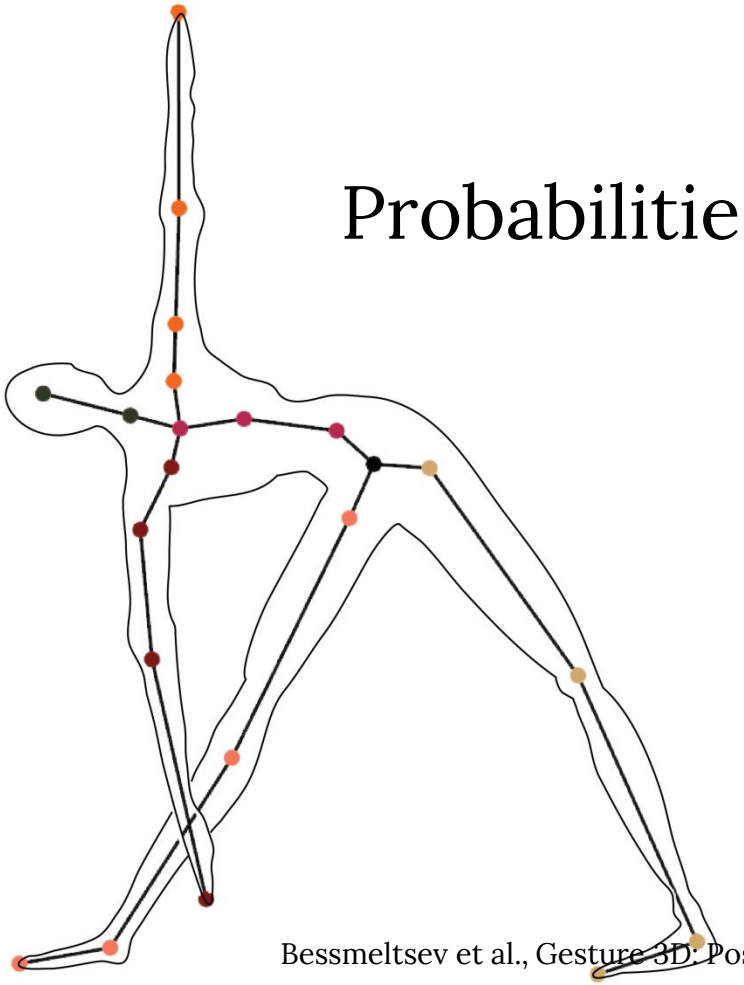
2D embedding

Input: rigged character + gesture drawing



Probabilities of joint and bone locations

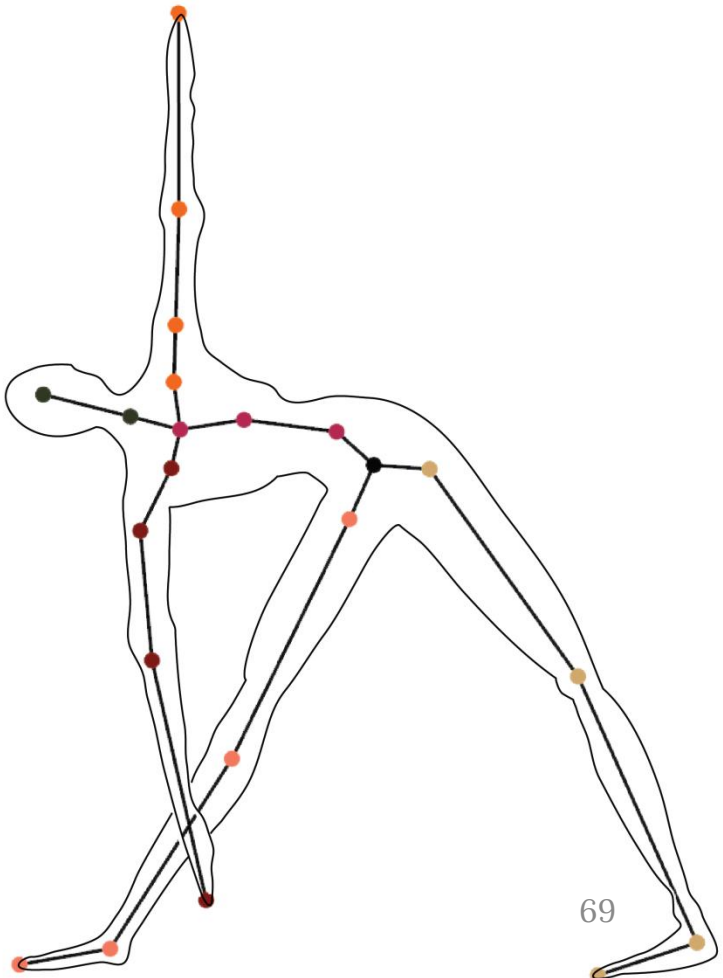
Discrete optimization

Bessmeltsev et al., Gesture 3D: Posing 3D Characters via Gesture Drawings, SIGGRAPH 2016

3D optimization

Balance 2D embedding with

- Simplicity
- Foreshortening cues



3D optimization

Balance 2D embedding with

- Simplicity
- Foreshortening cues

- Depth order from T-Junctions

Answering your question: yes

3D Sketching using Multi-View Deep Volumetric Prediction

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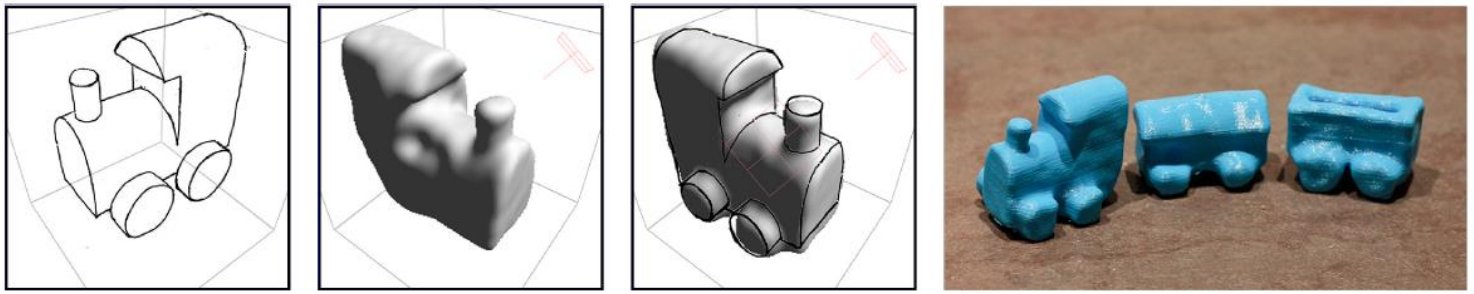

a) Initial drawing | b) 3D prediction seen from another viewpoint | c) New drawing and updated prediction | d) 3D printed objects

Figure 1: Our sketch-based modeling system can process as little as a single perspective drawing (a) to predict a volumetric object (b). Users can refine this prediction and complete it with novel parts by providing additional drawings from other viewpoints (c). This iterative sketching workflow allows quick 3D concept exploration and rapid prototyping (d).

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Sketches are messy

and often in bitmap format

- Reconstruct directly
  - Probably ML/DL?
- Vectorize
- Simplify

Sketches are messy

and often in bitmap format