Perception, Drawing and Interactive Modeling

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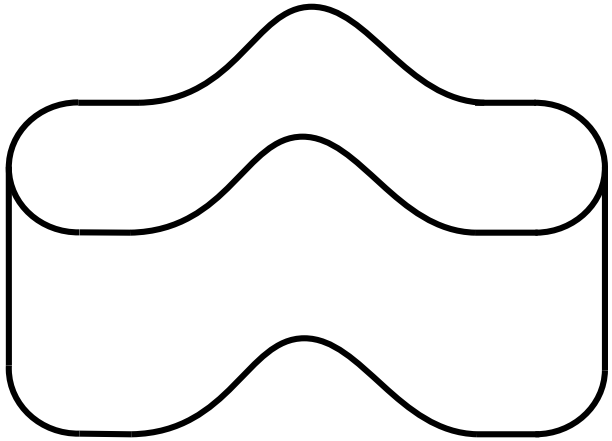
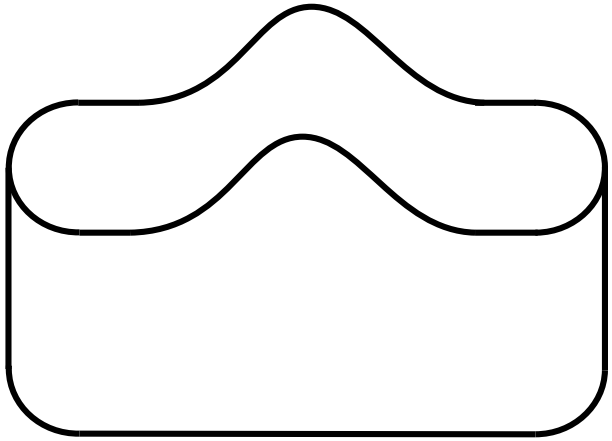
Sketchpad (Ivan Sutherland 1963)

Humans have an audio IN and OUT,
a video IN but no explicit video OUT!

video IN: Projection & Perception



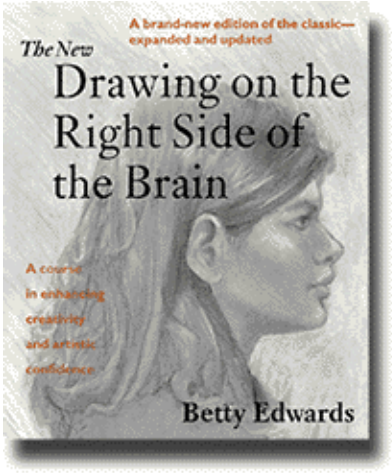
video IN: Projection & Perception



video OUT: Sketching & Sculpting

Most children between the ages of about 9-11 have a passion for realistic drawing.

…many adolescents say, “This is terrible! I have no talent for art. I’m not doing it anymore.”



…regardless, we all mould, gesture and doodle!

Concept Modeling

The transformation of a creative vision into a digital 3D model, that is easy to refine and reuse.

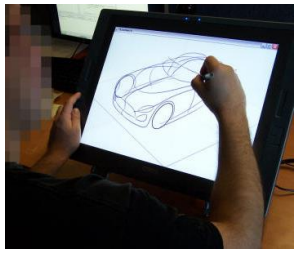
Concept Modeling comes after Ideation

History of sketching tools

Sketchpad [Sutherland 1963]

SKETCH [Zeleznik et al 1996]

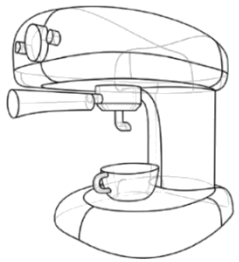
Teddy [Igarashi et al 1999]



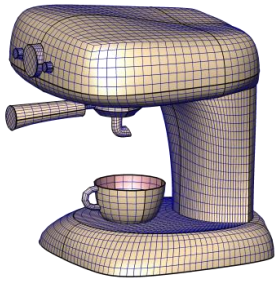
ILoveSketch [Bae et al 2008]

evolution of the espressoman…

- I♥Sketch.
- 3D Analytic Drawing.



- 3D Curve network surfacing.



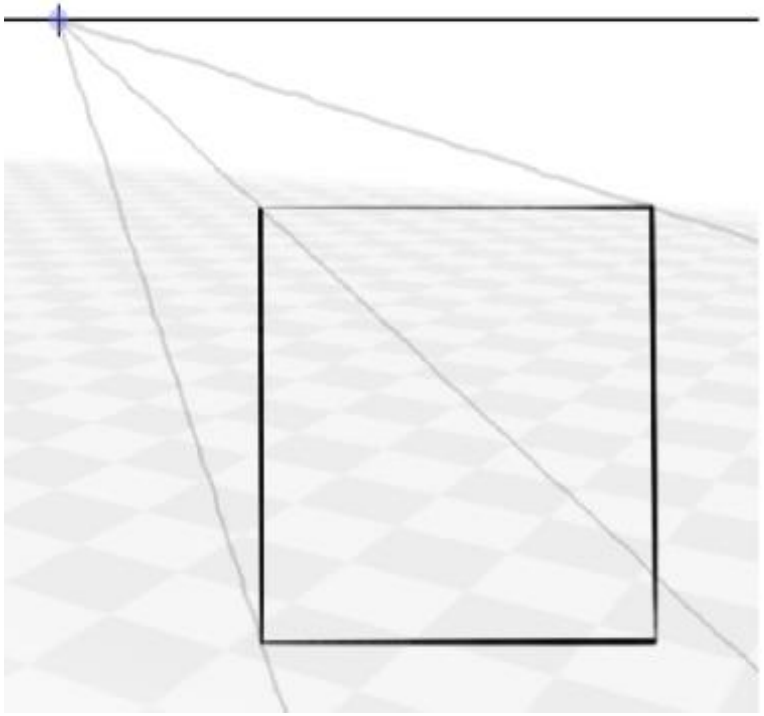
- Slices, FlatFab: planar sections.
- CrossShade.
- True2Form.

- MeshMixer.

I♥SKETCH: multi-view sketching

[**Bae, Balakrishnan & Singh**, ILoveSketch: As-natural-as-possible sketching system for creating 3D curve models. *ACM UIST 2008*]
[**Bae, Balakrishnan & Singh**, EverybodyLovesSketch: 3D Sketching for a Broader Audience. *ACM UIST 2009*] www.ilovesketch.com

Sketching performance & perception



Sketching performance & perception

Humans have an audio IN and OUT,
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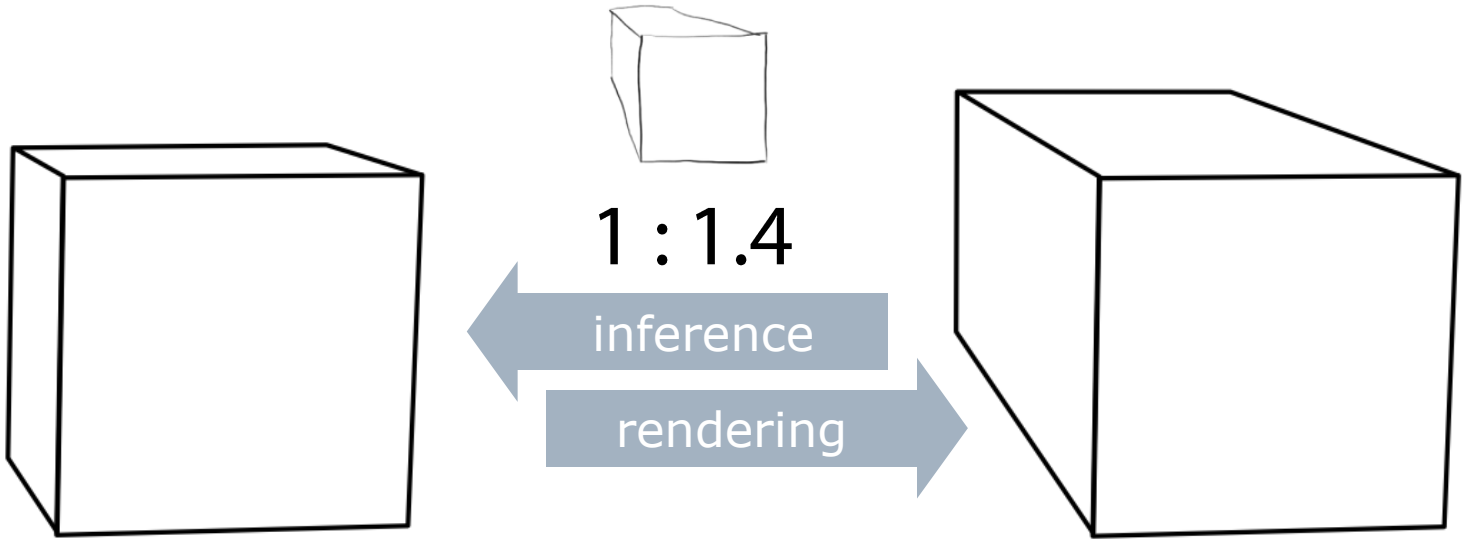
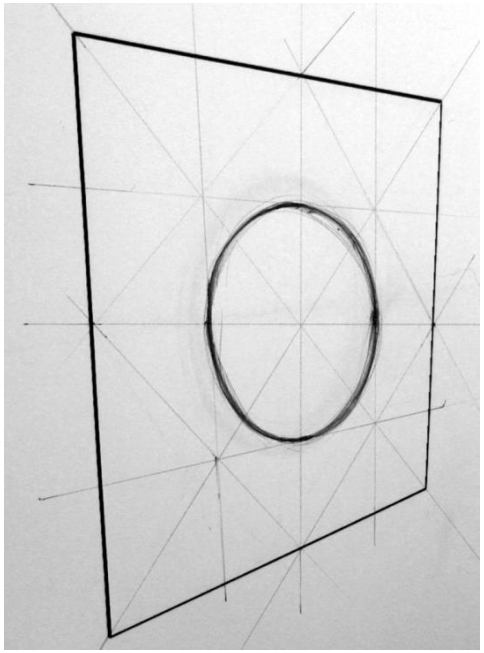
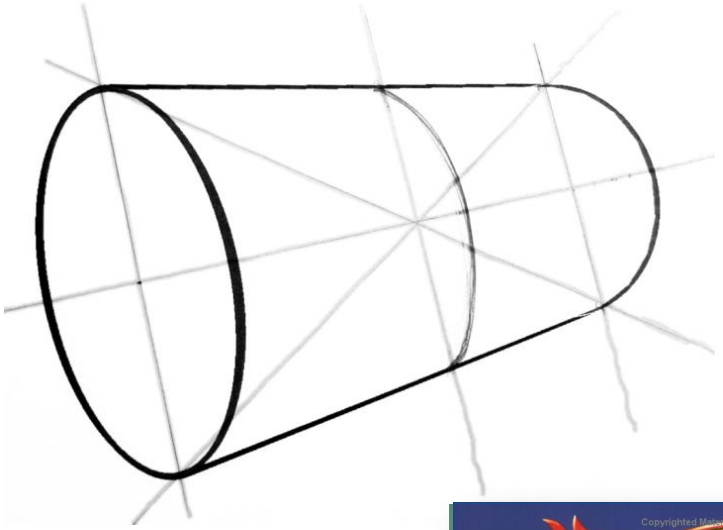
Modeling Perceptual Bias

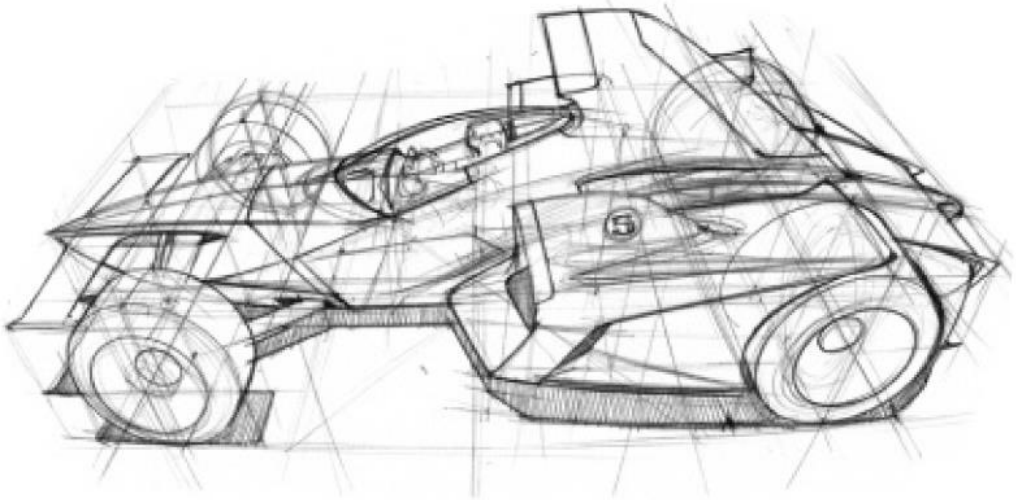


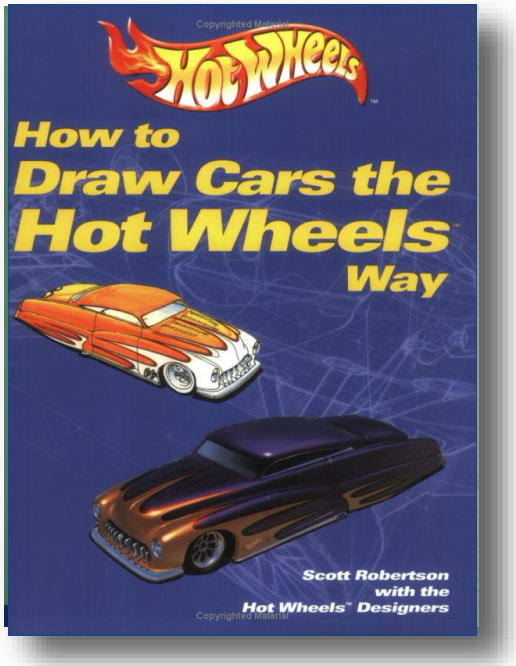
[**Schmidt, Khan, Kurtenbach, Singh,** On expert performance in 3D curve drawing tasks. *SBIM 2009*] www.dgp.toronto.edu/~rms/data/CurveDrawing

Experts and drawing systems

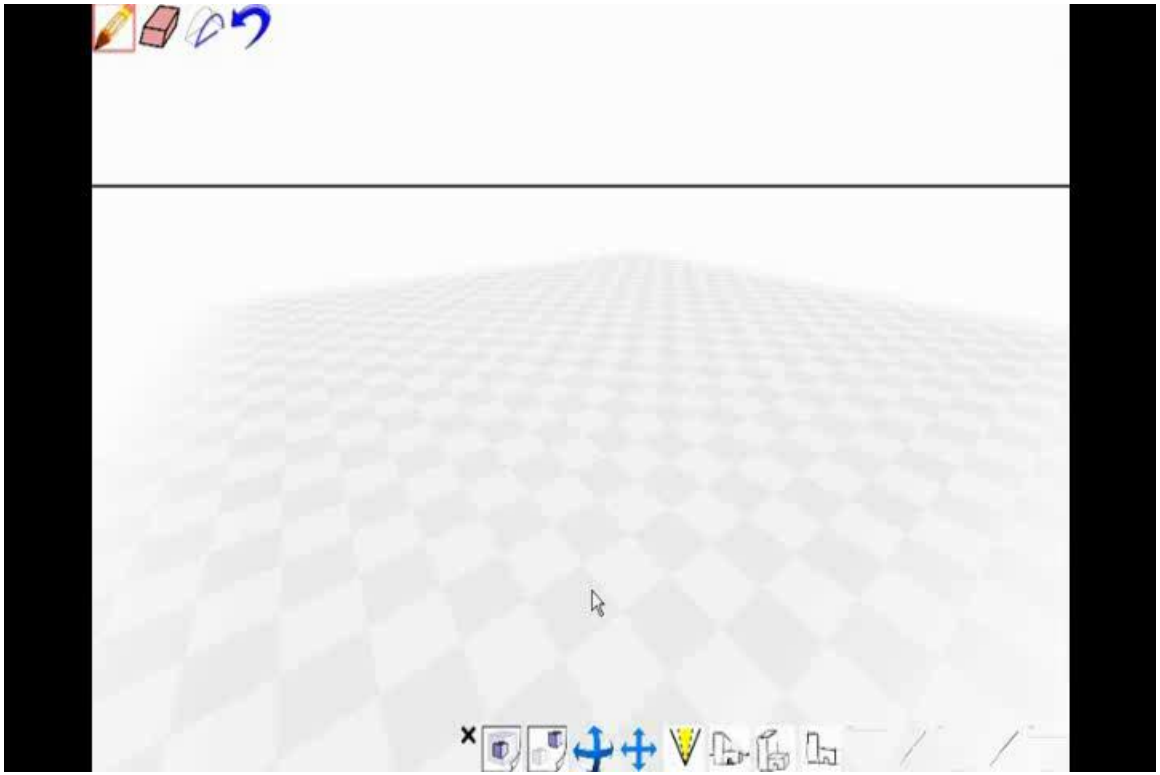








Analytic Drawing: single-view sketching

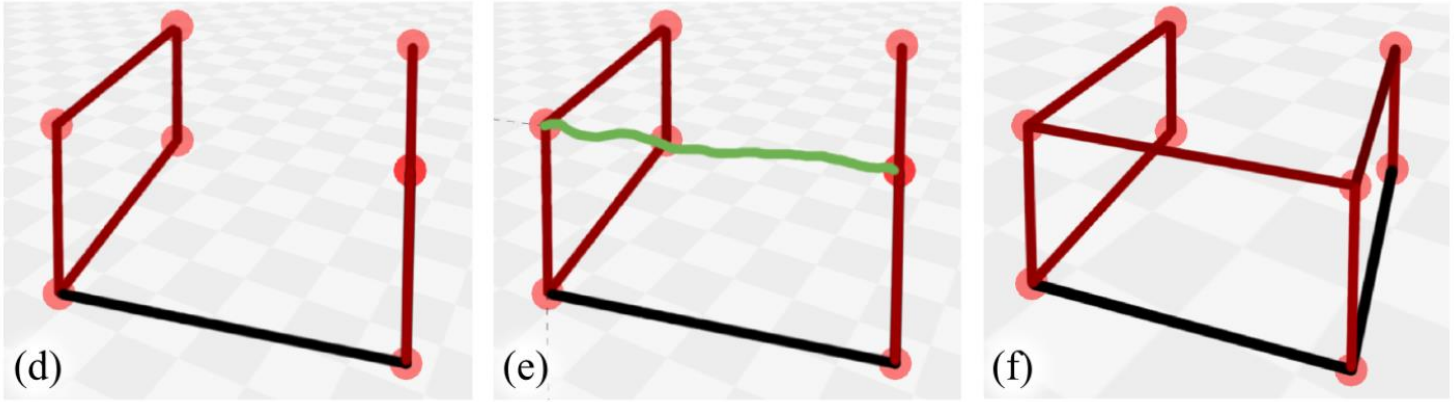


[**Schmidt, Khan, Singh, Kurtenbach,** Analytic drawing of 3D scaffolds. *SIGGRAPH Asia 2009*]
www.dgp.toronto.edu/~rms/pubs/DrawingSGA09.html

Analytic Drawing: inference engine

- Scaffold constraints: position, direction, length.
- 3D curve *fitness*: snapping, geometric priors.

Redundancy resolves ambiguity.



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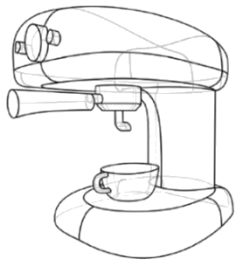

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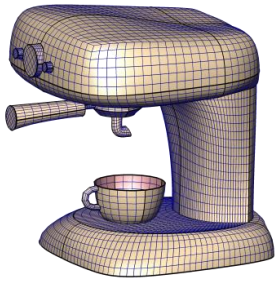

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- CrossShade.
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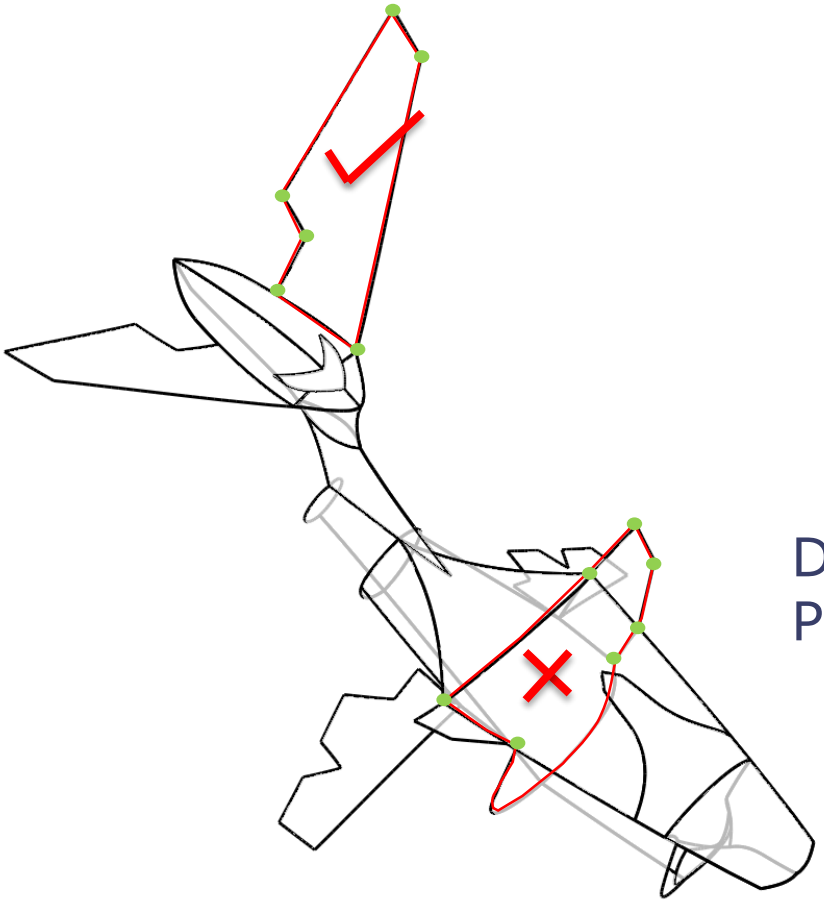
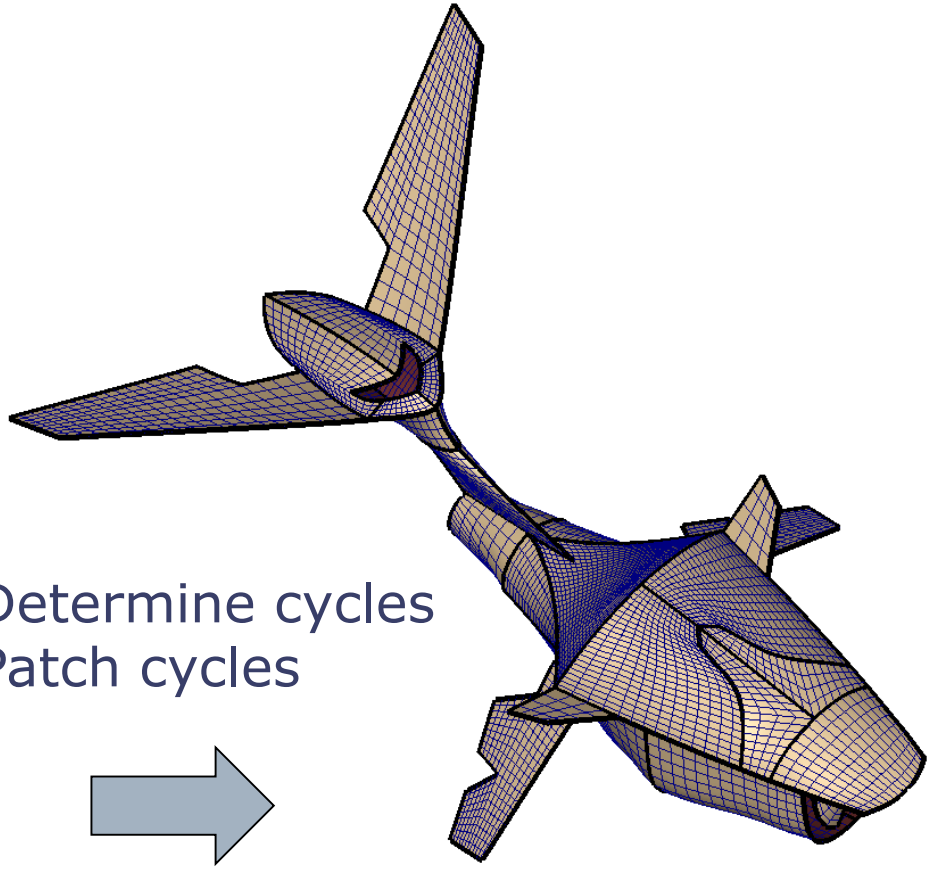
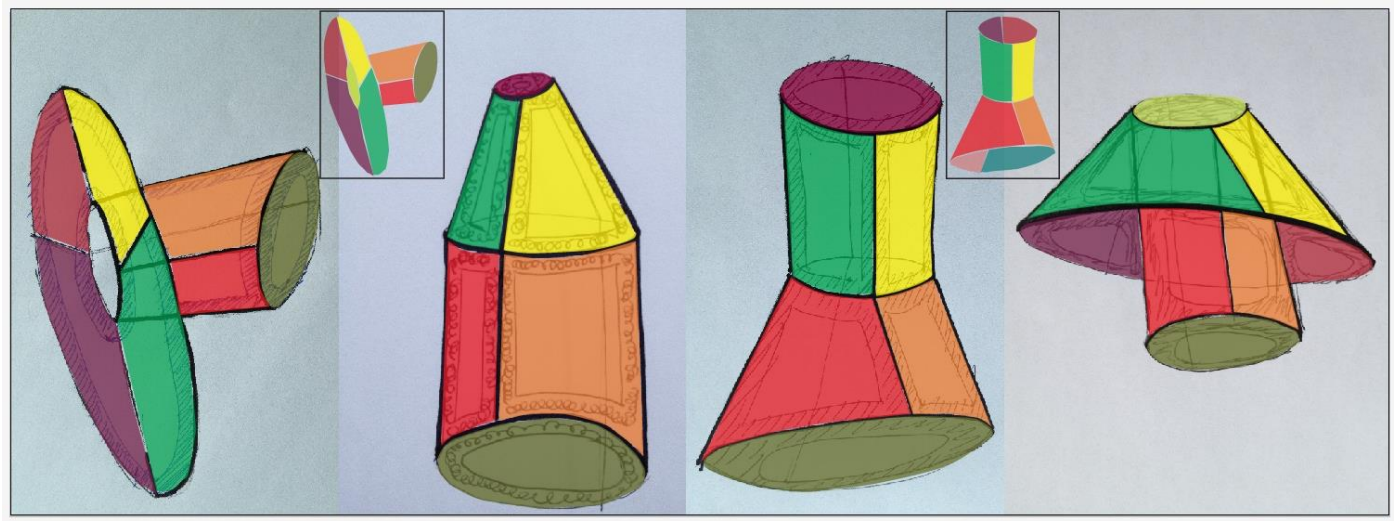
Curve network surfacing

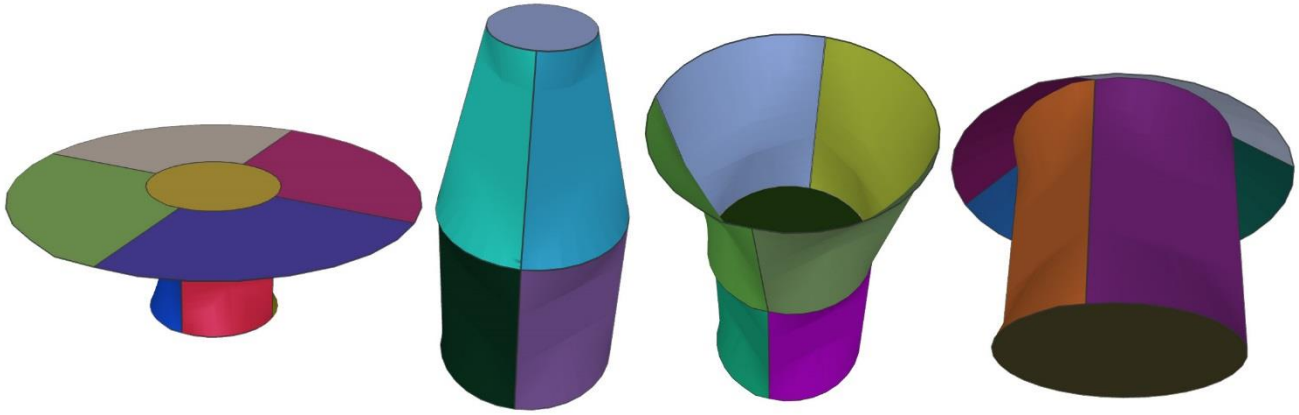


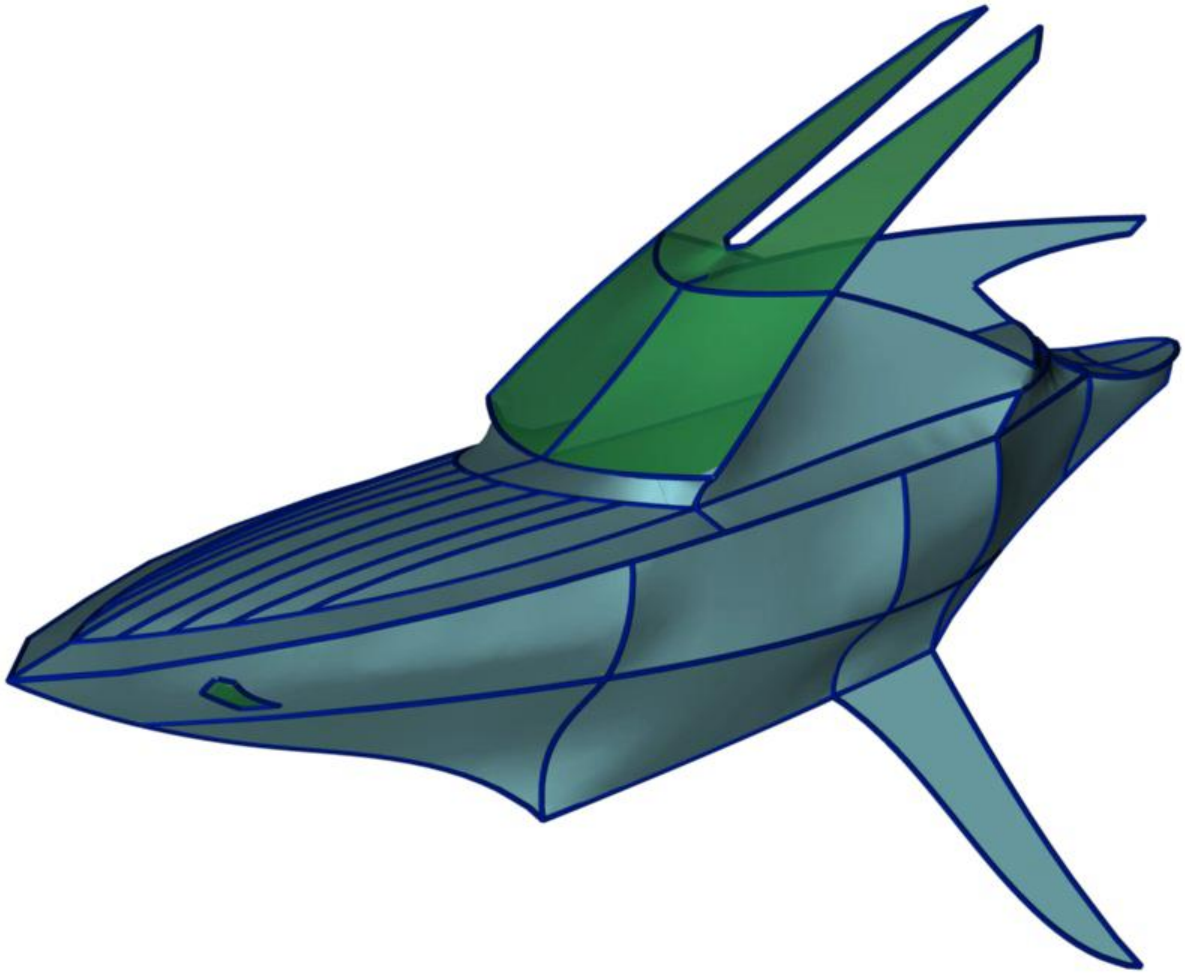
Determine cycles
Patch cycles



Determine cycles: topology+geometry

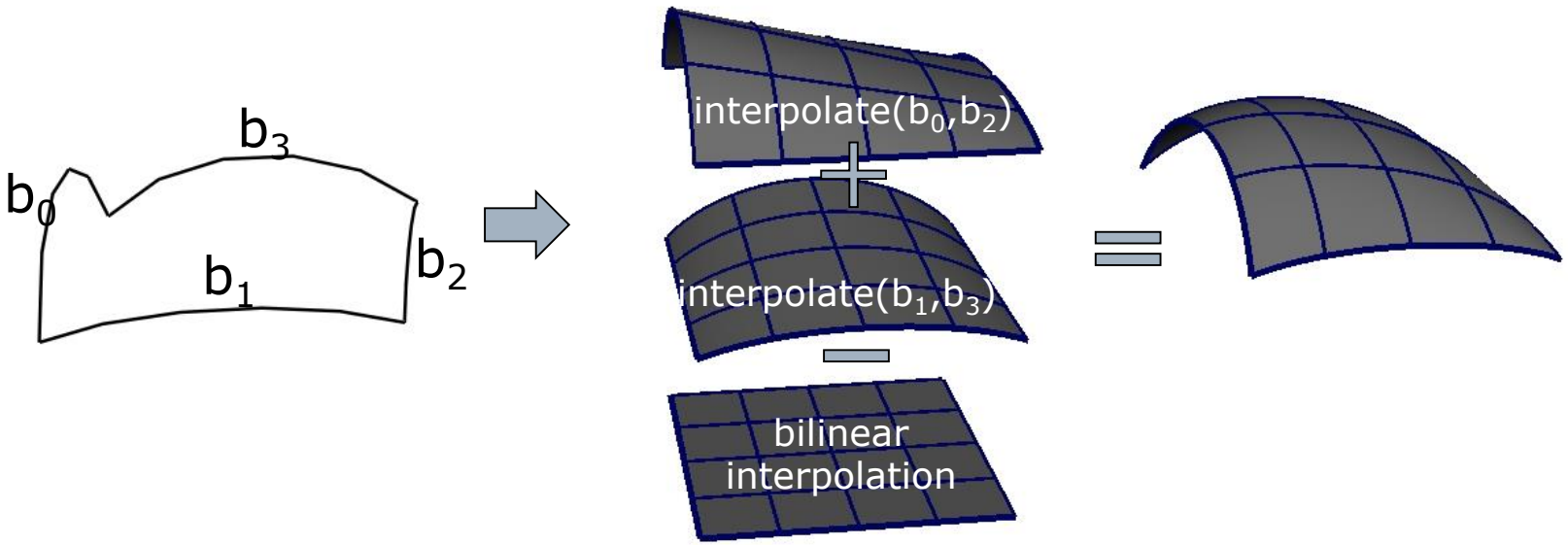




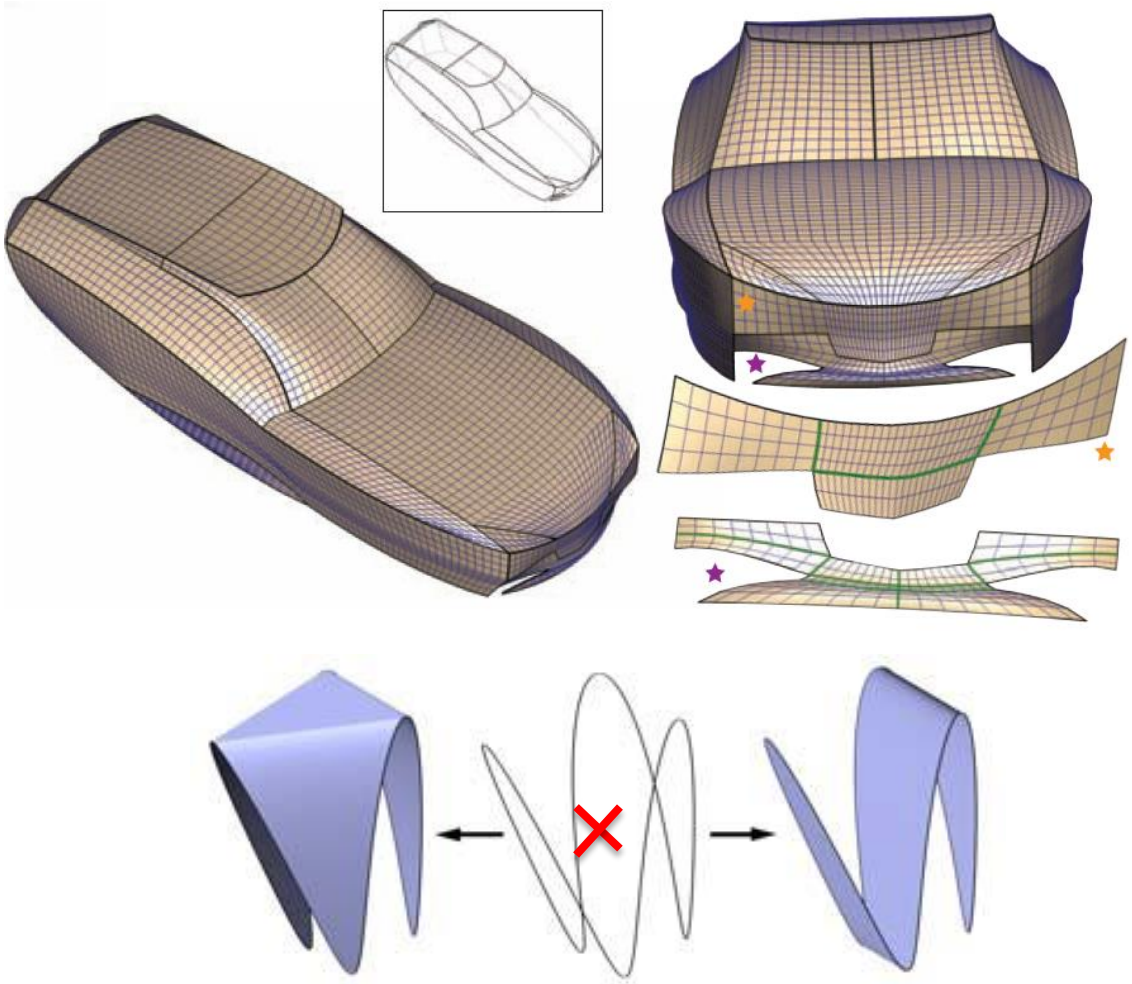


[**Sadri & Singh**, Flow Complex based shape reconstruction from 3D curves. *SIGGRAPH 2014*]

Patch cycles: Coons Patch



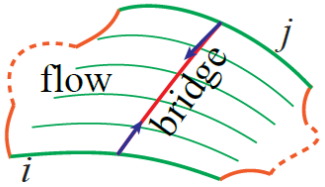
Patch cycles: design quadrangulation



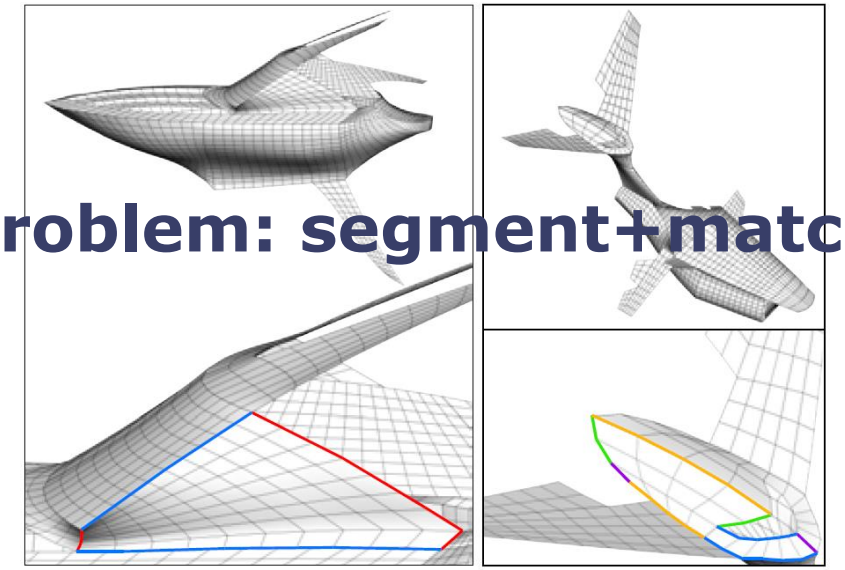
[**Bessmeltsev, Wang, Sheffer, Singh**, Design-Driven Quadrangulation of Closed 3D Curves. *SIGGRAPH Asia 2012*]

Patch cycles: How do designers work?

- Cycles represent **flow-lines**
  …smooth, low variation curves aligned with creases and curvature lines.
- Curve segment pairs like river banks define flow-lines.



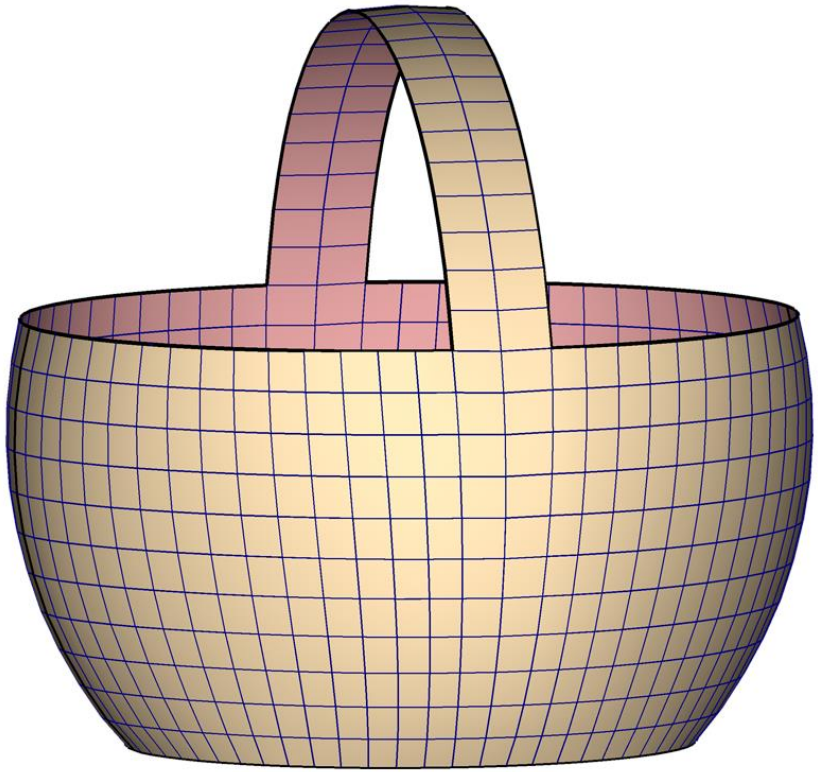
- Crossing flow-line families form quads.



Problem: segment+match

Patch cycles: Stable matching

- matching cost= bridge curvature + segment shape.
- Interleave segmentation and matching.



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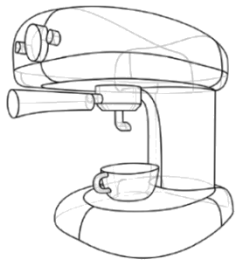

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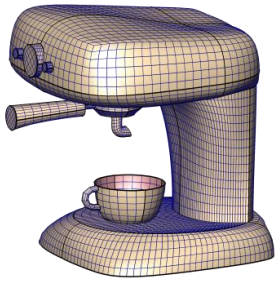
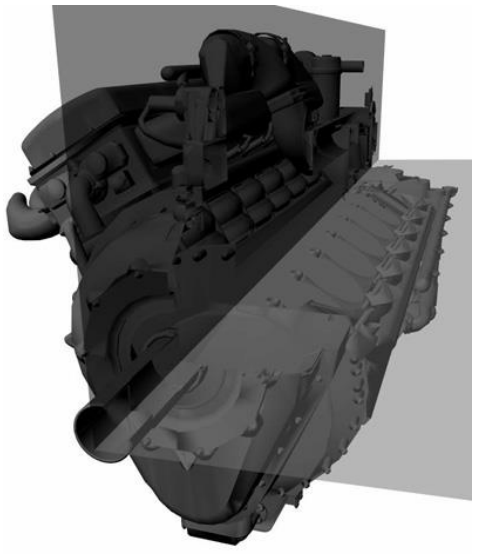


- Slices, FlatFab: planar sections.
- CrossShade.
- True2Form.

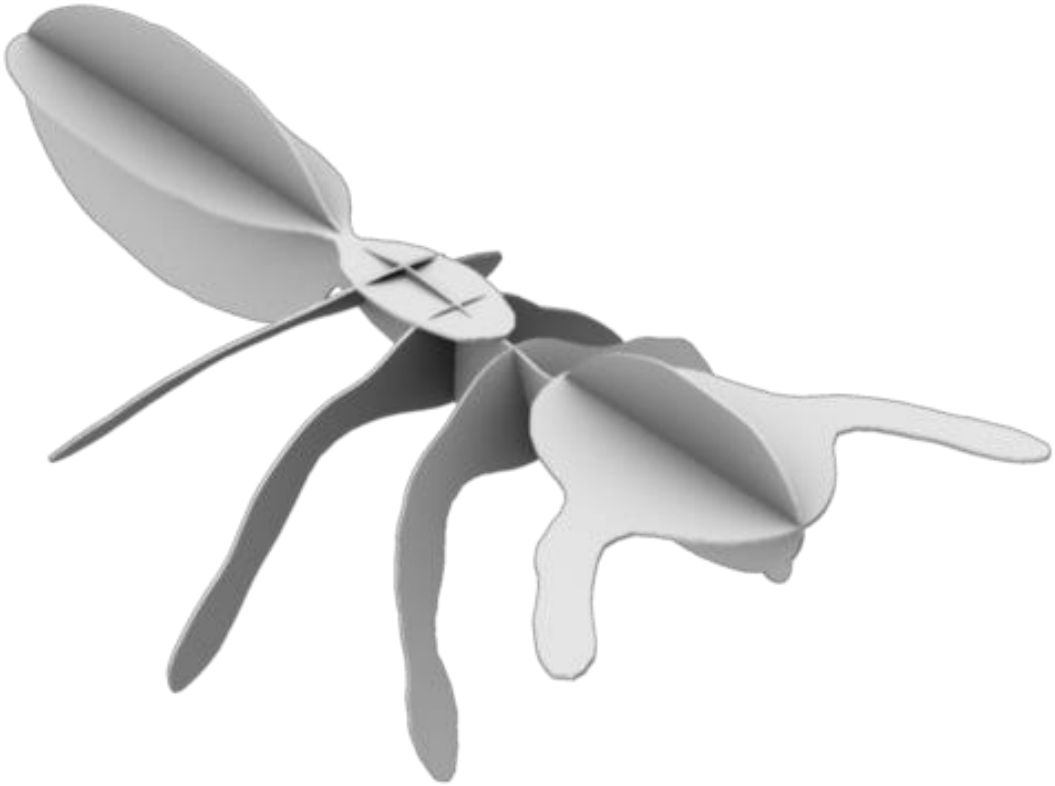
- MeshMixer.

How important are non-planar curves?



Slices: problem statement

Compute a recognizable abstraction of a 3D model using a minimal set of planar sections.



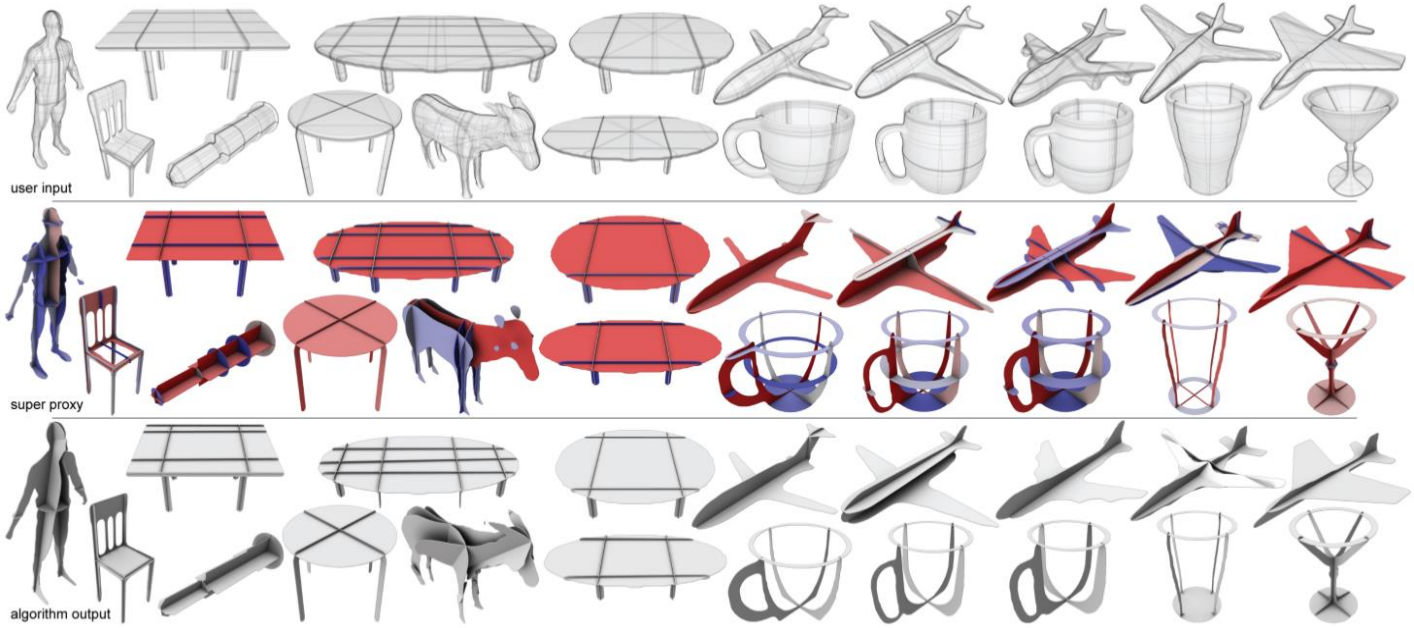
[**McCrae, Singh, Mitra,** Slices: A Shape-proxy Based on Planar Sections. *SIGGRAPH Asia 2011*]
http://www.dgp.toronto.edu/~mccrae/projects/slices/

Slices: Human creation=>Algorithm=>Human recognition

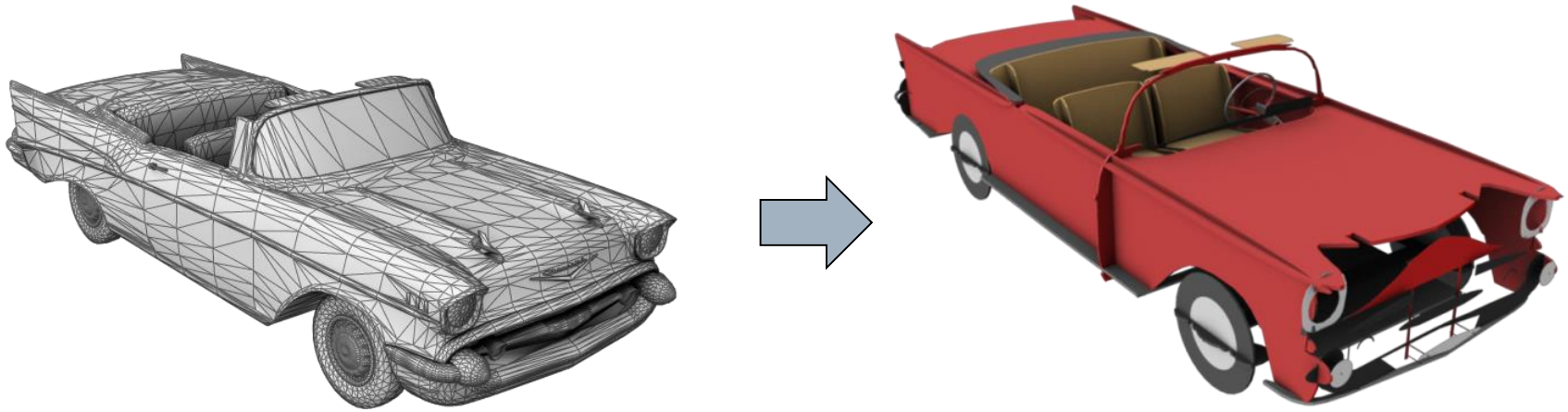
- Humans consistently selected a small set of planar sections, strongly correlated with geometric shape features.
  18 humans, 19 models, avg. 4.77 planes.

- Problem reposed as min planar section cover of shape features.

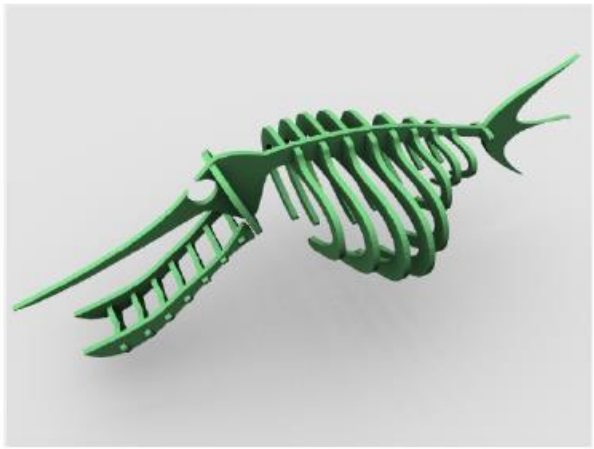
- Recognition: mesh/human/algorithm (rate >90%, response < 2s).
  PCA (rate=57%) random (rate=38%) (response > 4s).

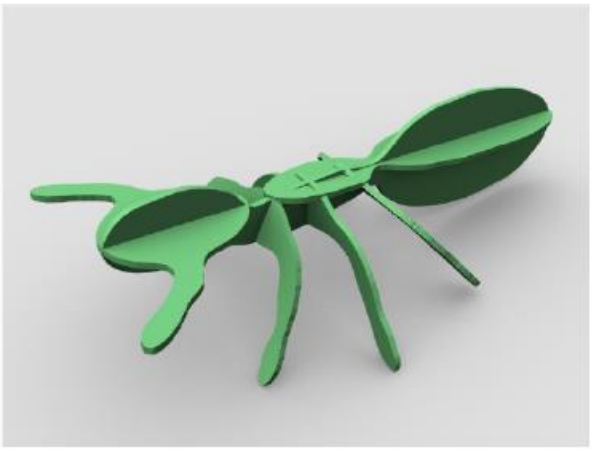


Slices



FlatFab: interactive slices



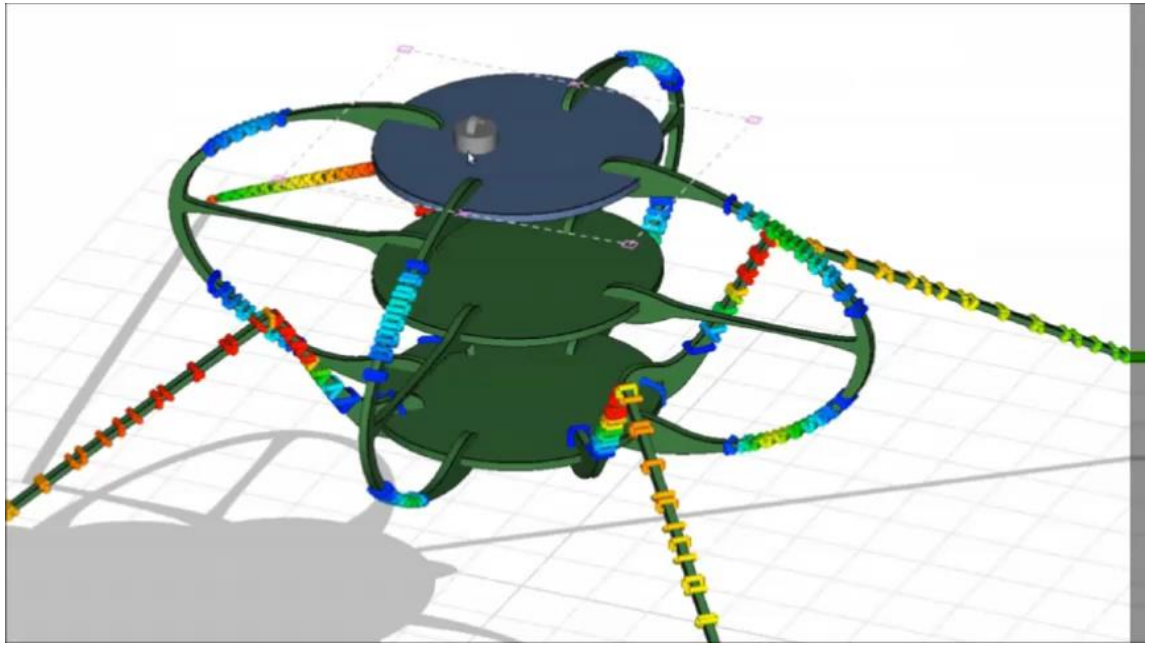


[**McCrae, Umetani, Singh,** FlatFitFab: Interactive Modeling with Planar Sections. *ACM UIST 2014*]
http://www.flatfab.com

FlatFab: design principles

- Design collateral …3D objects, 2D images.
- Shape Regularity.
- Near frontoparallel views.
- Single view interface.

FlatFab

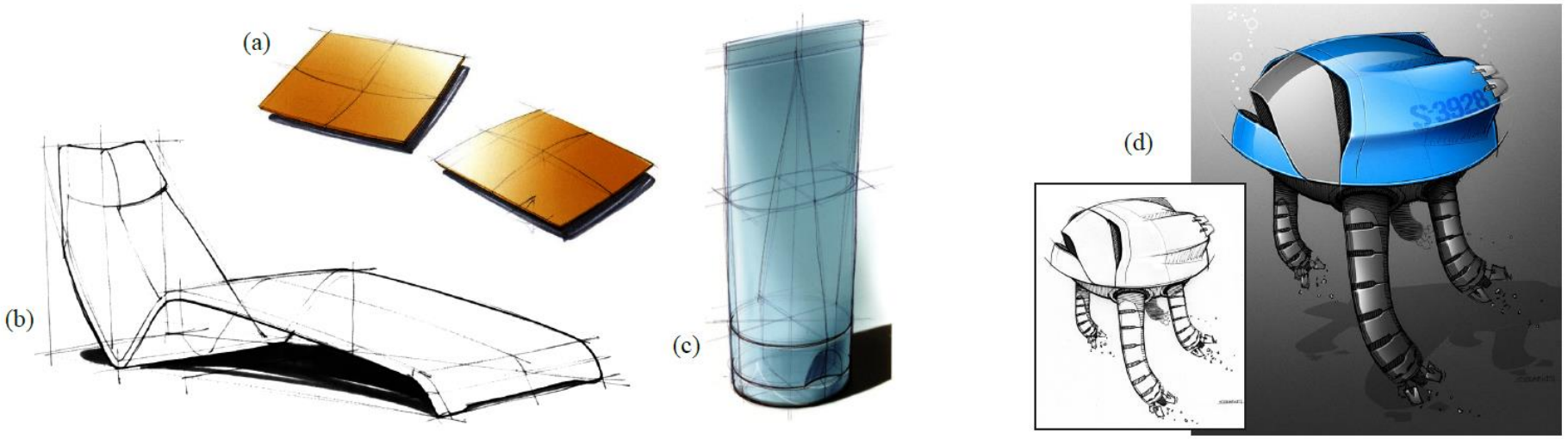


CrossShade: special planar curves?

CrossShade: special planar curves?

[**Shao, Bousseau, Sheffer, Singh,** CrossShade: Shading Concept Sketches Using Cross-Section Curves *SIGGRAPH 2012*] http://www.crossshade.com/

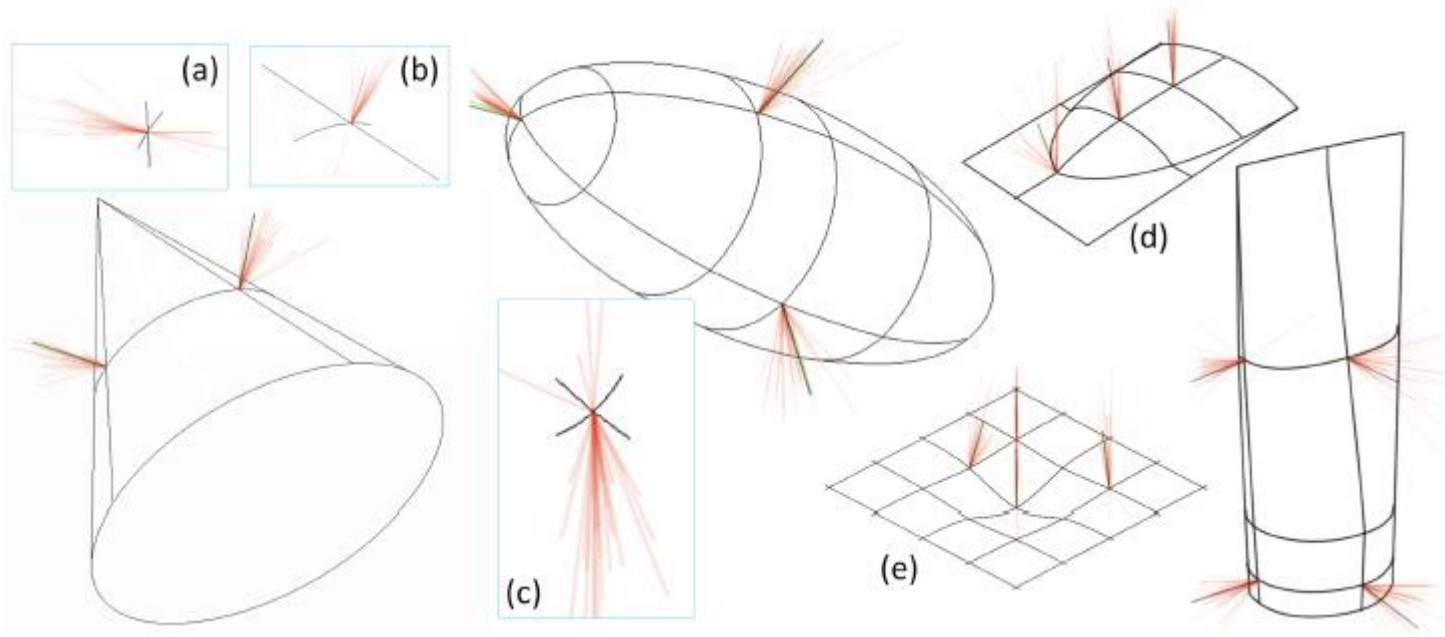
CrossShade: design analysis



"Cross-sections on a surface explain or emphasize its curvature."

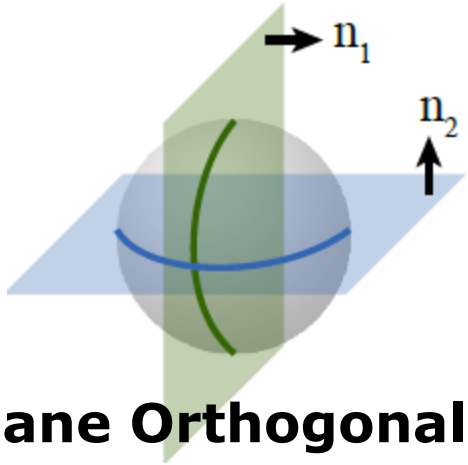
"…bend or transform the object's surface."

CrossShade: perceptual study

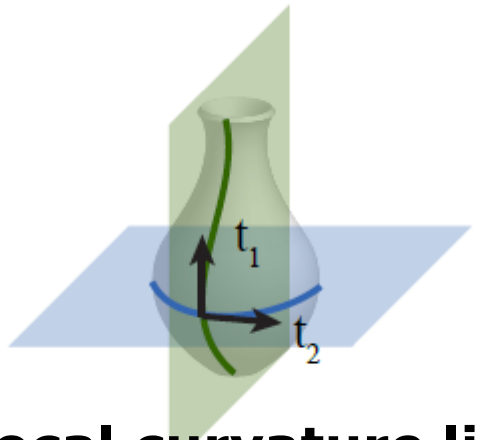


Viewers are *persistent*, *consistent* and *accurate* in X-hair perception.

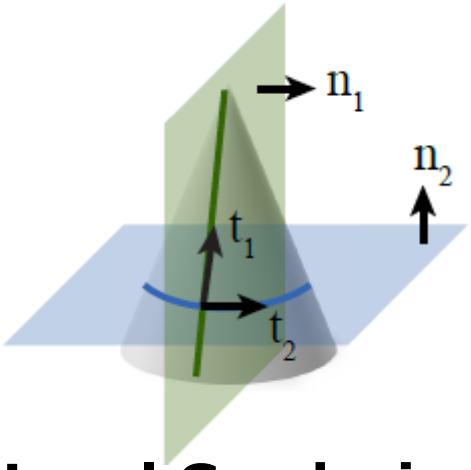
CrossShade: defining cross-hairs



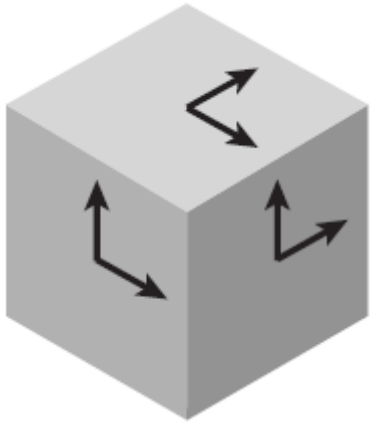
Plane Orthogonality



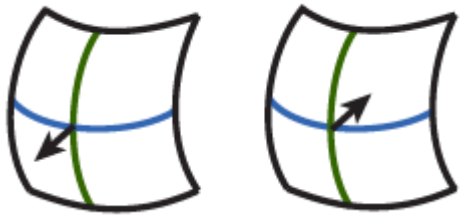
Local curvature lines



Local Geodesics

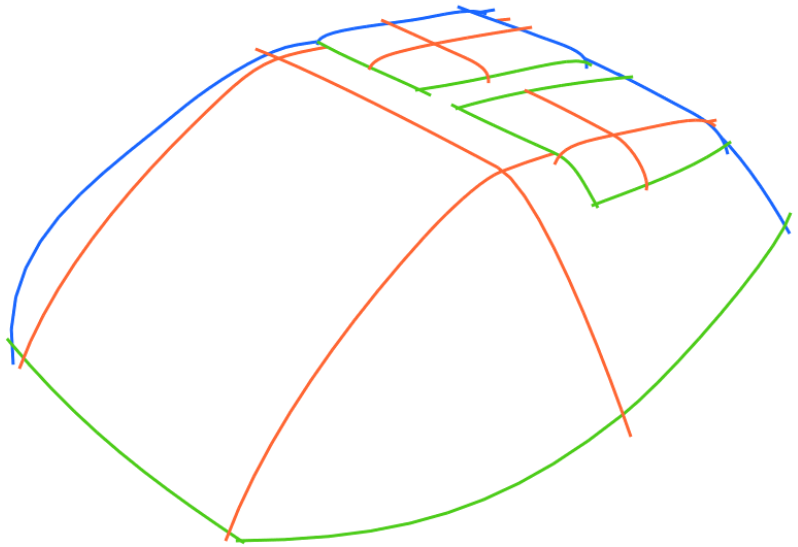


Minimal Foreshortening



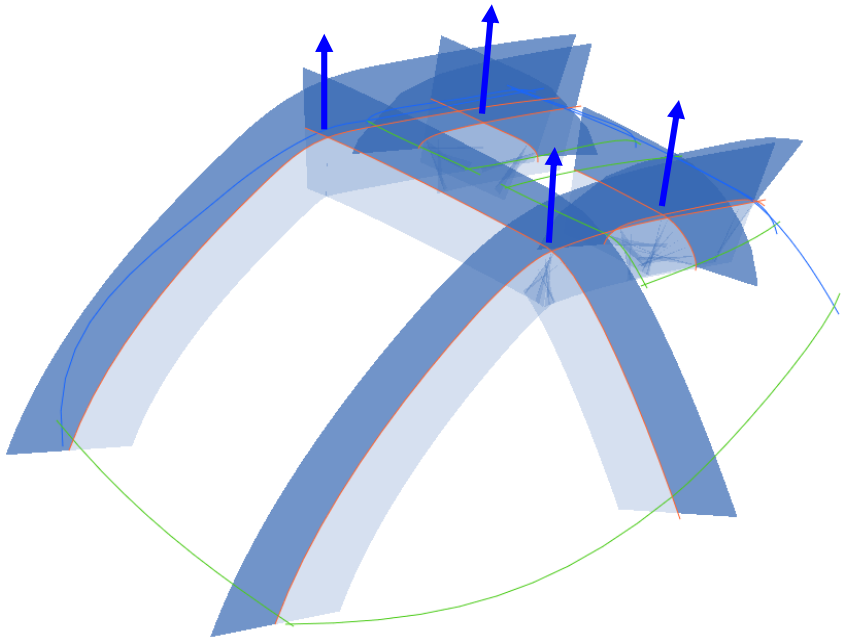
Orientation

CrossShade: Algorithm



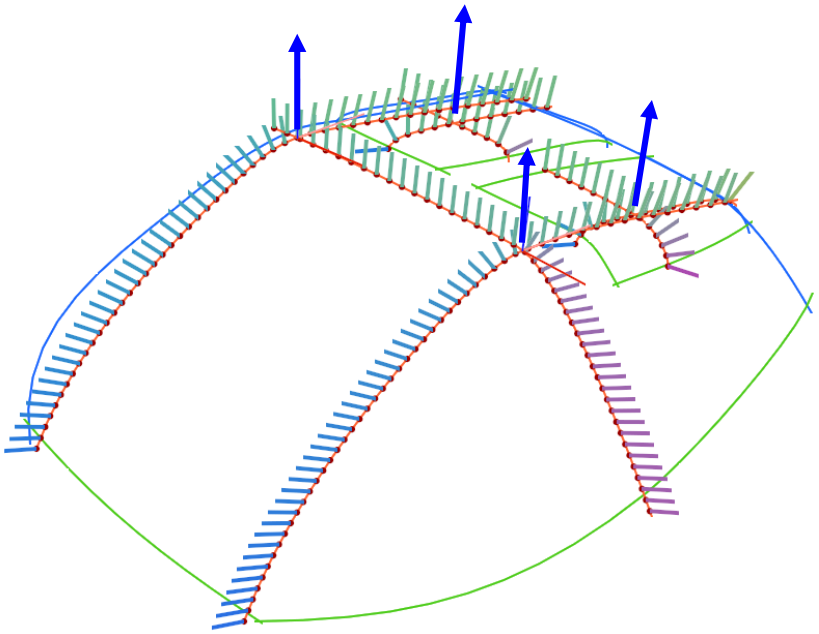
CrossShade: Algorithm

- Compute X-section planes, X-hair normals: *use 5 properties.*



CrossShade: Algorithm

- Compute X-section planes, X-hair normals: *use 5 properties.*
- Propagate normals along X-section curves: *minimize twist.*



CrossShade: Algorithm

- Compute X-section planes, X-hair normals: *use 5 properties.*
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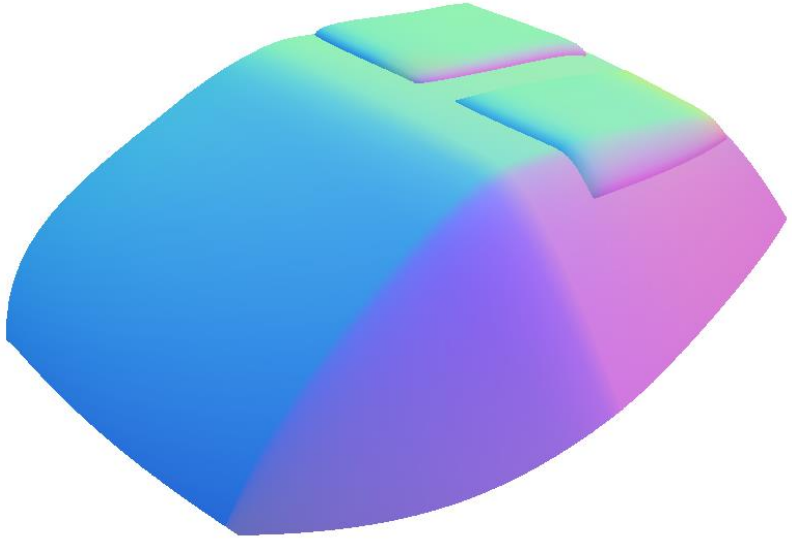
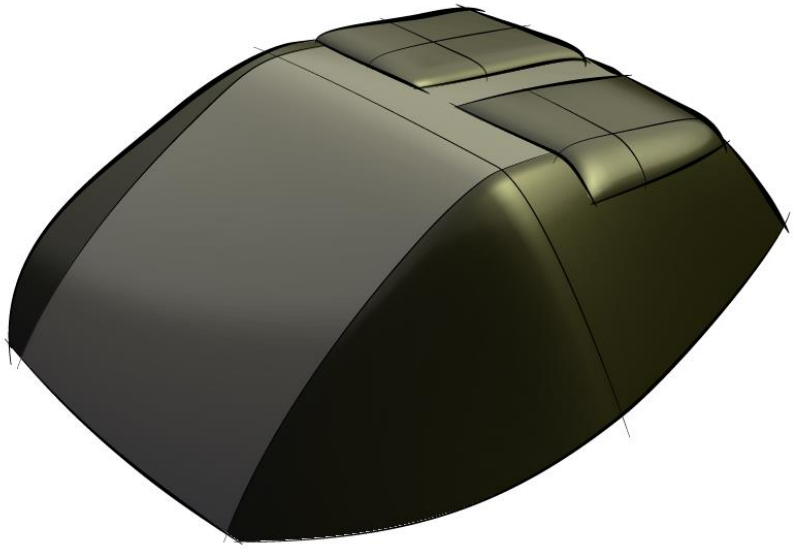
- Propagate normals into interior regions: *Coons interpolation.*

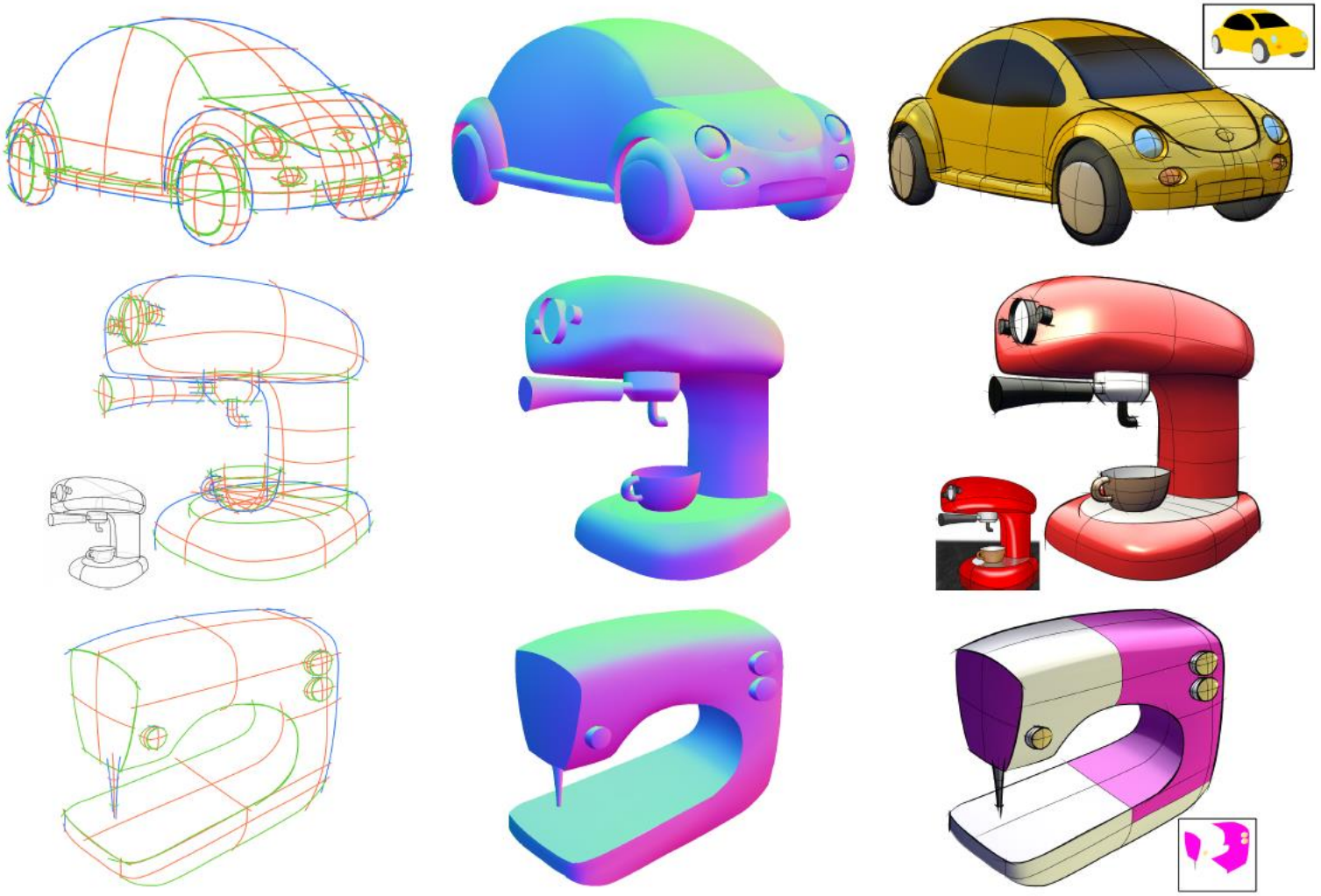


CrossShade: Algorithm

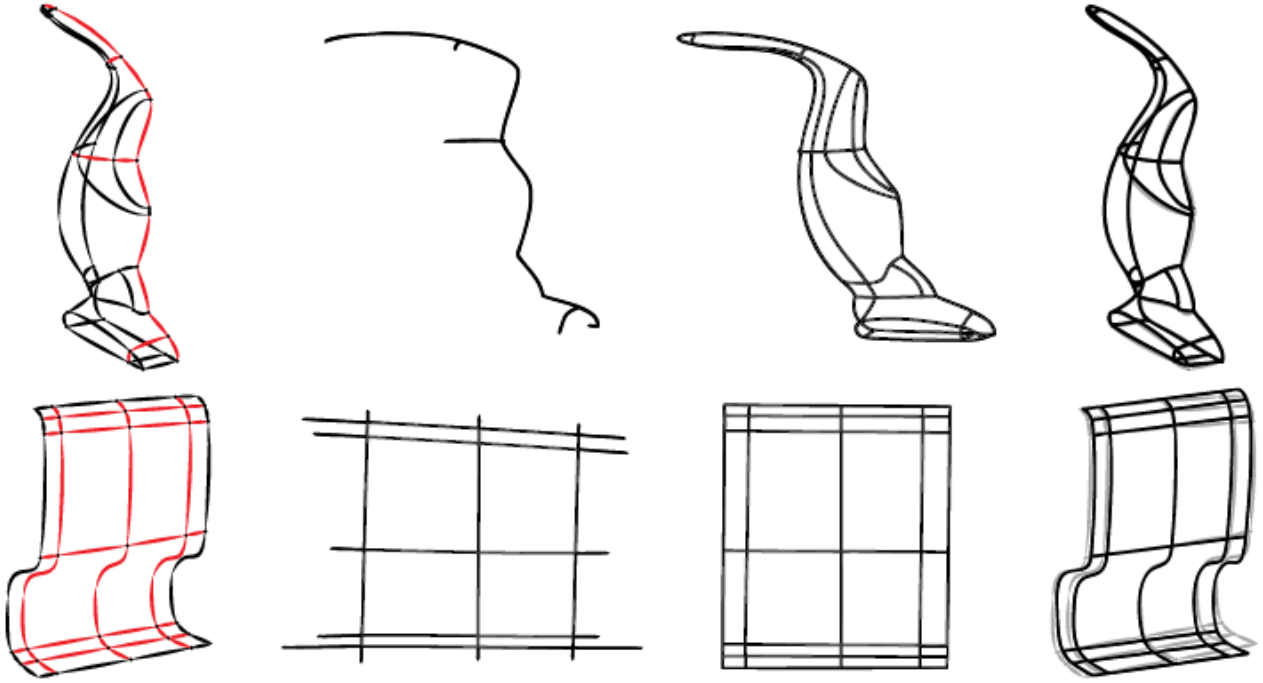
- Compute X-section planes, X-hair normals: *use 5 properties.*
- Propagate normals along X-section curves: *minimize twist.*
- Propagate normals into interior regions: *Coons interpolation.*
- Shade!



CrossShade: Results



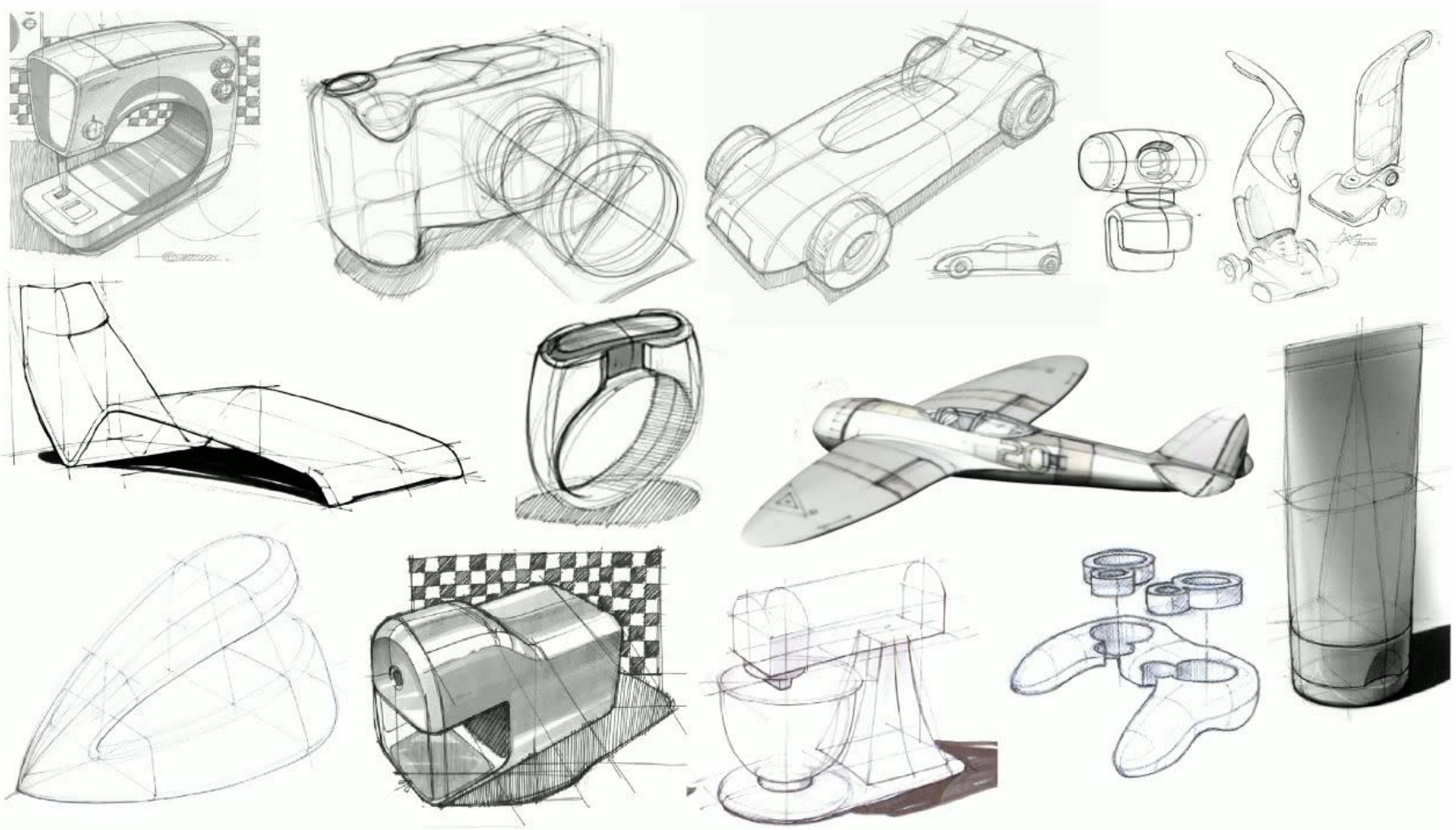
True2Form



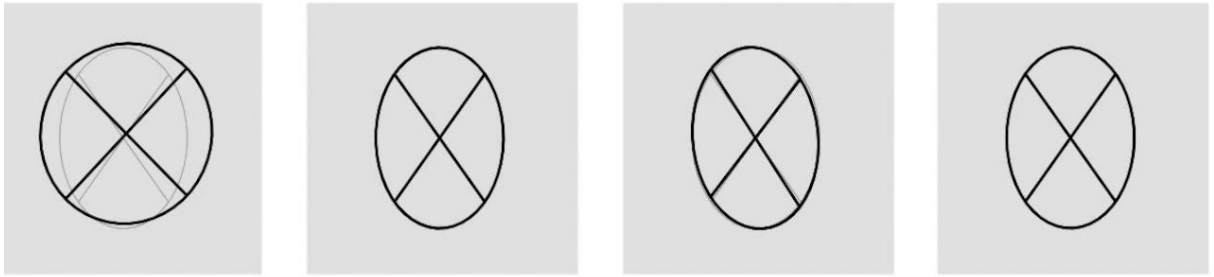
2D sketch | Crossshade *side view* 3D | True2Form *side view* 3D | True2Form *input overlay*

[**Xu, Chang, Bousseau, McCrae, Sheffer, Singh,** True2Form: 3D curve networks from 2D sketches via selective regularization. *SIGGRAPH 2014*]

True2Form: fidelity and regularity

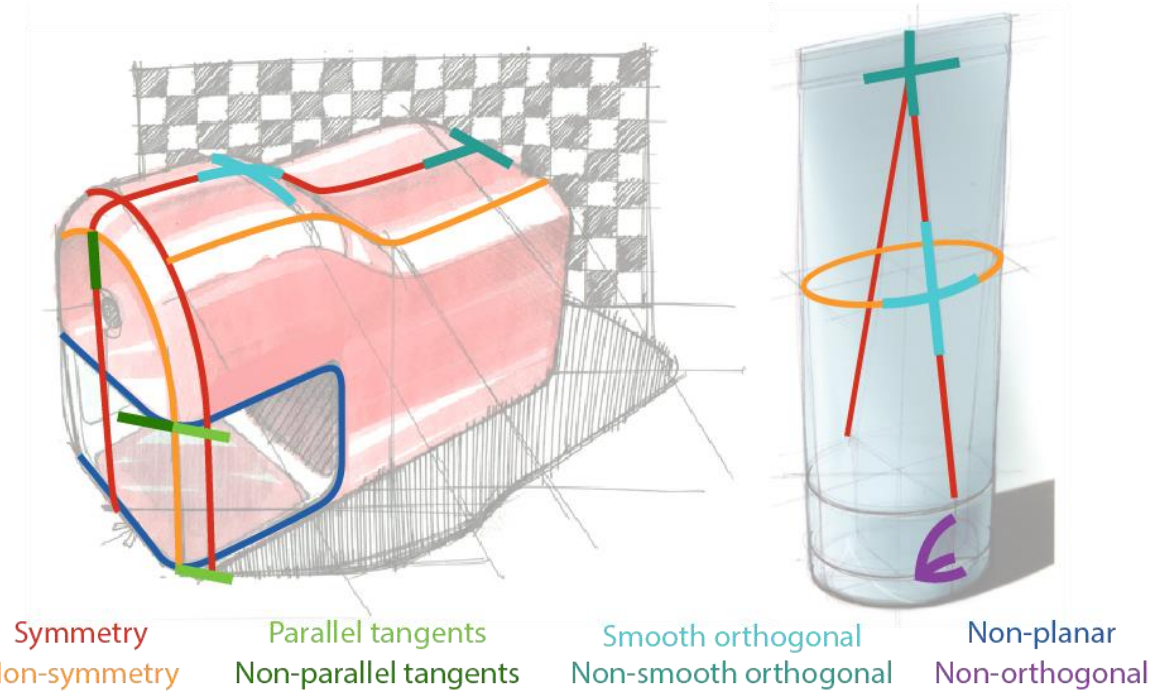


True2Form: Sketch Fidelity



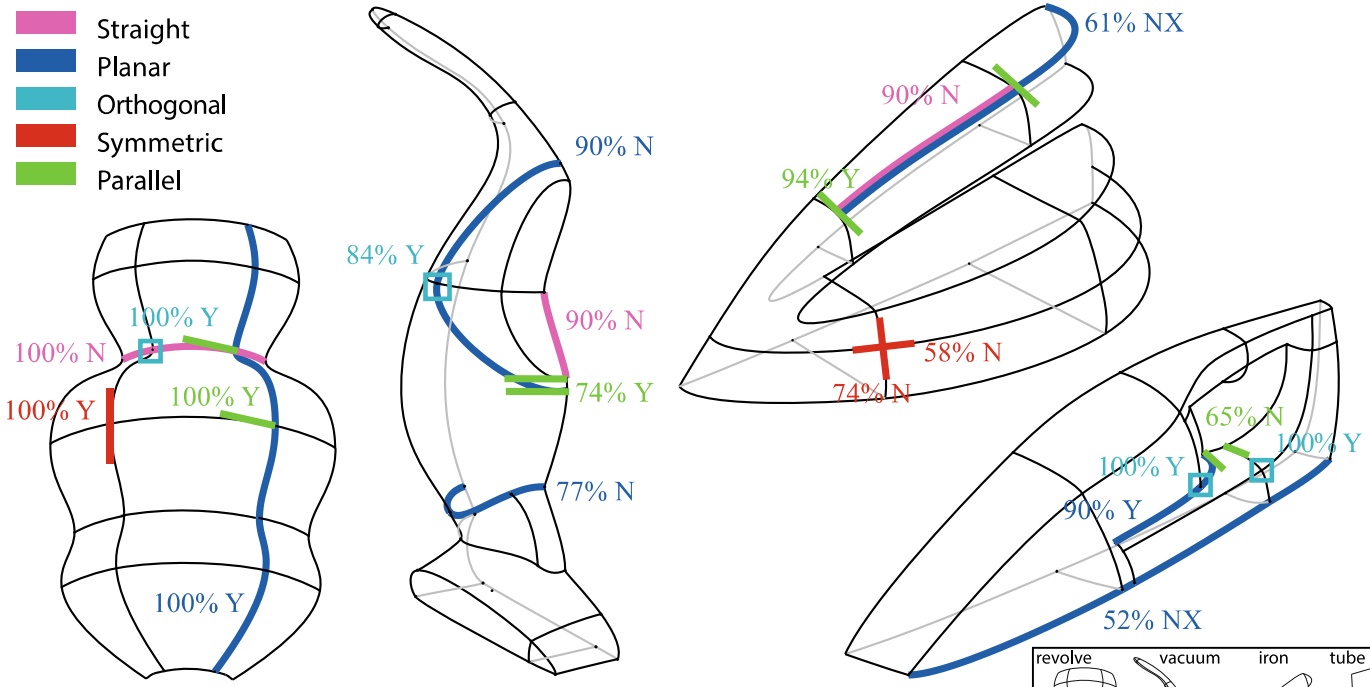
- Projection accuracy
- Minimal variation
- Minimal foreshortening

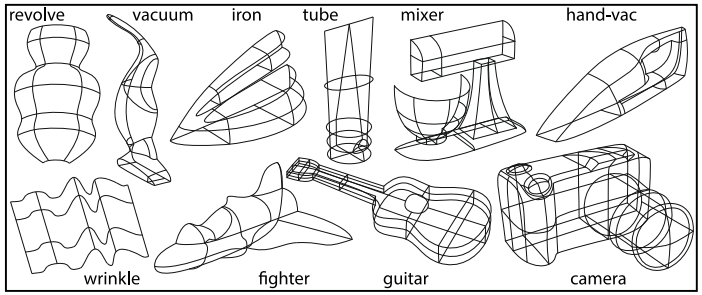
True2Form: Shape Regularity



- Parallel
- Orthogonal
- Symmetry
- Curve Planarity

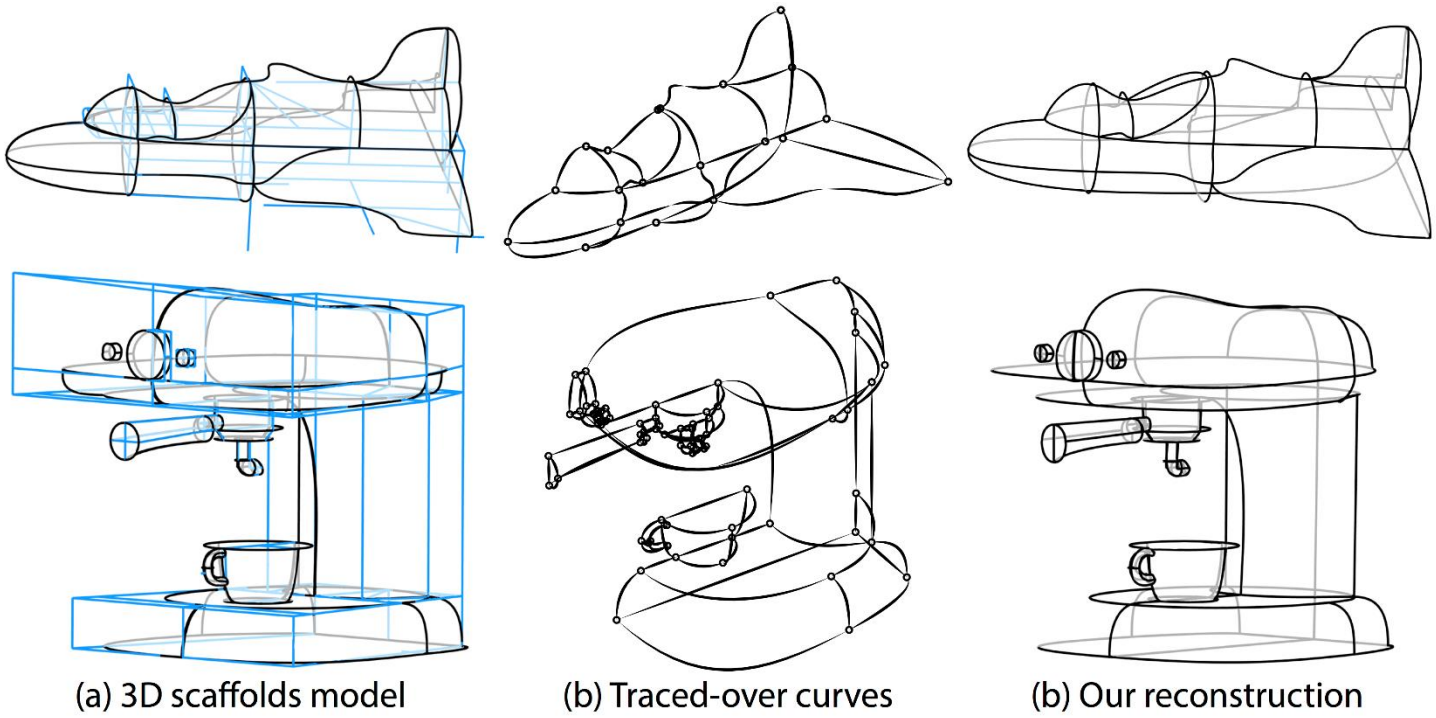
True2Form: perceptual validation





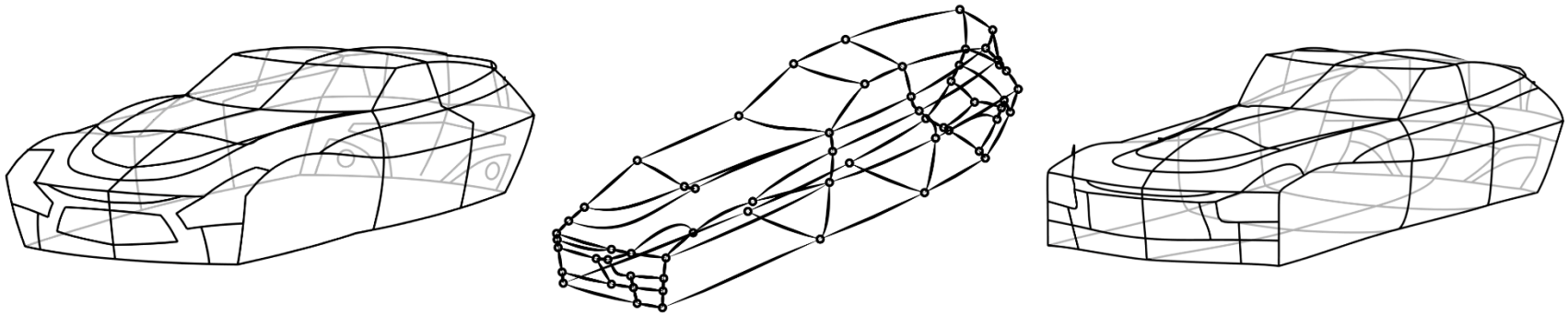
- Humans consistently perceive 3D parallelism, symmetry, orthogonality, linearity and planarity cues in 2D sketches.
- Human perception matches our algorithm, when consistent.

True2Form vs. Analytic Drawing



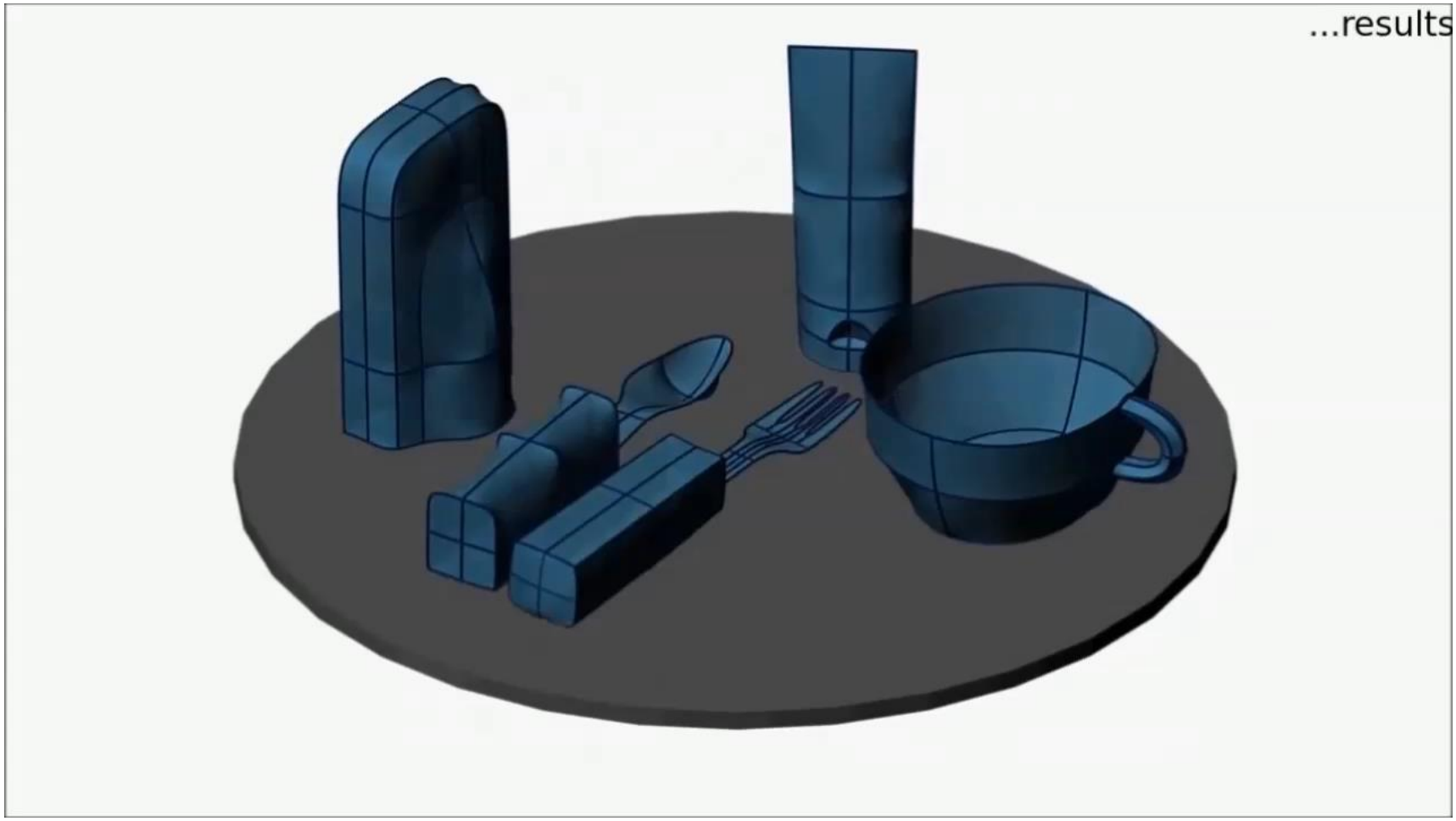
(a) 3D scaffolds model (b) Traced-over curves (b) Our reconstruction

True2Form vs. ILoveSketch



(a) ILoveSketch model (b) Traced-over curves (c) Our reconstruction

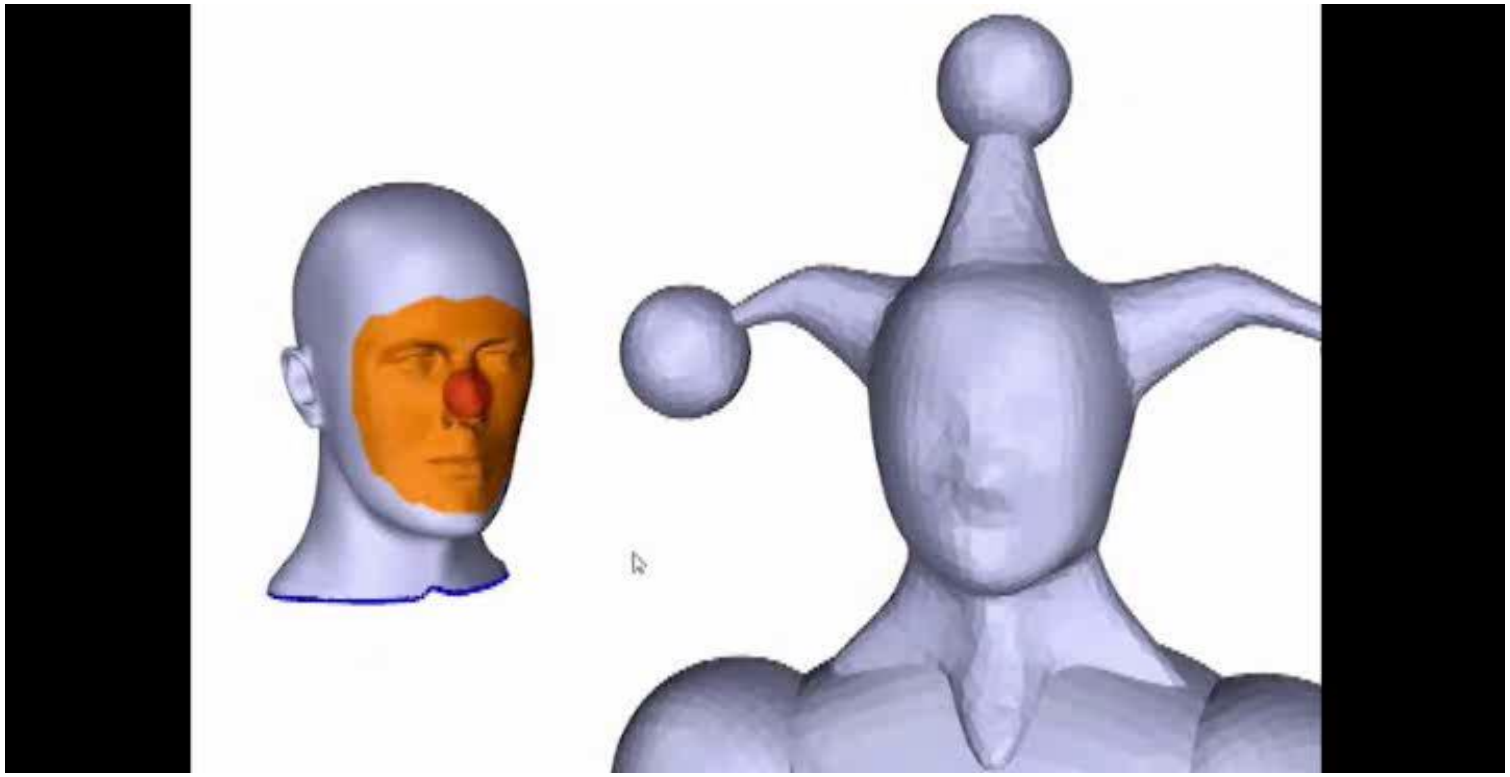
True2Form: results



Conceptual Design

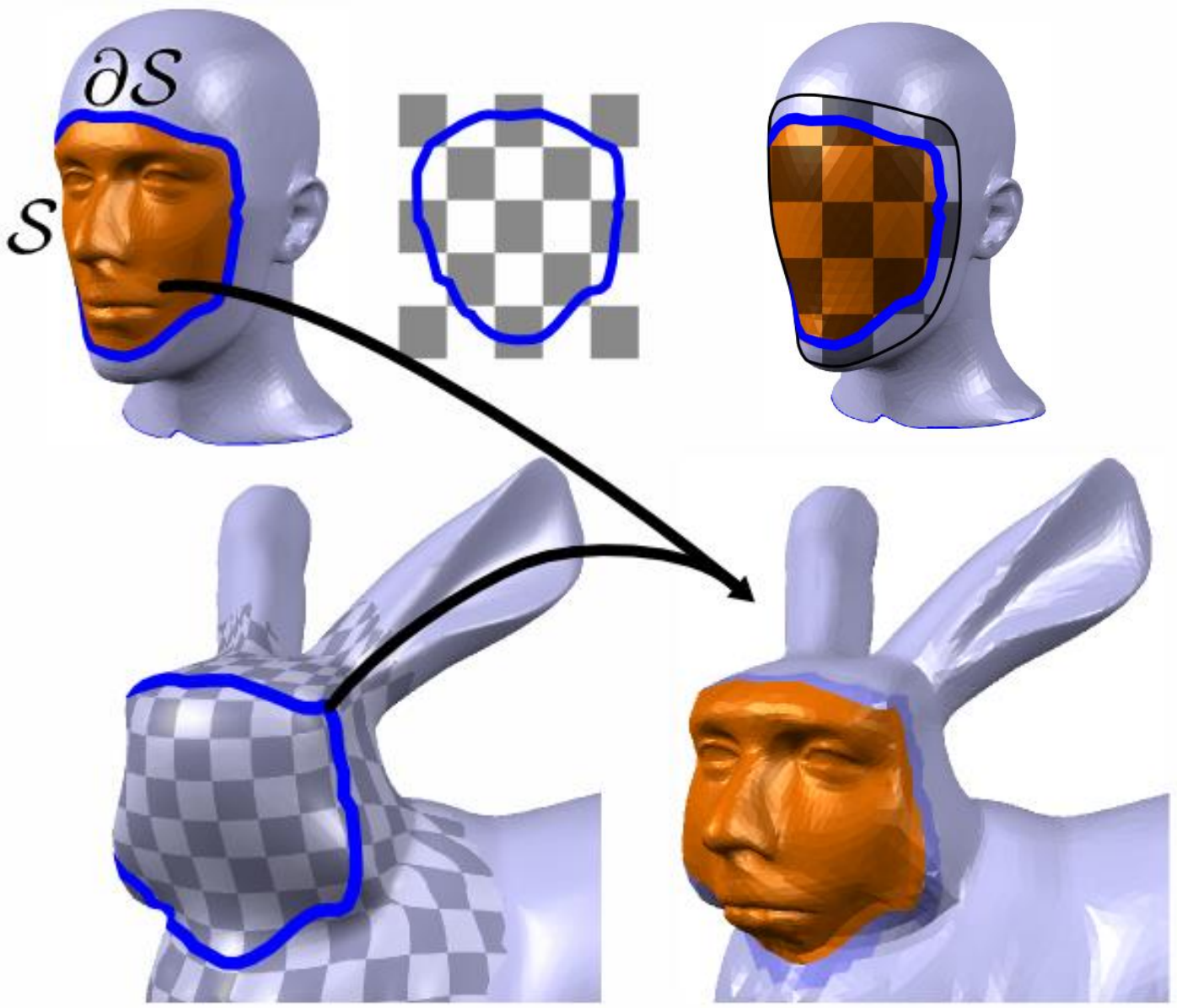
The transformation of a creative vision into a digital 3D model, that is easy to **refine and reuse.**

MeshMixer



[**Schmidt, Singh,** MeshMixer *SIGGRAPH 2010 talks*]
www.meshmixer.com (acquired by Autodesk Inc.)
[**Takayama, Schmidt, Singh, Igarashi, Boubekeur, Sorkine,** GeoBrush: interactive mesh geometry cloning. *Eurographics 2011*]

Parametric boundary based deformation



Key Messages

- Centuries of visual experience captured in artistic practice.
- We have no VIDEO OUT and a **biased** VIDEO IN.
- Regularization: priors, procedural, constraints.
- Principled approaches to art+perception focused design:
  - Understand artistic and perceptual insights.
  - Model or statistically fit artist and viewer data.
  - Leave user ultimate creative control.
  - Validate results perceptually.
- Better tools = Better VIDEO OUT
  Better tools != Better content

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www.dgp.toronto.edu/~karan/sketchsculpt.htm