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.

Teddy

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

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).

Suggestive systems (matching 2D to 3D)

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

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

Constructive systems

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


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

Skeleton extraction

- Delaunay triangulation
- Chordal axis transform

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

Trouble with contours and silhouettes

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

- Find hidden lines
- “Smarter” inflation

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.

FiberMesh

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

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
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*.

I ❤ SKETCH

Geom-independent gestures
Geom-dependent gestures
Multi-stroke input

Virtual sketchbook

2D paper

2D curve

Bimanual paper navigation

Bimanual space navigation

3D space

Axis widget

3D curve

Sketchability

(a) (b) (c)
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, EverybodyLovesSketch: 3D sketching for a broader audience. UIST 2009]
Expert Drawing I: Circle-on-Plane
Expert Drawing II: Silhouette Curves

Please fill in the missing curve section
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

current view

inference engine

stroke group

sketch plane 1

edge 1

stroke group

sketch plane 1
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

\[ F(l) = S(s, l) G(l) \sum_i C(c_i, l) \]

- **S**
- **G** A mixture-of-Gaussian terms.
- **C** is a set of constraints

\[ C(c_i, l) = \begin{cases} C(c_i) & \text{if } l \text{ satisfies } c_i, \\ 0 & \text{otherwise} \end{cases} \]

- Makes **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

[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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