Sketch based modeling: case studies

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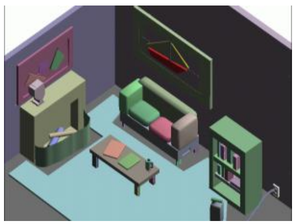
Agenda for the day

- SKETCH
- Teddy, Smoothsketch, Shapeshop, Fibermesh.
- ILoveSketch.
- 3D Analytic Drawing.
- MeshMixer.

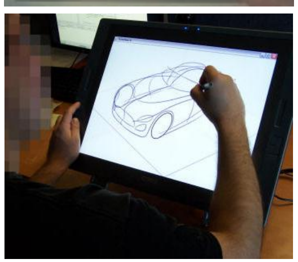
History of sketching tools

Sketchpad [Sutherland 1963]



SKETCH [Zeleznik et al 1996]

Teddy [Igarashi et al 1999]

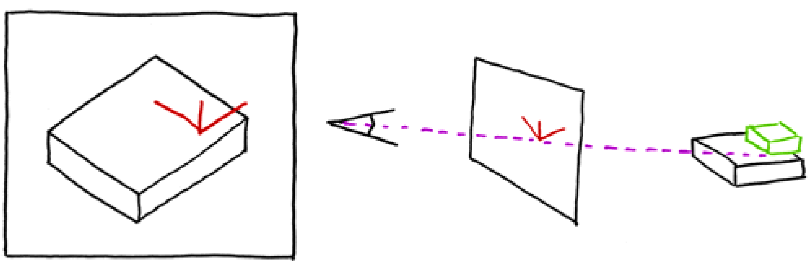


ILoveSketch [Bae et al 2008]

Analytic 3D drawing [Schmidt et al 2009]

SKETCH

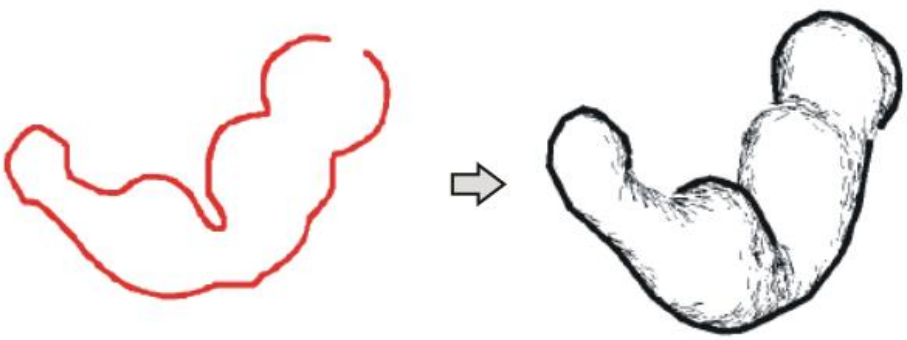
SKETCH recognizes and instances primitive shapes from a few strokes.



R. Zeleznik et al., ***SKETCH****: An Interface for Sketching 3d Scenes*, Proc. of SIGGRAPH'96, 1996.
Website: http://graphics.cs.brown.edu/research/pub/papers/sig96-sketch/sig.html

Teddy

- Teddy inflates a closed 2D stroke like blowing up a balloon.



T. Igarashi et al., ***Teddy**: A Sketching Interface for 3D Freeform Design*, Proc. of SIGGRAPH'99, 1999.

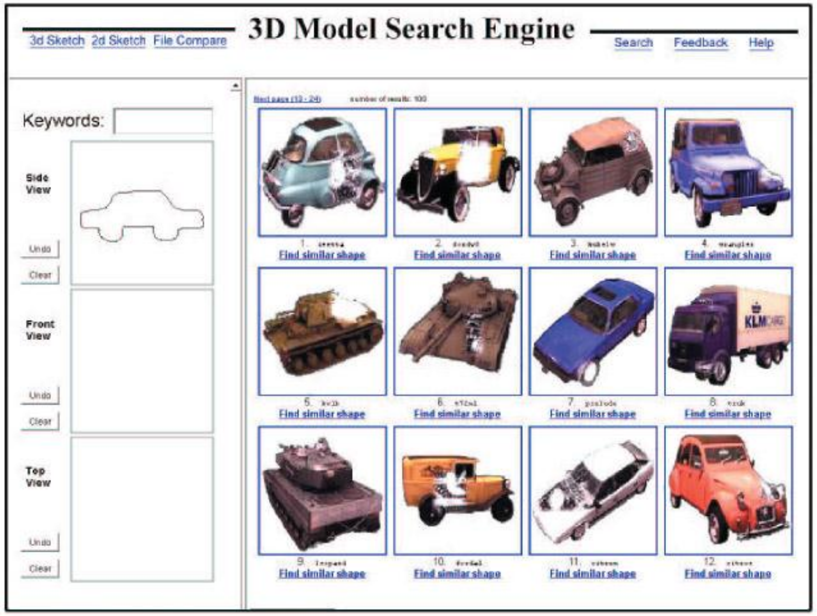
Model creation – categories

- Suggestive systems
  - Sketches compared to template objects
  - *symbolic* or *visual memory*

- Constructive systems
  - Sketches directly used to create object
  - *perceptual* or *visual rules*

Suggestive systems

- User draws complete or gestural sketch.
- Sketch matched against object database or known primitives (a la SKETCH).



Funkhouser et al., *A Search Engine for 3D Models*, Proc. of SIGGRAPH'03, 2003.

Suggestive systems (matching 2D to 3D)

- Extract several contours for each object
- Create feature vector
  - Direct comparison, eg. Euclidean distance

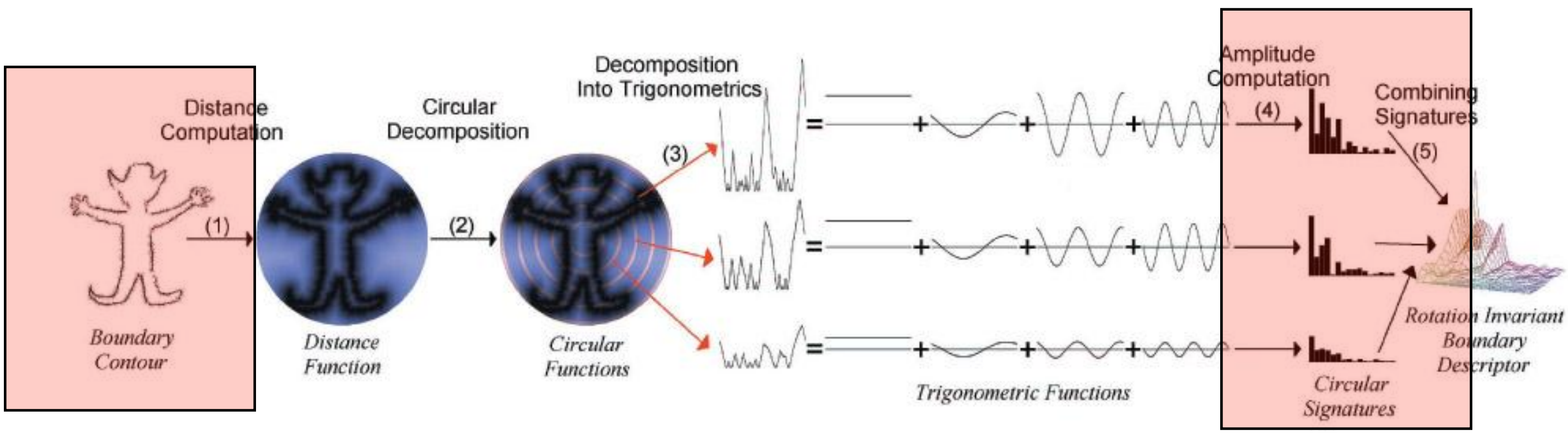
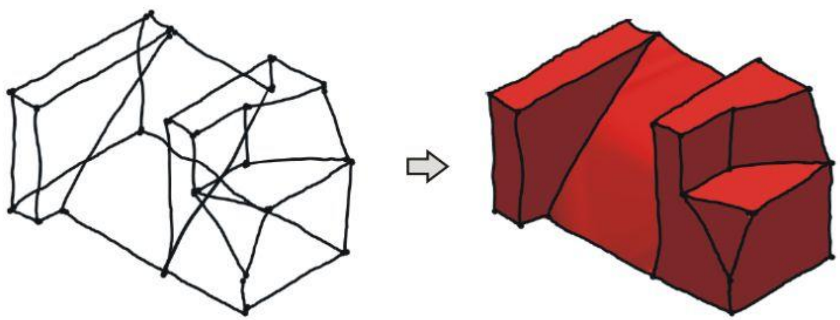


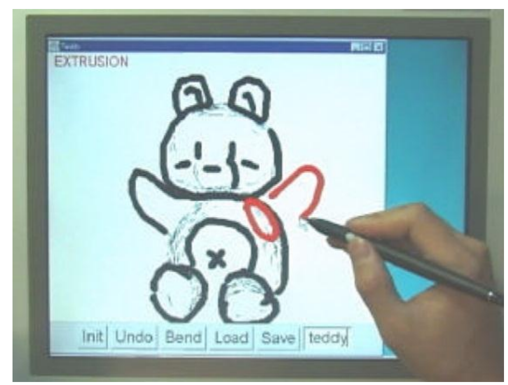
Fig. 9. Computing our shape descriptor for boundary contours.

Funkhouser et al., *A Search Engine for 3D Models*, Proc. of SIGGRAPH'03, 2003.

Constructive systems

- Rules and constraints rather than templates:
  - Restricting application domain (eg. sketching roads).
  - Restricting object type (eg. mechanical or organic).
  - Restricting task (eg. smoothing, cutting or joining).

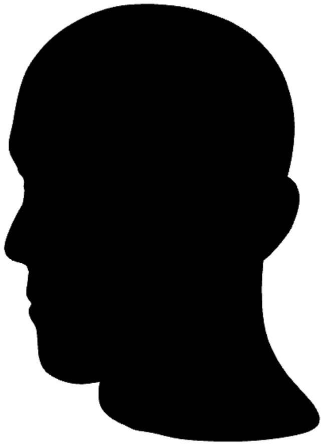




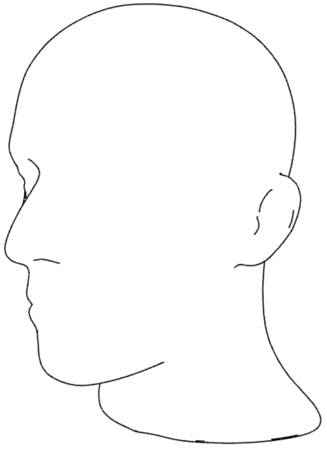
M. Masry and H. Lipson, *A Sketch-Based Interface for Iterative Design and Analysis of 3D Objects*, EG SBIM'05, 2005.
T. Igarashi et al., ***Teddy**: A Sketching Interface for 3D Freeform Design*, Proc. of SIGGRAPH'99, 1999.

Sketching contour lines

- Silhouette: separate object from background

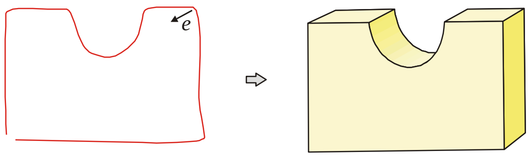


- Contour: separate visible from invisible

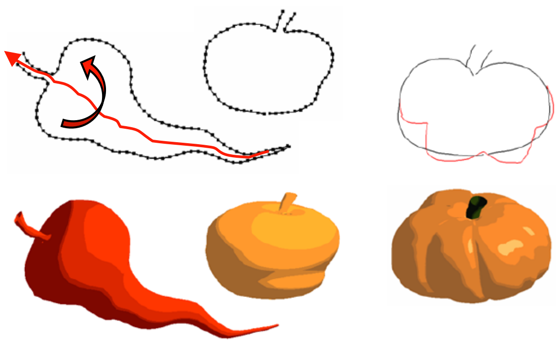


Constructive systems (contours)

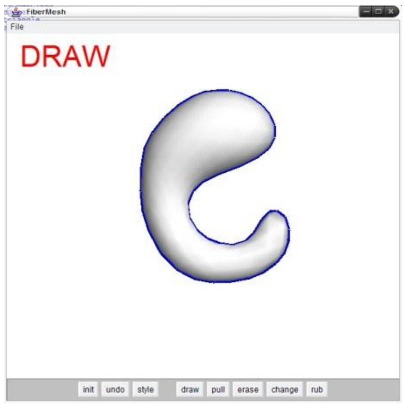
- Extrusion (Google Sketchup).



- Rotation about skeleton



- Inflation



Inflation

- Offset surface proportionally to distance from spine of the contour
- Produces smooth blobby objects

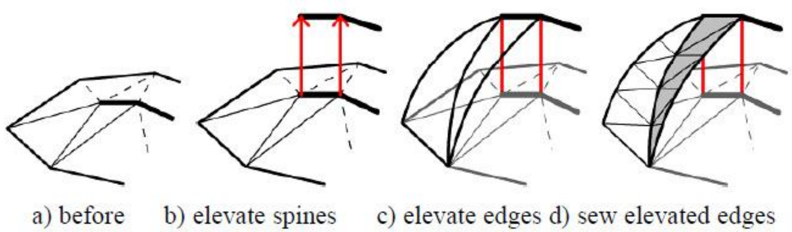
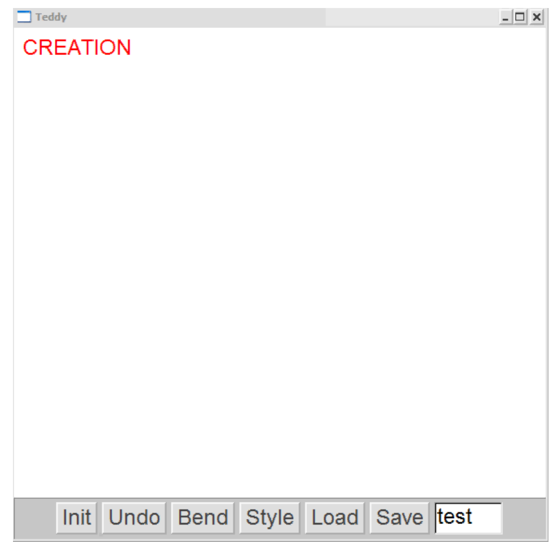


Figure 15: Polygonal mesh construction.



Igarashi et al., ***Teddy**: A Sketching Interface for 3D Freeform Design*, SIGGRAPH'99, 1999.

Skeleton extraction

- Delaunay triangulation
- Chordal axis transform

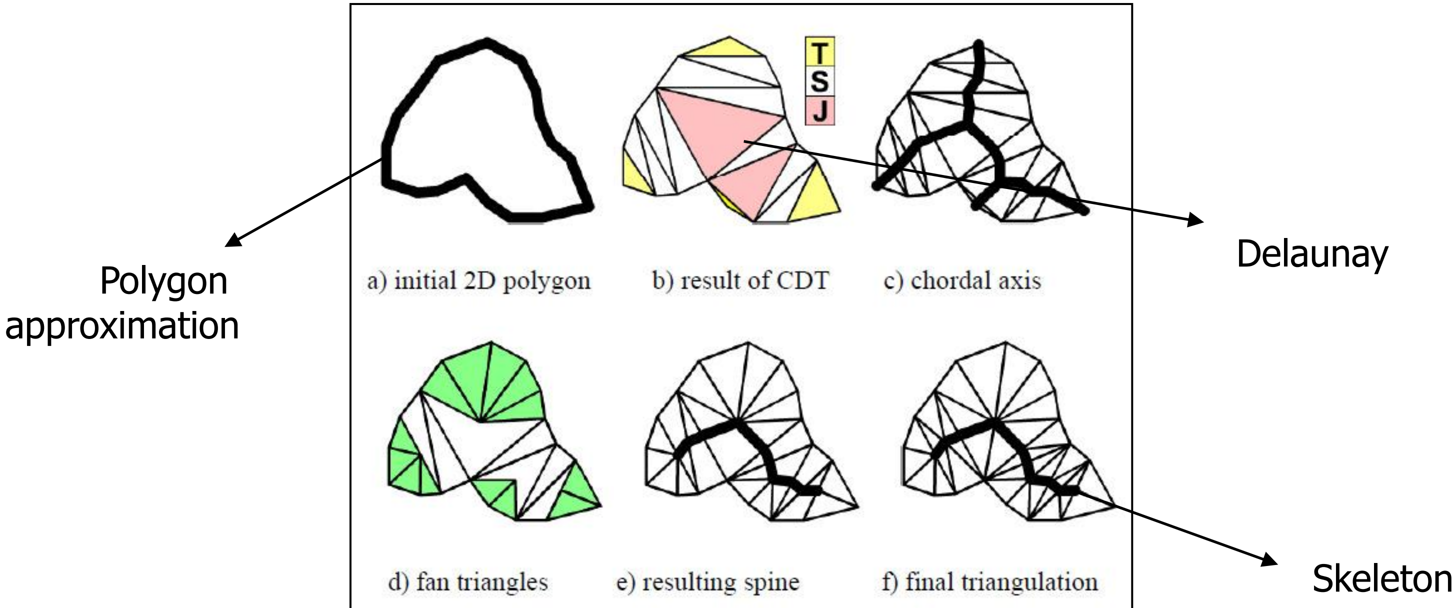


Figure 13: Finding the spine.

Igarashi et al., ***Teddy****: A Sketching Interface for 3D Freeform Design*, SIGGRAPH'99, 1999.

Implicit surfaces

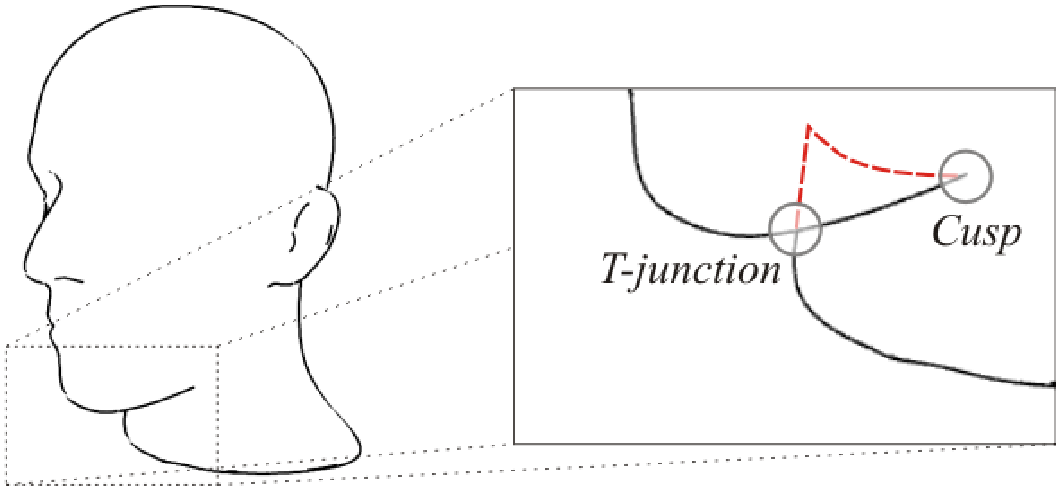
- Skeletal representation fits naturally with implicits
  - collection of line or point primitives
  - variational implicits
- ShapeShop3D

Figure 11: *Gremlin model created using 64 primitives*

B. Wyvill et al., *Sketch-Based Construction and Rendering of Implicit Models*, Proc. Computational Aesthetics in Graphics, 2005.

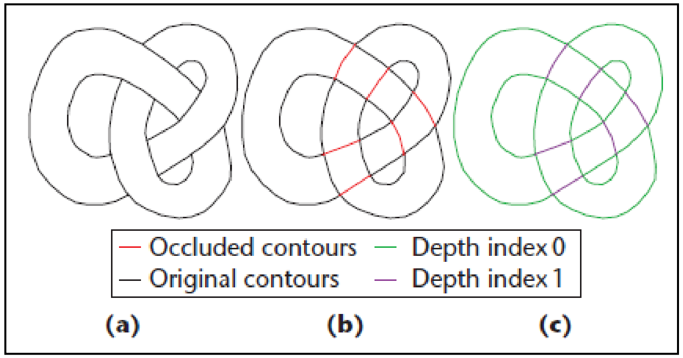
Trouble with contours and silhouettes

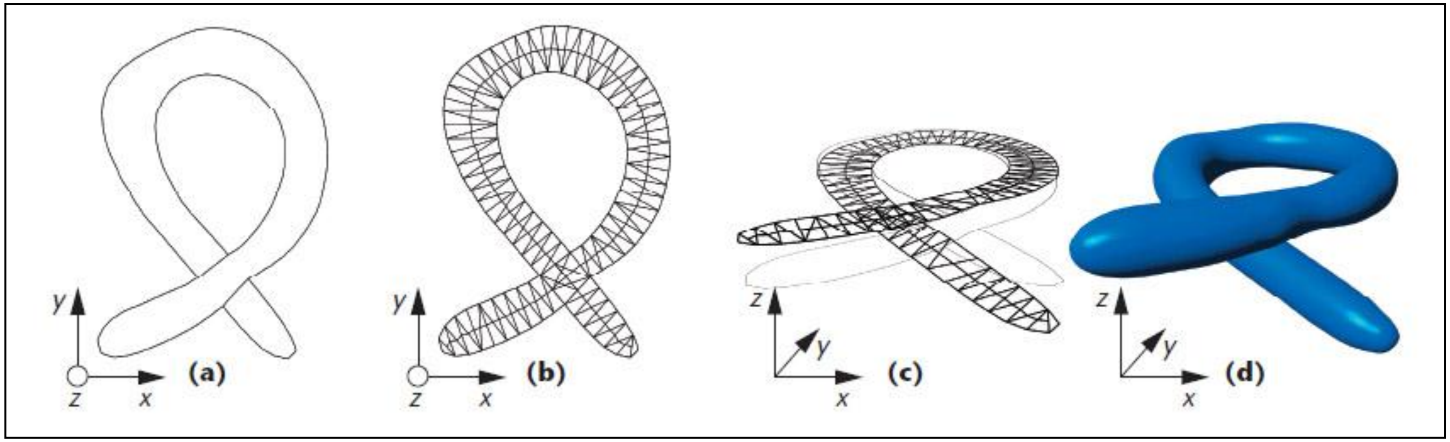
- Rarely planar.
- Can contain T-junctions and cusps.
- Occlusion.



Hidden contours

- Find hidden lines
- “Smarter” inflation





F. Cordier and H. Seo, *Free-Form Sketching of Self-Occluding Objects*, IEEE Computer Graphics and Applications, 27(1), 2007.

3D Curve networks: surface optimization

- Surface results from solving non-linear system
  - 3D curves defines geometric constraints
  - Smoothness constraints

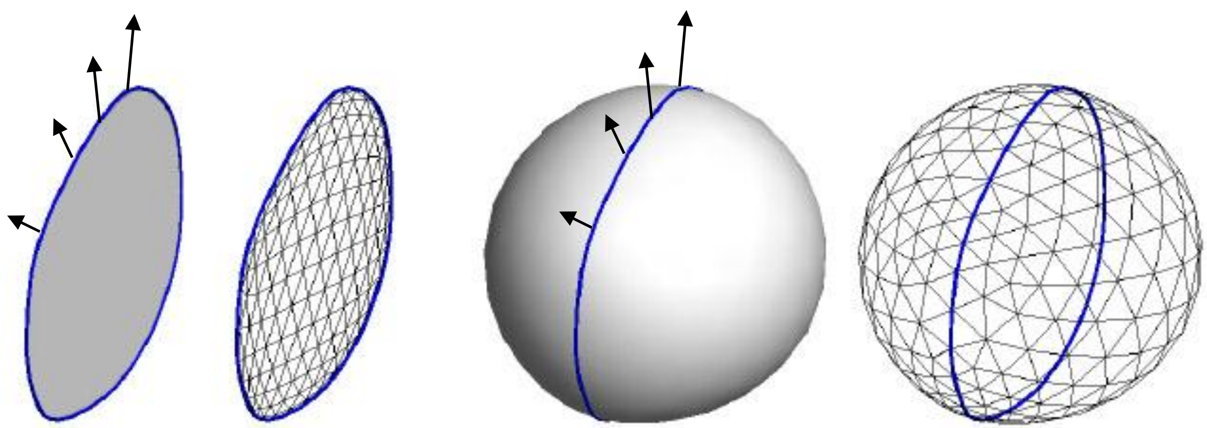
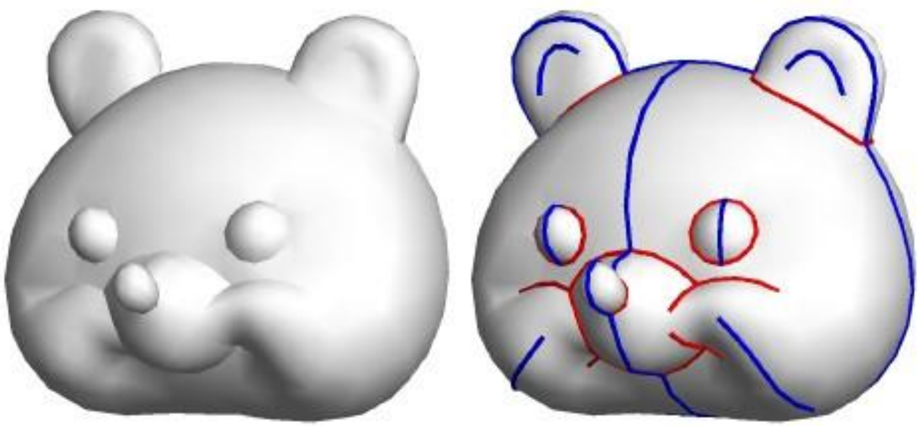


Figure 11: *The results of least-squares meshes (left) and our non-linear solution (right) for a planar curve.*

A. Nealen et al., ***FiberMesh****: Designing Freeform Surfaces with 3D Curves*, Proc. of SIGGRAPH'07, 2007.

FiberMesh

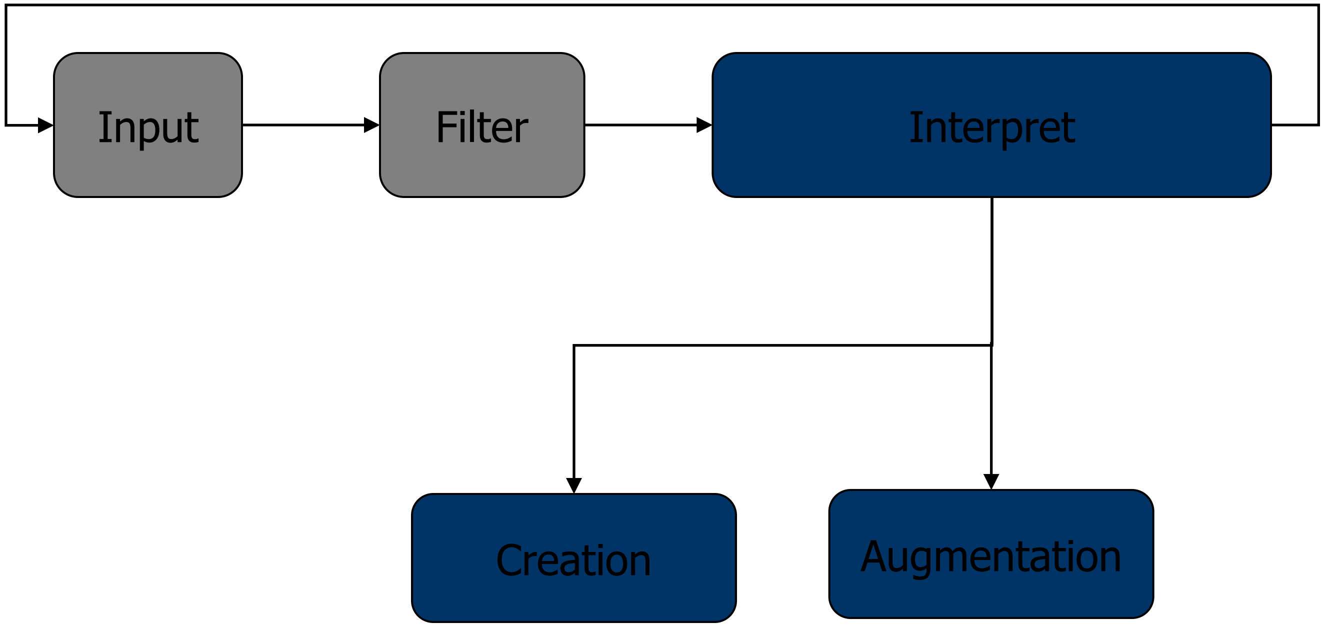
- User can specify additional curves on the surface
  - Further constraints that define surface
  - Sharp features



A. Nealen et al., ***FiberMesh****: Designing Freeform Surfaces with 3D Curves*, Proc. of SIGGRAPH'07, 2007.

Pipeline revisited

- More ways to use sketched input!



I ♥ SKETCH (multi-view sketching)

A corpus of research in sketch based modeling exists without a single such system in practical use…

Why?

- No clear overall user workflow.
- Insufficient vocabulary and quality of 3D curves.
- Poor transition from 2D sketching practice.

I ♥ SKETCH: multi-view sketching

s-view	——+	m-view
static	——+——	dynamic
precise	——+	free-form
symbolic	+——+	perceptual

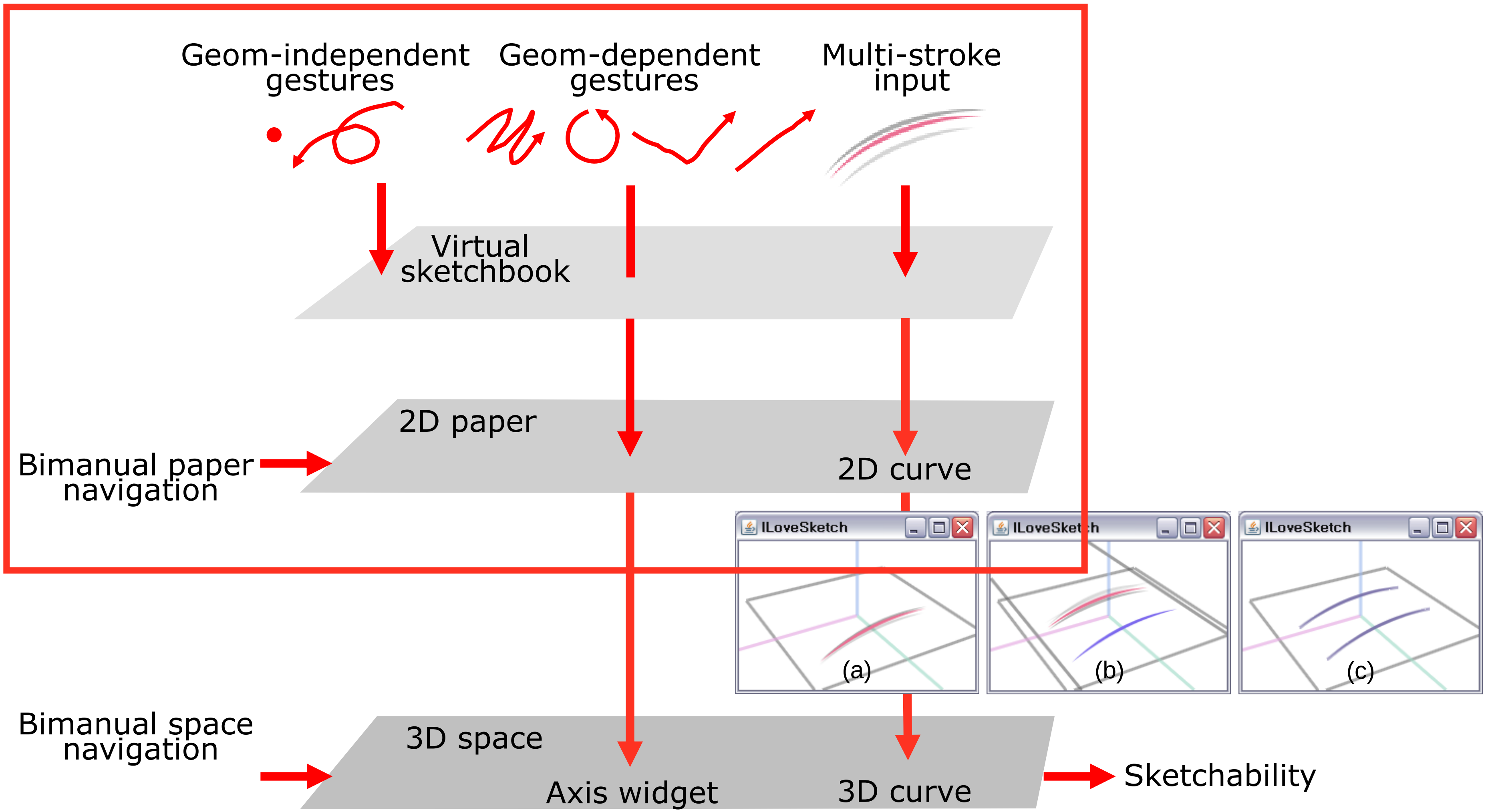
I ♥ SKETCH: multi-view sketching

A judicious leap from 2D to 3D.

- Presents a virtual 2D sketchbook with simple paper navigation and automatic rotation for ergonomic *pentimenti* style 2D sketching.
- Seamless transition to 3D with a suite of *multi-view curve sketching* tools with context switching based on *sketchability*.

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

I ♥ SKETCH

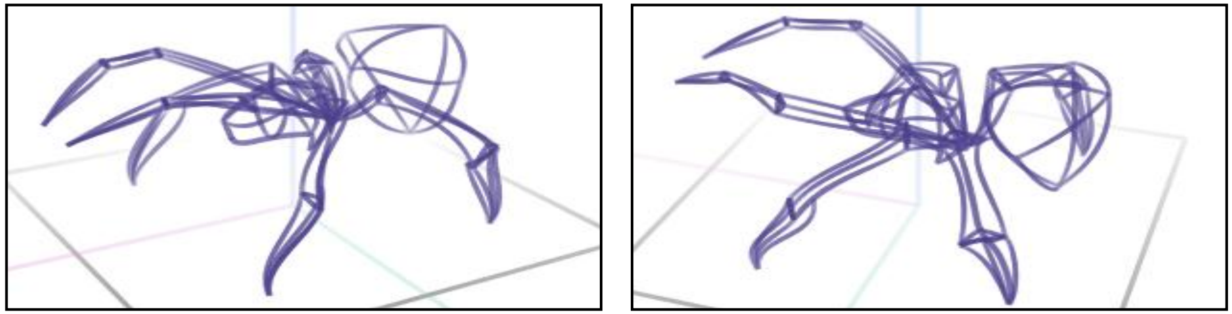


Geom-independent gestures
Geom-dependent gestures
Multi-stroke input
Virtual sketchbook
2D paper
Bimanual paper navigation
2D curve
ILoveSketch
(a)
(b)
(c)
Bimanual space navigation
3D space
Axis widget
3D curve
Sketchability

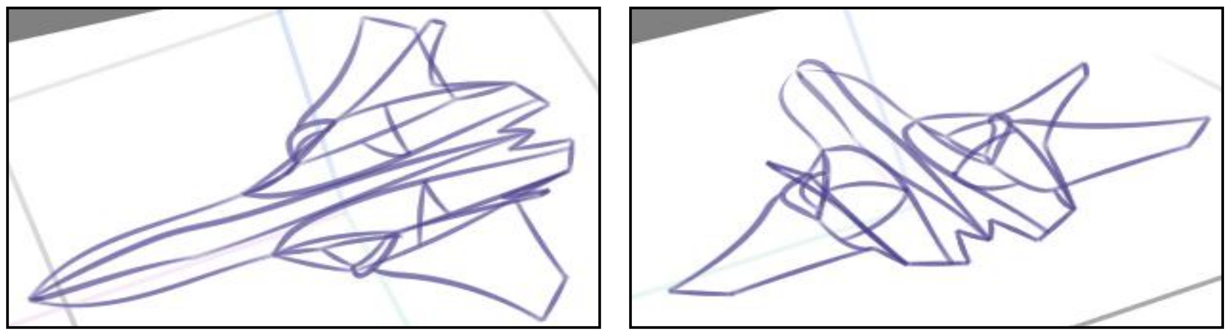
I ♥ SKETCH

Evaluated by a senior professional automotive designer.

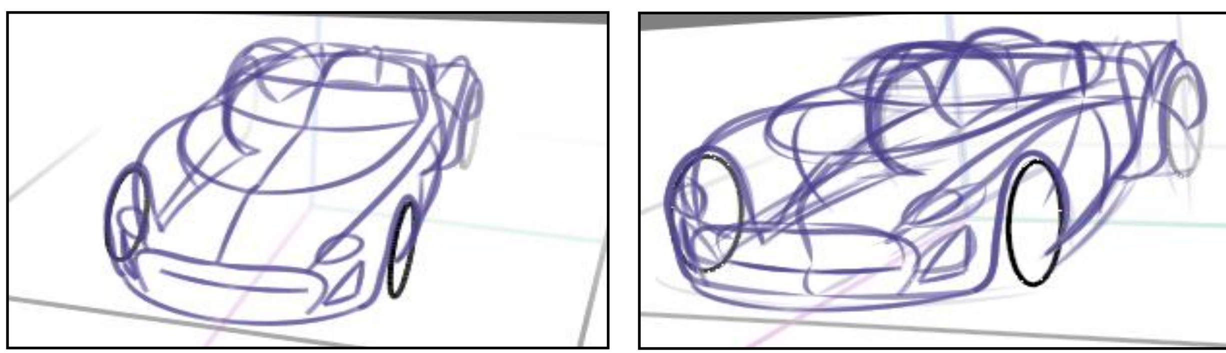
After 1.5 hours



30 mins. later



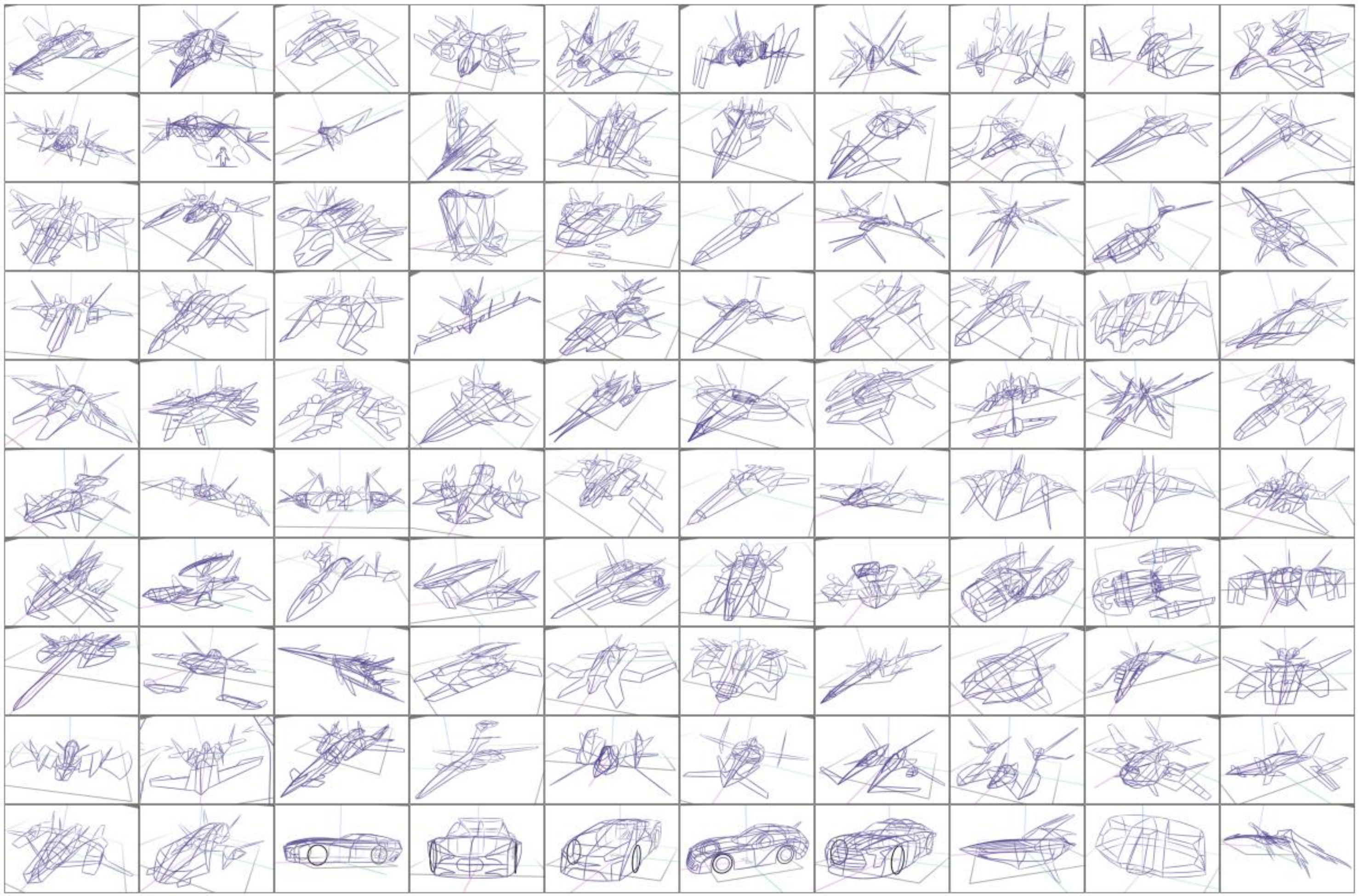
2.5 hours later



I♥SKETCH (at SIGGRAPH 09 eTech)

100 models created over 4 days (made public for research)

http://www.dgp.toronto.edu/~shbae/ilovesketch_siggraph2009.htm

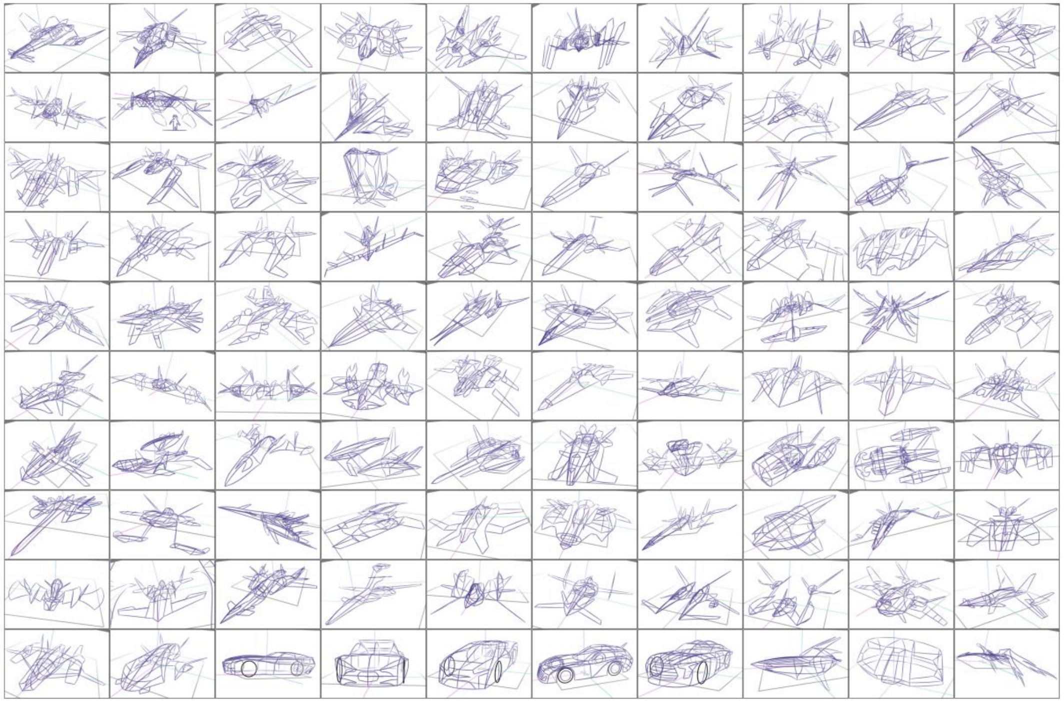


I ♥ SKETCH (at SIGGRAPH 09 eTech)

2 open problems:

determine patch topology

define surface patches (quad meshing with N-sided patches?)

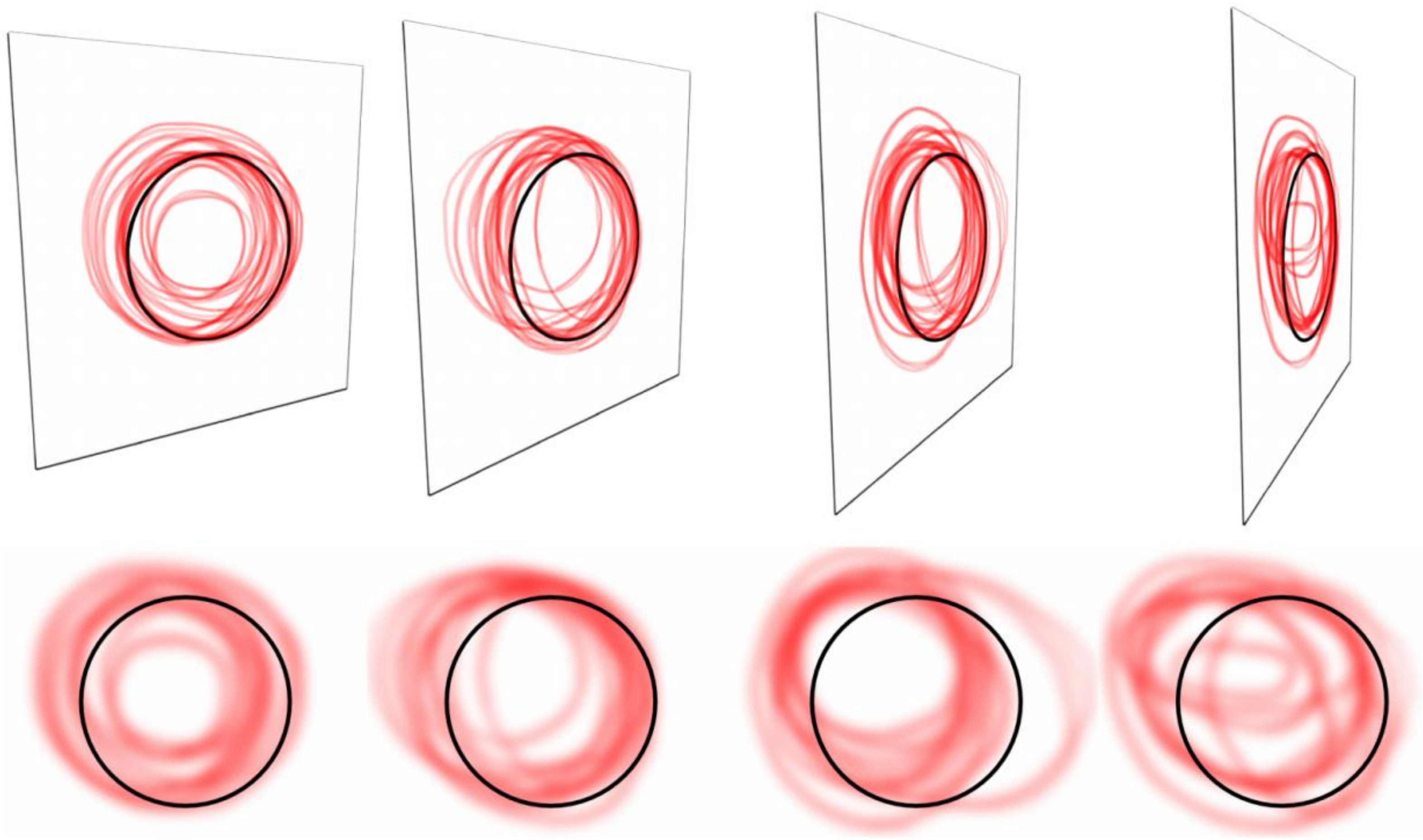


EverybodyLovesSketch

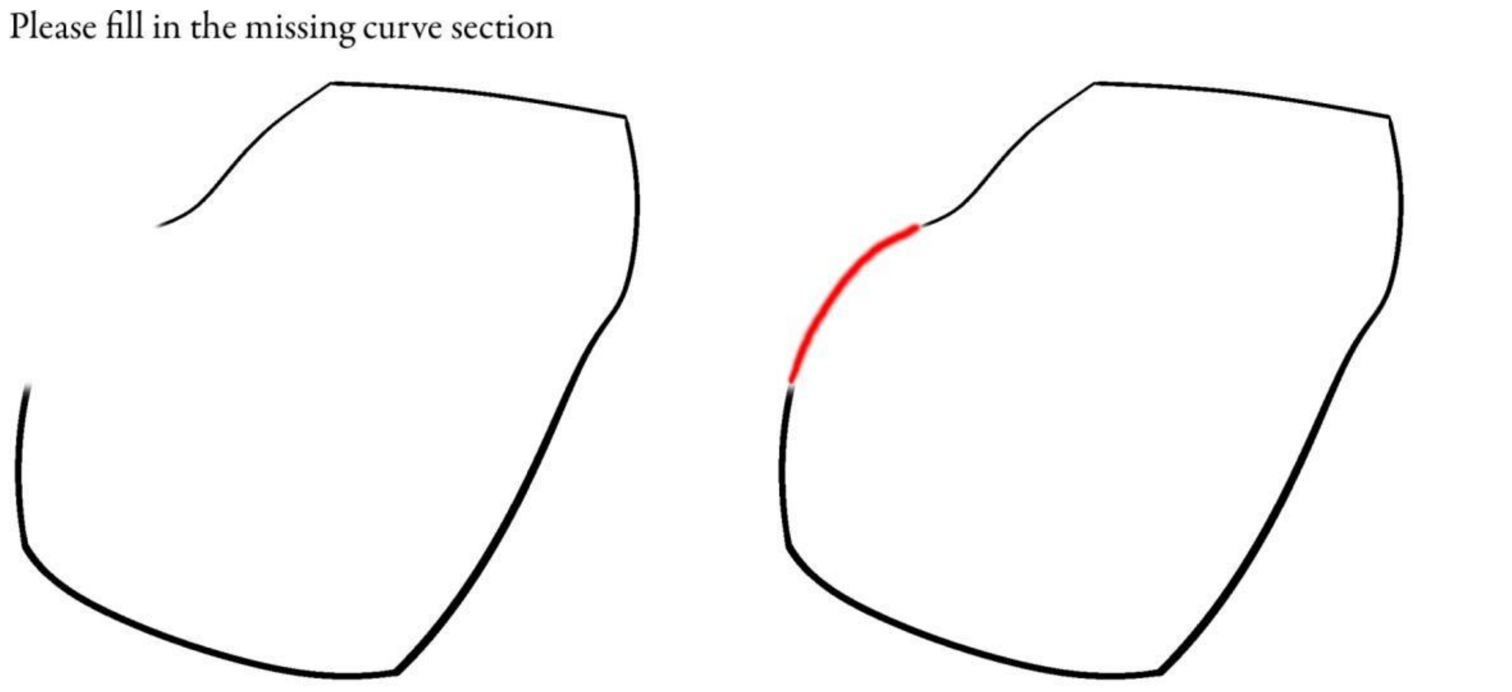
- ILoveSketch refined for a broad audience.
- Analysis of analytic drawing practice.
  - Ticks.
  - Perspective grid.
- Surfacing for projective curve sketching.
- Comprehensive evaluation.

[**Bae, Balakrishnan & Singh**, EverbodyLovesSketch: 3D sketching for a broader audience. *UIST 2009*]

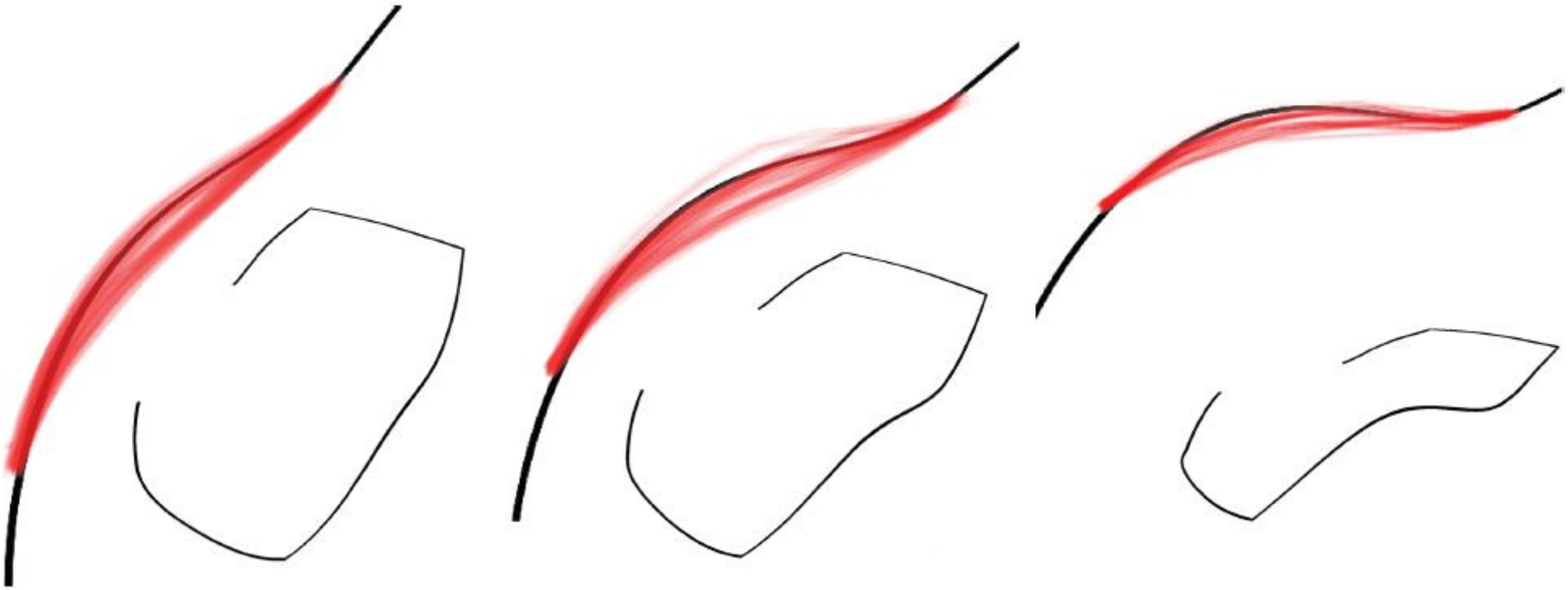
Expert Drawing I: Circle-on-Plane



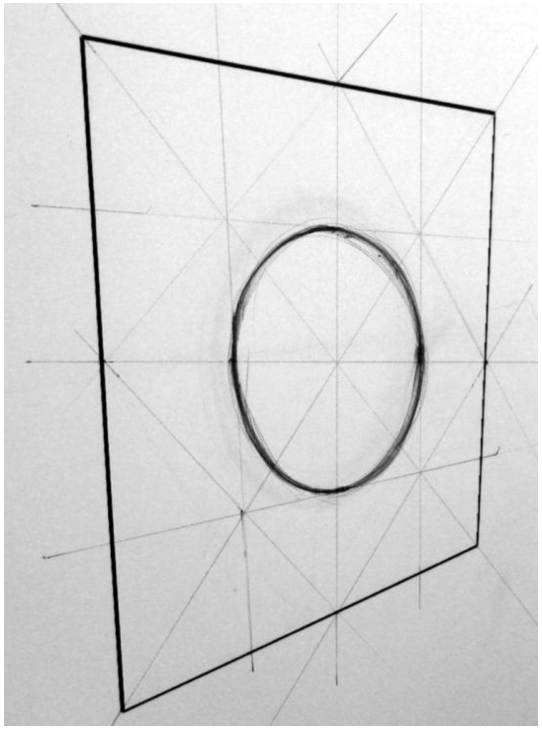
Expert Drawing II: Silhouette Curves

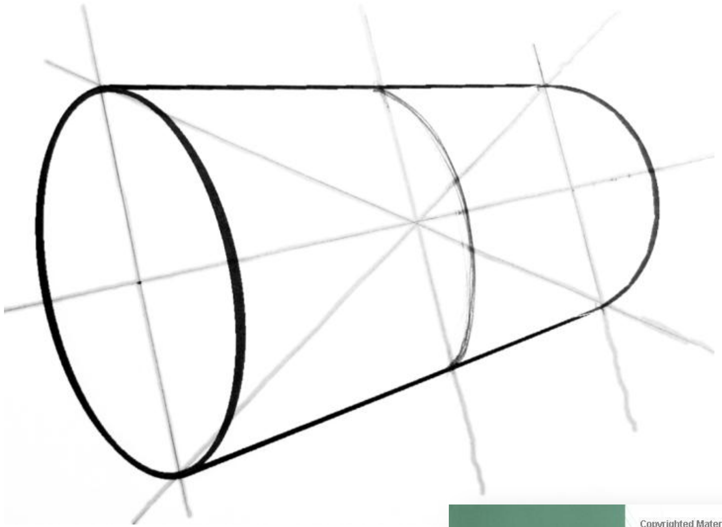


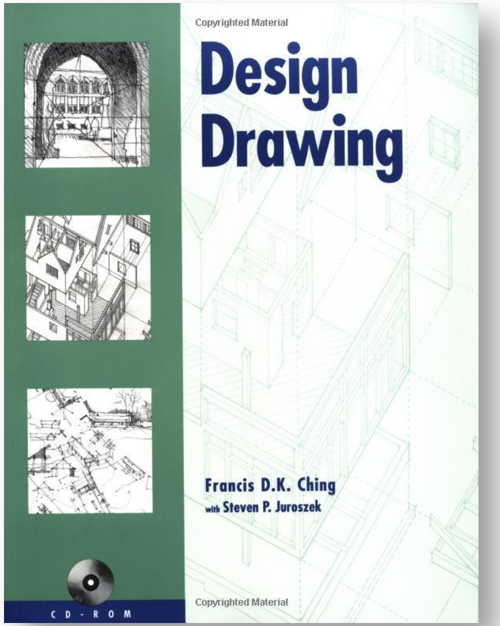
Expert Drawing II: Silhouette Curves



Experts and drawing systems

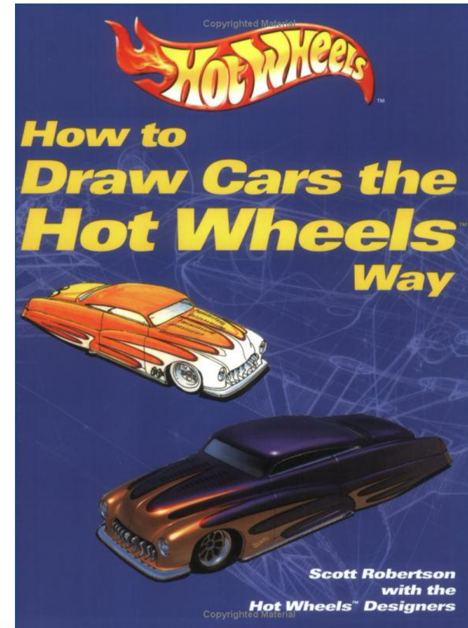


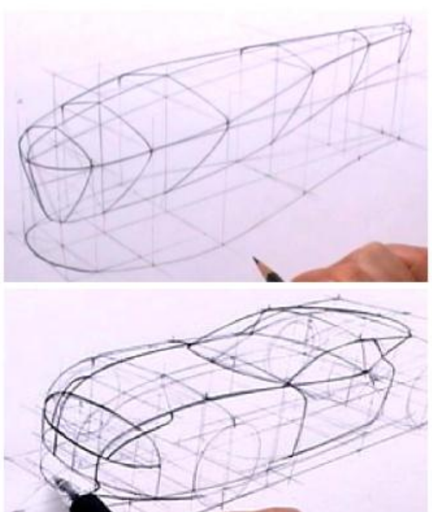


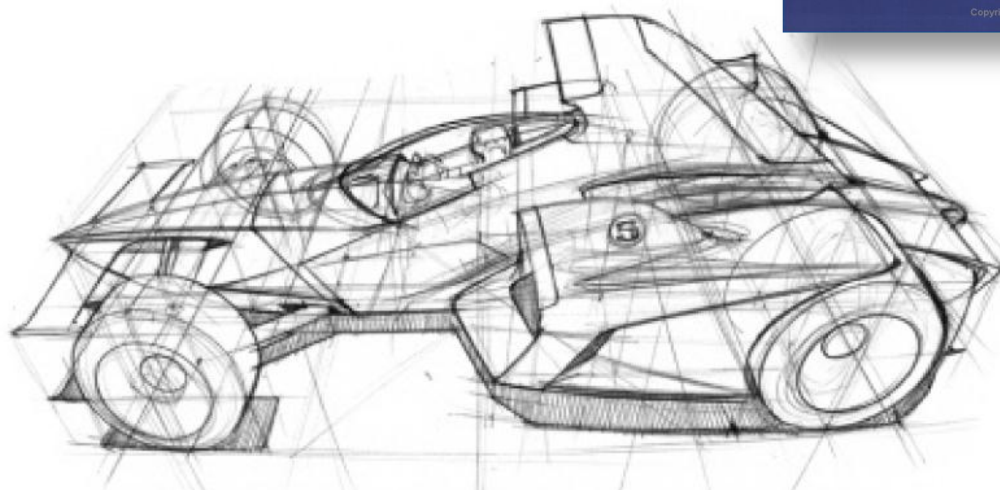


Analytic Drawing: single-view sketching

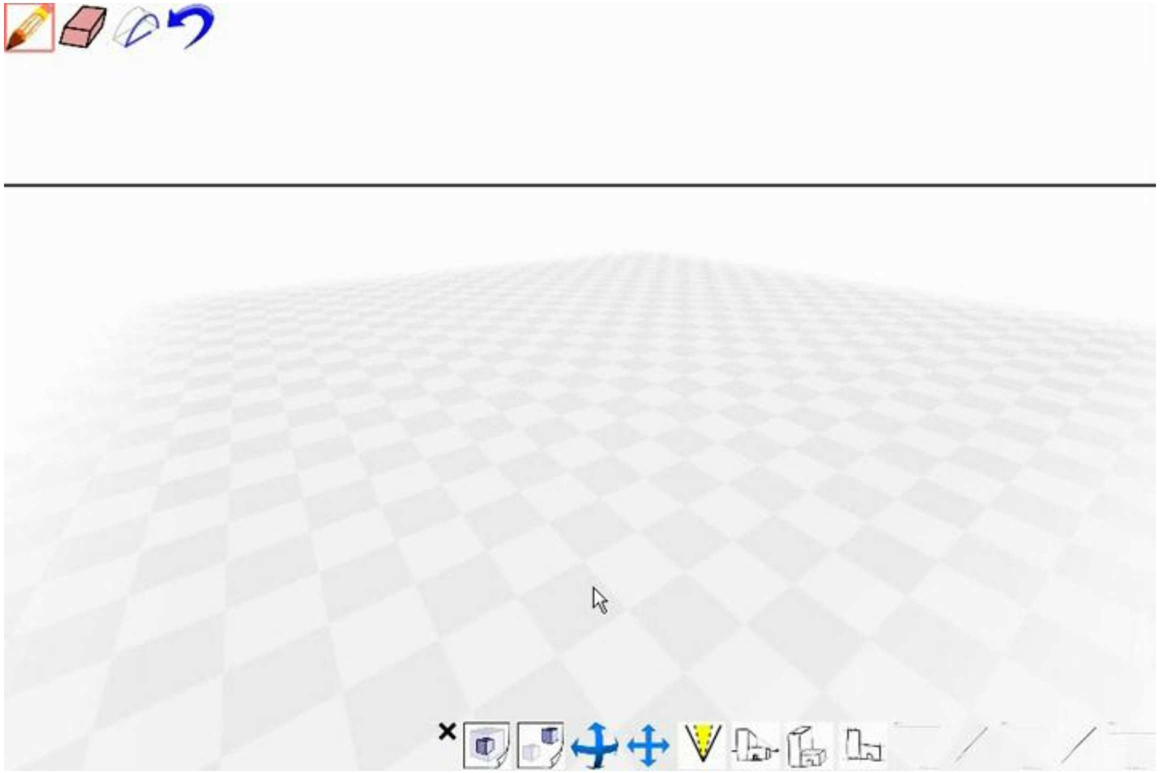
1. Pick a drawing system
   - 2-point perspective, isometric,…
   - Rules for how to interpret lines
2. Construct a 3D scaffold
3. Draw curves within the scaffold



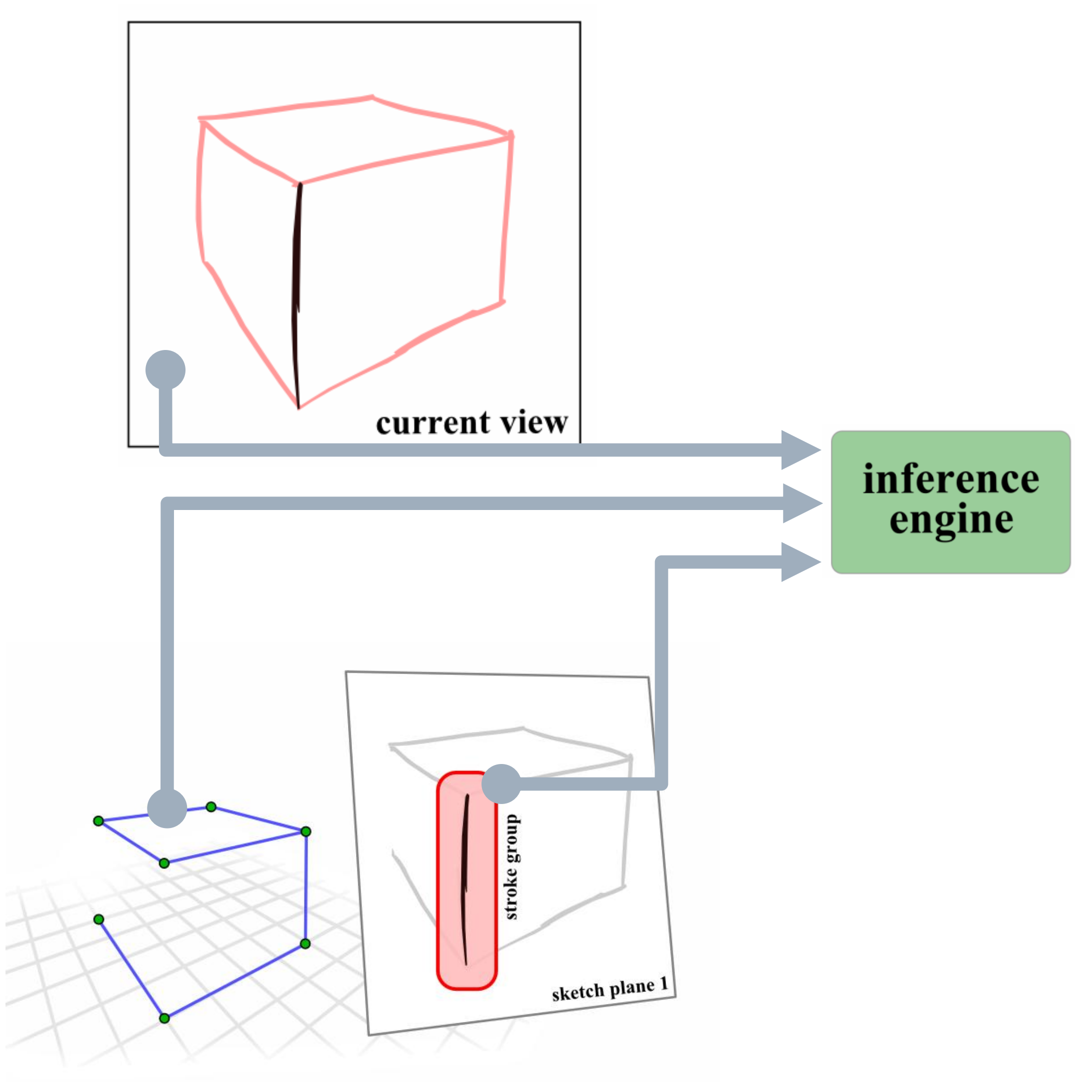




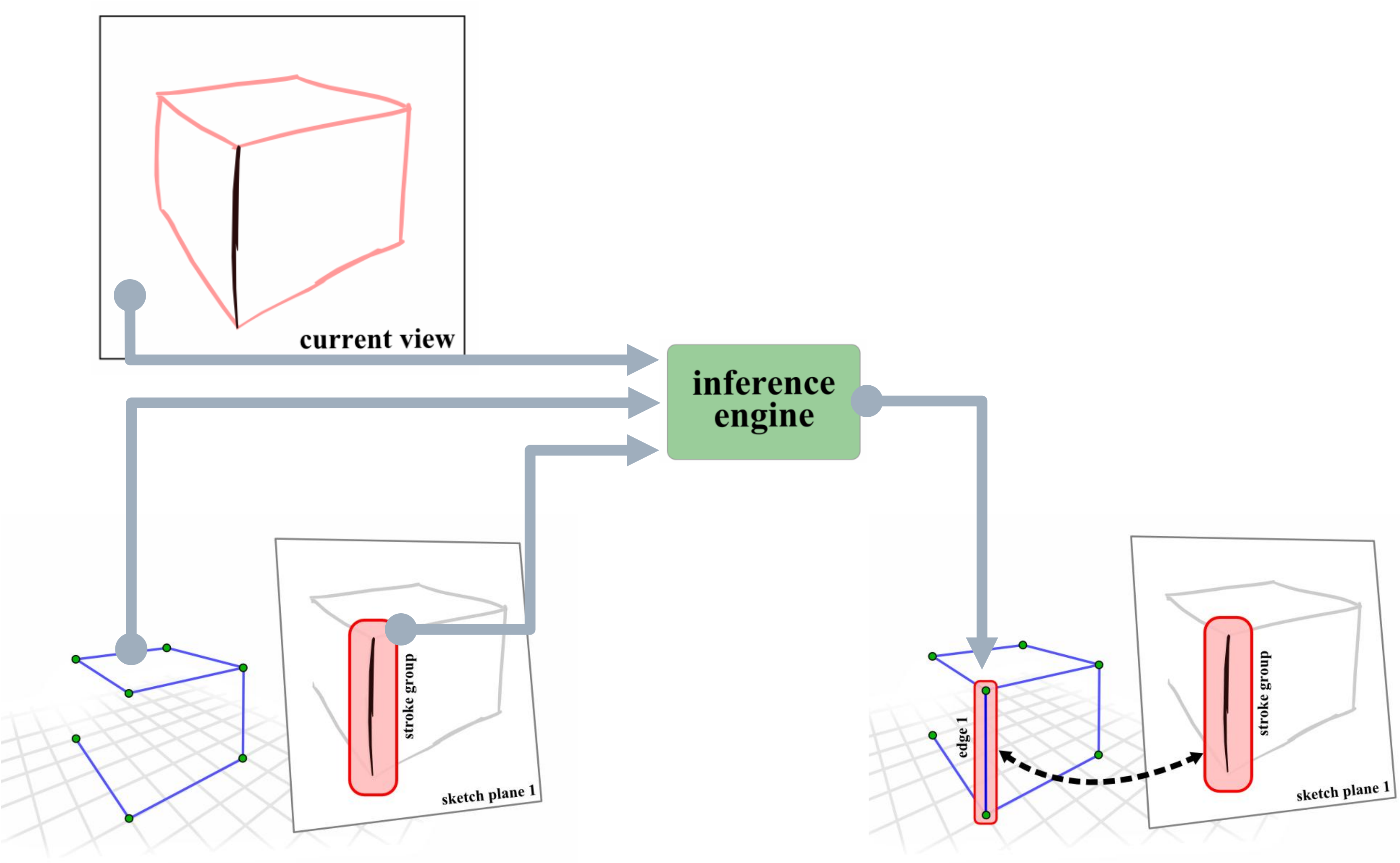
Drawing Interface Overview



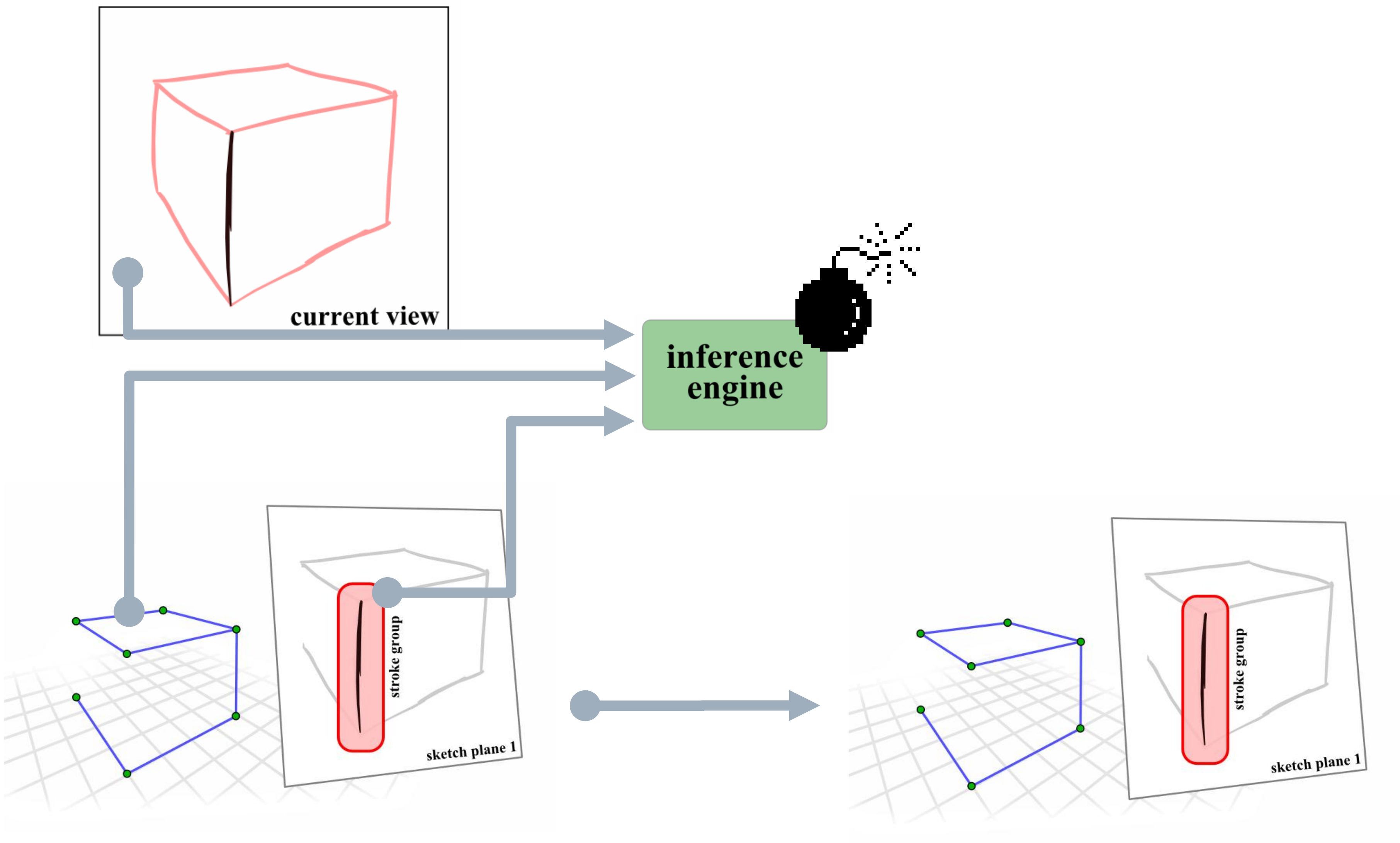
Pure Drawing Interface



Pure Drawing Interface

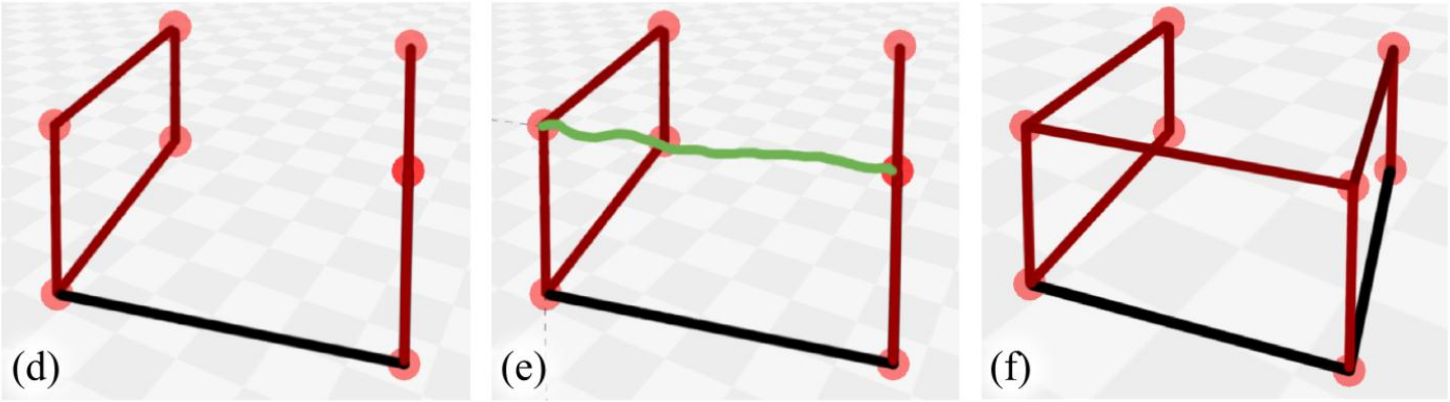


Pure Drawing Interface



Inference Engine

- Want to evaluate "fitness" of a 3D segment.
  - Relative to stroke
  - Relative to context (current scaffold)
- Scaffold == constraints (position, length, direction).
- Redundancy resolves ambiguity.



Fitness function (probabilistic model)

(**Term 1**) deviation between stroke and projected segment

- "snapping" term
- Used in most sketching systems

+ scaffold context:

(**Term 2**) Prior preferences for 3D geometry

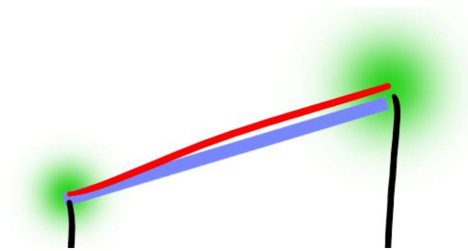
- Same length/direction as existing segments

(**Term 3**) Weighted count of constraint sets

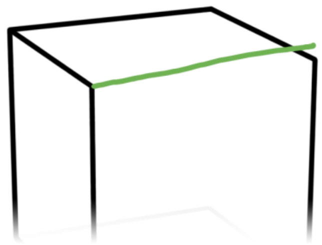
- This term is not smooth…

Fitness function

$$\mathbf{F}(l) = \mathbf{S}(s, l)\mathbf{G}(l) \sum_i \mathbf{C}(\mathbf{c}_i, l)$$

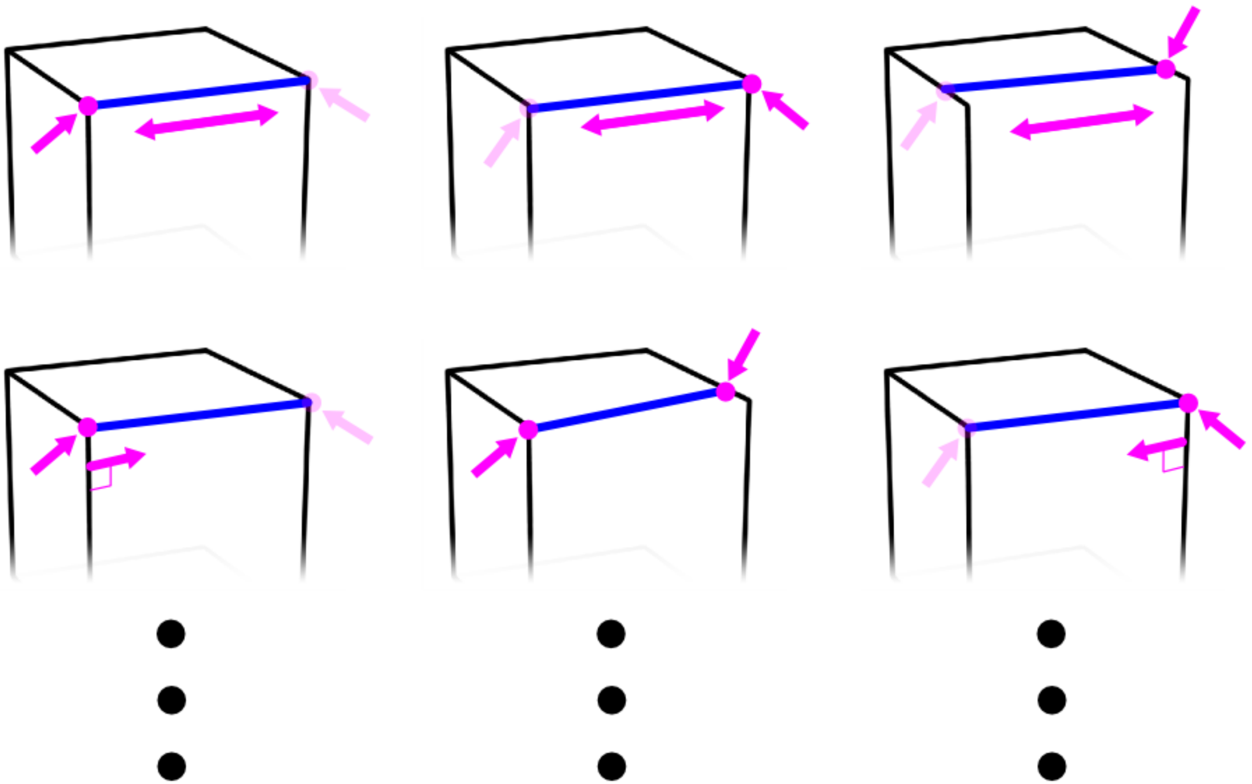
- $\mathbf{S}$ 
- $\mathbf{G}$ A mixture-of-Gaussian terms.
- $\mathbf{C}$ is a set of constraints
- $\mathbf{C}(\mathbf{c}_i, l) = \begin{cases} \mathbf{C}(\mathbf{c}_i) & \text{if } l \text{ satisfies } \mathbf{c}_i, \\ 0 & \text{otherwise} \end{cases}$
- Makes $\mathbf{F}$ highly discontinuous

Inference Algorithm



Inputs: stroke, scene

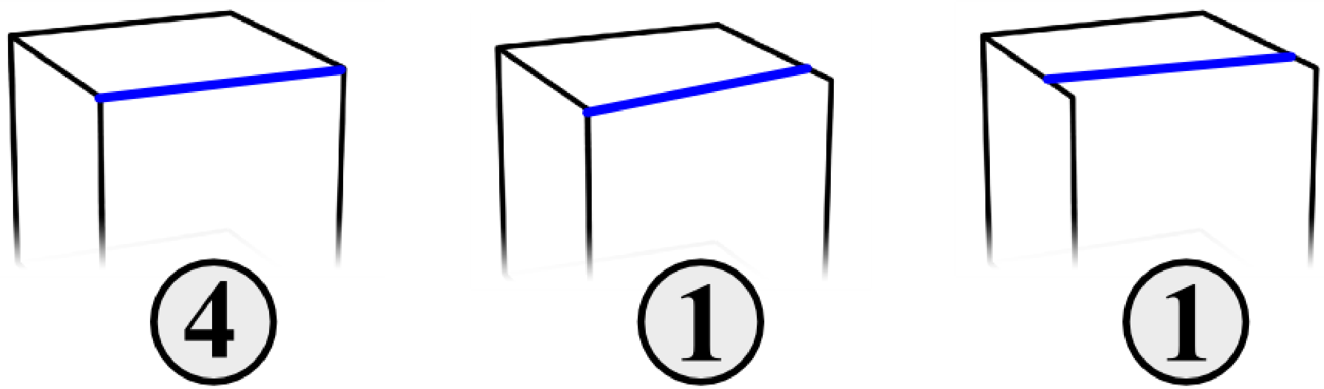
1. Query scene for potential constraints
2. Exhaustively enumerate constraint groupings



Inference Algorithm

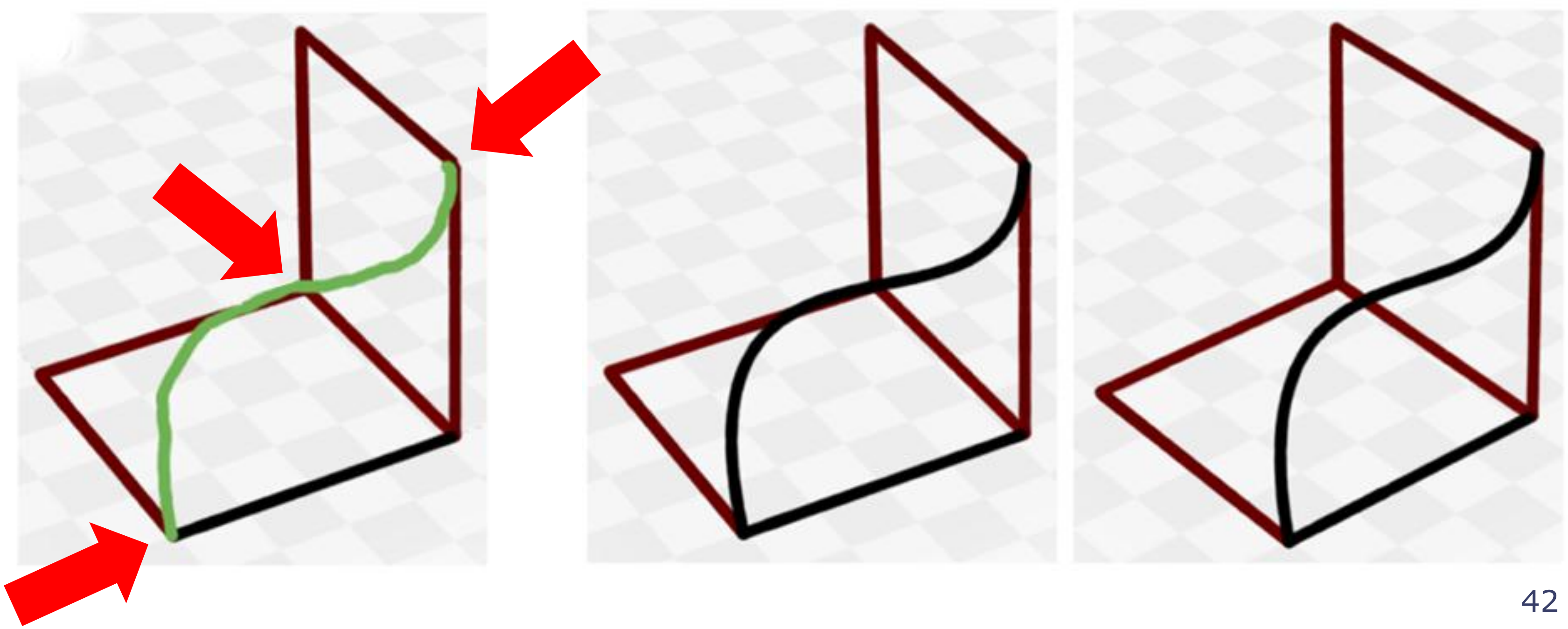
Inputs: stroke, scene

1. Query scene for potential constraints
2. Exhaustively enumerate constraint groupings
3. Return highest-scoring segment

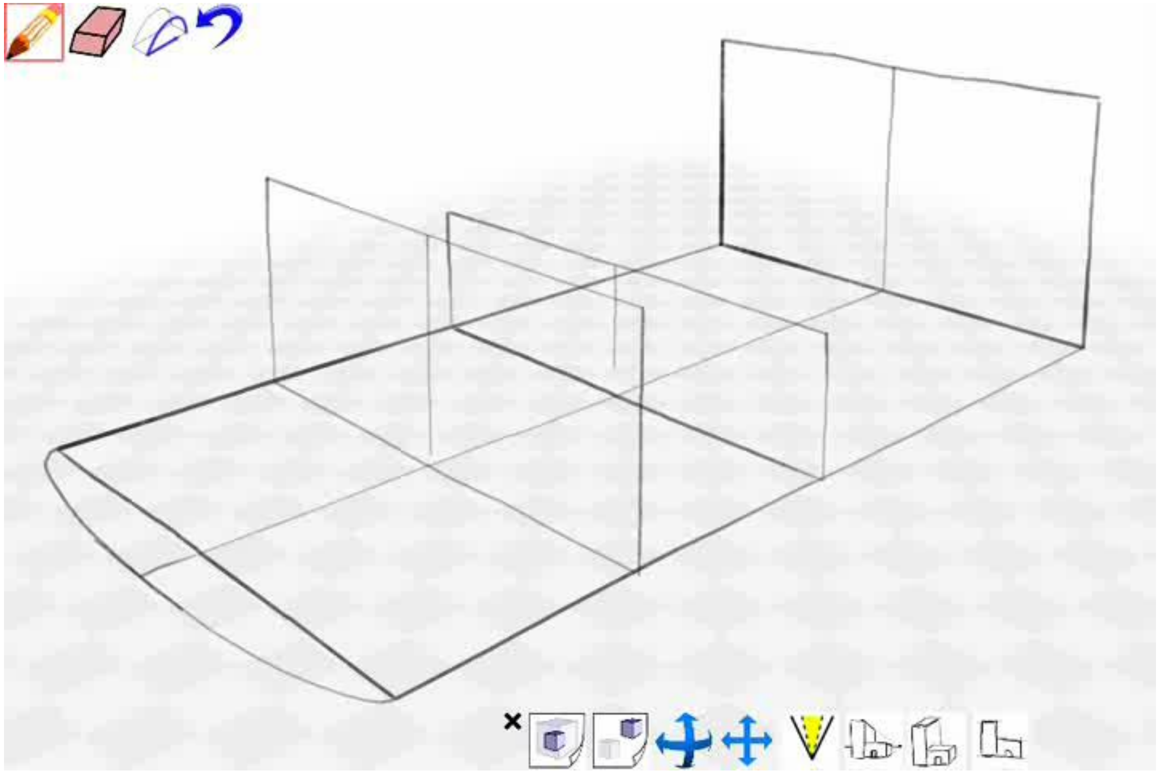


Curve Inference

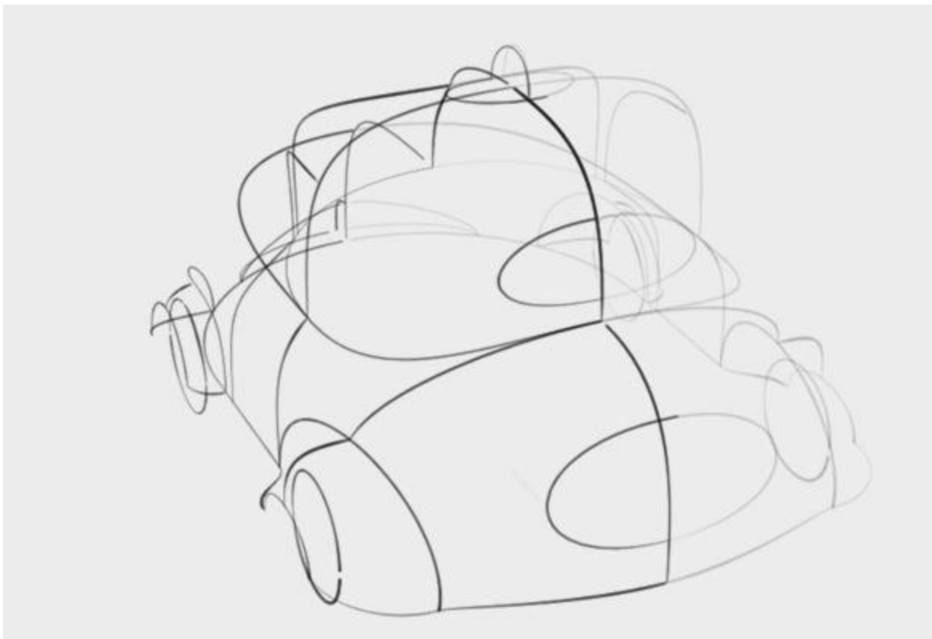
- Curve is cubic Bezier least-squares fit to stroke.
- Same fitness function as lines.
  - Snapping tolerance increased for sketchy curves.
  - Curve prior favours circular arcs.
  - Planarity and symmetry constraints added.



Curves



Analytic drawing of 3D scaffolds



s-view — m-view
static — dynamic
precise — free-form
symbolic — perceptual

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

Drive: single-view sketching

A sketch-based system to create conceptual layouts of 3D path networks.

Drive Features

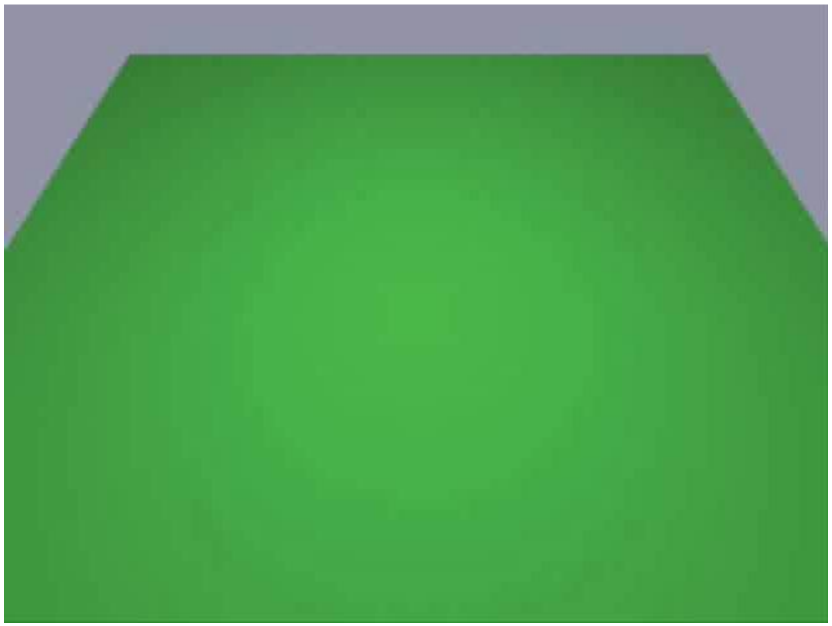
- Elegant interface:

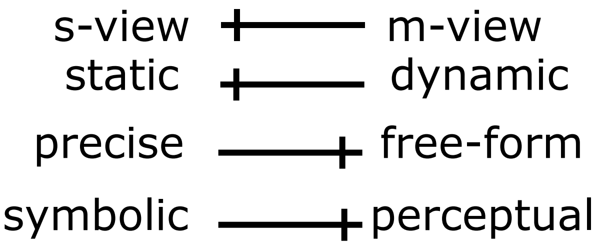
  open stroke = path

  closed stroke = selection-action menu.
- Piecewise clothoid path construction.
- Crossing paths.
- Break-out lens. (single-view context)
- Terrain sensitive sketching.

[**McCrae & Singh**, Sketching based Path Design, *Graphics Interface 2009*]

Drive





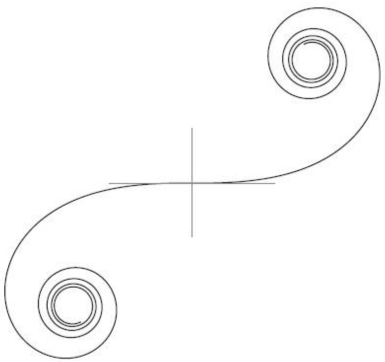
[**McCrae & Singh**, Sketching based Path Design, *Graphics Interface 2009*]

What are Clothoids?

- Curves whose curvature changes linearly with arc-length.
- Described by Euler in 1774, a.k.a. Euler spiral.
- Studied in diffraction physics, transportation engineering (constant lateral acceleration) and robot vehicle design (linear steering).

$$C(t) = \int_0^t \cos \frac{\pi}{2} u^2 du$$

$$S(t) = \int_0^t \sin \frac{\pi}{2} u^2 du$$

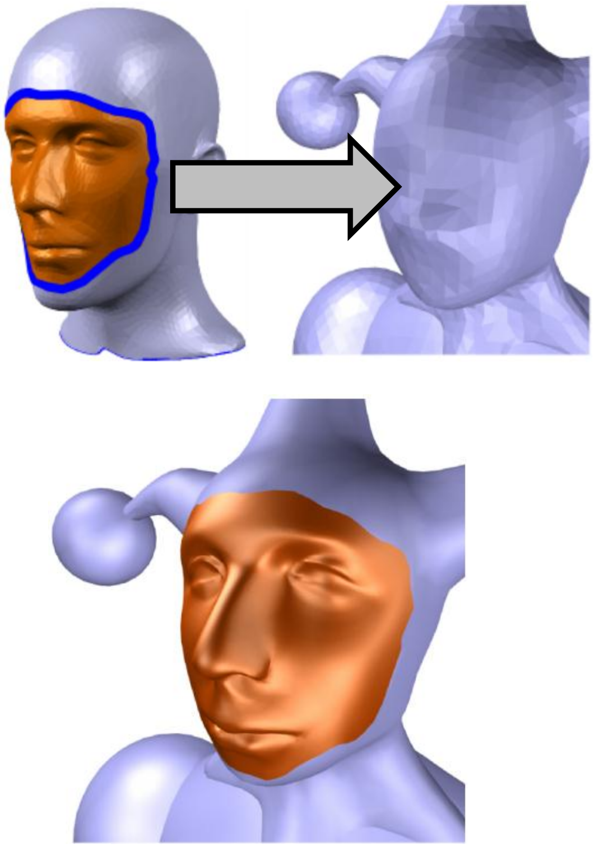


Conceptual Design

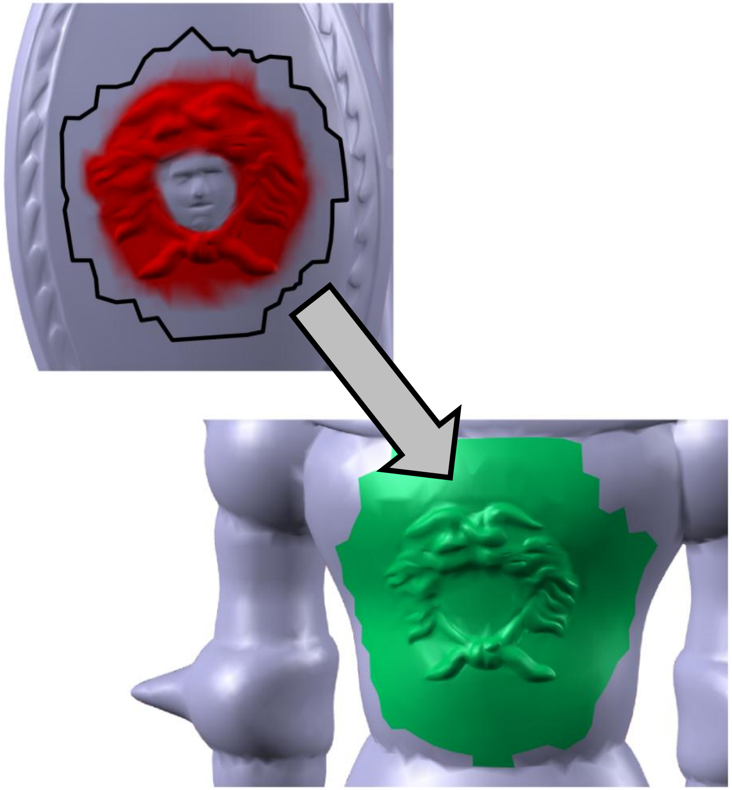
The transformation of a creative vision into a digital 3D model, that is easy to **refine and reuse.**

Meshmixer: 3D model composition

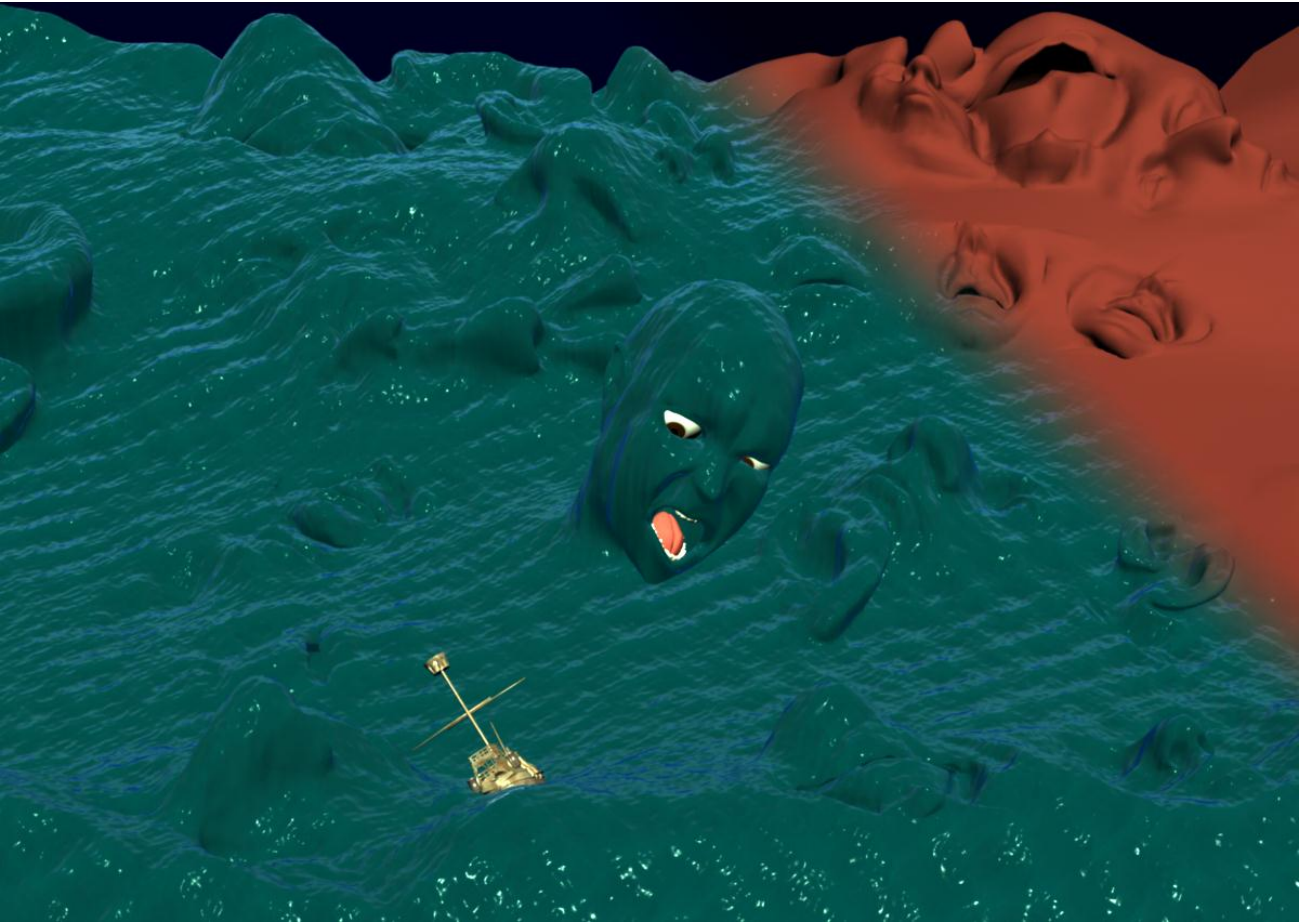
Composing **Parts**:
Mesh Drag-and-Drop



Composing **Details**:
Mesh Clone Brush



MeshMixer



Key Messages

- Visual field (single-view) and visual world (multi-view) are complementary.
- Symbolic (visual memory) and free-form (visual rules) drawing can co-exist.
- Modeling systems presented:
    - ILoveSketch www.ilovesketch.com
    - Analytic Drawing www.dgp.toronto.edu/~rms/pubs/DrawingSGA09.html
    - MeshMixer www.meshmixer.com

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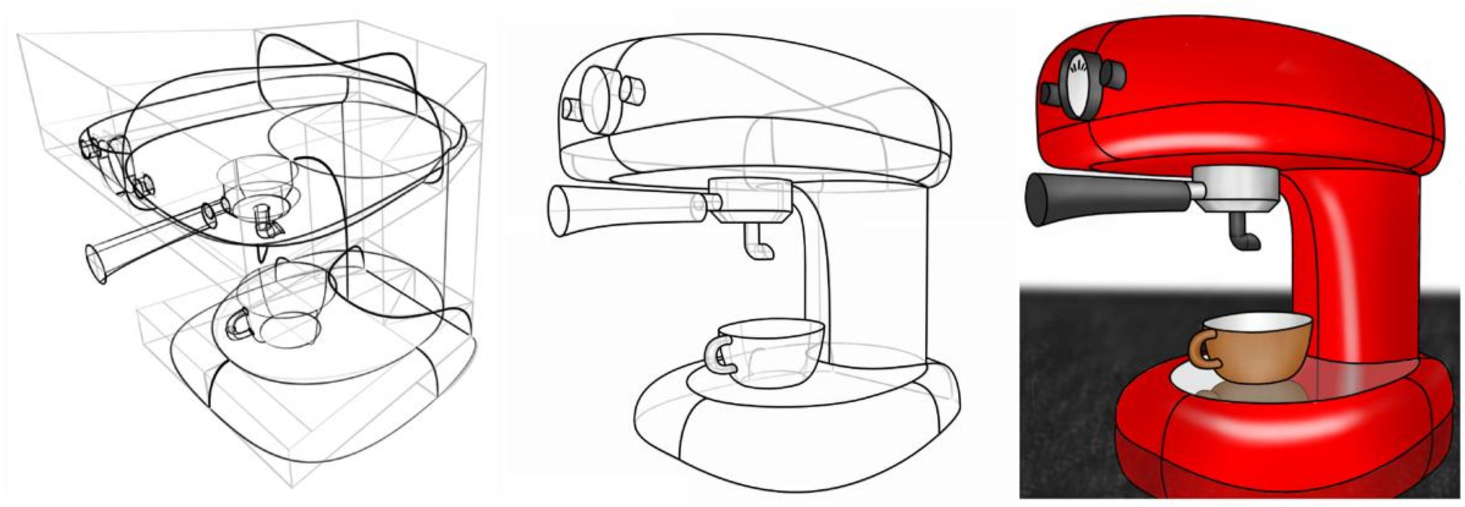
CRSNG



http://www.dgp.toronto.edu/~karan