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

Mikhail Bessmeltsev
Motivation

30x speed

© ARTV Tutorials
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

\[ n \cdot (p - o_{\text{camera}}) = 0 \]
What lines should we render?

Occlusion contours

\[ n \cdot (p - O_{\text{camera}}) = 0 \]
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
  \[ n \cdot (p - O_{\text{camera}}) = 0 \]
- Suggestive contours
  \[ \min_{p} n \cdot (p - O_{\text{camera}}) \]
Not a universal tool

Objects without concavities don’t have suggestive contours
Recall: Principal Directions and Curvatures

\[ \kappa_\theta = \kappa_1 \cos^2 \theta + \kappa_2 \sin^2 \theta \]

\( \kappa_1, \kappa_2 \) eigenvalues of \( A_p \); \( T_1, T_2 \) eigenvectors of \( A_p \)
Ridges and valleys

Extrema of principal curvature

\[ \frac{\partial k_1}{\partial T_1} = 0 \]
Ridges and valleys

Local max of $k_1 > 0$ \textcolor{blue}{ridge}

Local min of $k_1 < 0$ \textcolor{red}{valley}
Recall:

Second Fundamental Form

\[ DN_p : T_p S \rightarrow T_p S \]

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

“Shape operator”
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
Can you classify these lines?
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

\[ n \cdot (p - o_{\text{camera}}) = 0 \]

**Necessary, but not sufficient**

for shape recognition
Completing Contours

SmoothSketch: 3D free-form shapes from complex sketches

Olga A. Karpenko
Brown University

John F. Hughes
Brown University

We only see visible contours
Complete into loops and inflate!
Completing Contours

Diagram showing contour drawing, visible contour drawing, projector, T-point, cusp, z = 0 plane, visible contour points, and hidden contour.
Completing Contours

- Heuristics:
  - Measure some energy of Bézier curve
Completing Contours

- Heuristics:
  - Measure some energy of Bézier curve
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)

\[ \Delta z_0 = a \]

\[ z_0 \bigg|_{\partial \Gamma} = 0 \]

\[ a \in \mathbb{R} \]
After inflation

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

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

\[ z^i = z_0^i + g^i(x) \]

\[ \min \int_{\Omega} \| \nabla g_i \|^2 dx \]

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\textsuperscript{1*}  
\textsuperscript{1} University of Toronto

Adrien Bousseau\textsuperscript{2*}  
\textsuperscript{2} REVES - INRIA Sophia Antipolis

Alla Sheffer\textsuperscript{3}  
\textsuperscript{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

\[ n_1 \cdot n_2 = 0 \]
CrossShade

Find a normal field over the drawing

\( n_i \): tangent plane normals

\( t_{ij} \): tangents

\[
\begin{align*}
n_1 \cdot n_2 &= 0 \\
t_1 \cdot t_2 &= 0
\end{align*}
\]

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**: $T \times N$
- **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

\[
\begin{align*}
  t_1 \times n_2 &= 0 \\
  t_2 \times n_1 &= 0
\end{align*}
\]

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

At least one is a geodesic

\[
\begin{align*}
\mathbf{t}_1 \times \mathbf{n}_2 &= 0 \\
\mathbf{t}_2 \times \mathbf{n}_1 &= 0
\end{align*}
\]
CrossShade: overview

**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


Contents lists available at ScienceDirect
Computers & Graphics
journal homepage: www.elsevier.com/locate/cag

SMI 2014

Modeling 3D animals from a side-view sketch

Even Entem a,b,*, Loic Barthe a, Marie-Paule Cani b, Frederic Cordier c, Michiel van de Panne d

a IRIT - University of Toulouse, France
b University of Grenoble-Alpes, CNRS (Laboratoire Jean Kuntzmann) and Inria, France
c University of Haute Alsace, France
d University of British Columbia, Canada

A R T I C L E I N F O

Article history:
Received 8 July 2014
Received in revised form 29 September 2014
Accepted 29 September 2014
Available online 8 October 2014

Keywords:
Implicit modelling
Sketch-based modelling
Organic shapes
Direct reconstruction

A B S T R A C T

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

Martin Guay*  Marie-Paule Cani  Rémi Ronfard
Laboratoire Jean Kuntzmann - Université de Grenoble - Inria

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
Drawings are inexact
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
2D embedding

Orientation

Gestalt continuation
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

Johanna Delanoy  
Inria Université Côte d'Azur

Mathieu Aubry  
LIGM (UMR 8049), Ecole des Ponts

Phillip Isola  
OpenAI

Alexei A. Efros  
UC Berkeley

Adrien Bousseau  
Inria Université Côte d'Azur

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).
Sketches are messy
and often in bitmap format

• Reconstruct directly
  – Probably ML/DL?
• Vectorize
• Simplify
Sketches are messy
and often in bitmap format