Teddy: A Sketching Interface for 3D Freeform Design

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Outline

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Introduction

• Automated construct 3D freeform models
• Sketching Interface
  – Use 2D freeform strokes
• Easy to use
  – No control points or complicated editing operations
• Resulting Model
  – Hand-crafted feel
User Interface: Draw some freeform 2D strokes

Results (painted using a commercial texture-map editor)
User Interface

**Creation**
- Closed
- Create a new object

**Bending**
- First stroke
- Second stroke
- Specify reference
- Specify target

**Painting**
- Inside of the object, not closed
- Paint on the surface
- Inside of the object, closed
- Specify the area to be extruded/smoothed
- Start and end outside of the object
- Cut the object
- Scribbling
- Erase painted strokes

**Extrusion**
- Normal stroke
- Extrude the area
- Scribbling
- Smooth the area
- Click
- Quit extrusion

**Legend**
- **Mode**
  - Stroke
  - Action
Modeling Operations -- Creating

- Closed freeform stroke
  - Automatically connect the start and end points
- Fail if self-intersection
- Wide > Fat, Narrow > Thin
- Reasonable-looking freeform shape

a) snake  b) snail  c) cherry  d) muscular arm
Painting and Erasing

• Stroke must not cross the 2D silhouette
• Simply project onto object surface as 3D line segments
• Erase surface lines by drawing a scribbling stroke
Extrusion

- Two-stroke operation:
  - Closed stroke (red)
  - Stroke depicting the silhouette of the extruded surface

- Make a cavity
  - Drawing an inward silhouette
- Do not support holes

- Surface:
  a) digging stroke  b) result  c) rotated  d) closed stroke  e) after click

- Different shapes:
  a) long  b) thin  c) fat  d) sharp
Cutting

- Start outside, terminate outside
- Remove left of stroke
- ‘bite’ operation
- Extrusion after cutting
  - Useful to modify the shape

a) biting stroke  b) result  c) rotated view  d) after click
Smoothing

- Modify actual geometry
  - Removes polygons surrounded by the closed red surface line
  - Create entirely new surface covers the region
- Remove bumps and cavities
- Smooth creases (often caused by extrusion operation)

b) smoothing a sharp edge

- Remove bumps and cavities
- Smooth creases (often caused by extrusion operation)
Transformation

a) original    b) reference stroke    c) target stroke    d) result    e) rotated
Algorithm

- Result model is topological equivalent to sphere
- Input stroke resampled to smooth polyline → remove handwriting noise
Creating a New Object

1. Create closed planar polygon
2. Find spine and Triangulation(2D)
3. Elevate the vertices of spine
4. Construct polygonal mesh
Find spine & Triangulation

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

d) fan triangles  e) resulting spine  f) final triangulation
All edges length = predefine unit length

Edges = external edges (ee)

Edges $\neq$ ee

$\implies$ Internal edges (ie)

T : terminal triangle ($2ee + 1ie$)

S : sleeve triangle ($1ee + 2ie$)

J : junction triangle ($3ie$)

Triangulation method: constrained Delaunay triangulation (CDT)

pruning
Start from T-triangle\((2ee+1ie)\)

use \(ie = \text{diameter}\) to draw semicircle

if all T's vertices inside the semicircle => merge , else terminate.

All T's vertices in the semicircle => merge .
T's vertex lies outside => terminate.

Connect the vertices in the external edges to midpoint of internal edge .

Connect the vertices in the external edges to midpoint of J-triangle

Merge junction triangle .
Connect the vertices in the external edges to midpoint of J-triangle
Connect the midpoint of internal edges => final spine

Final triangulation
Elevate the vertices of spine

1. calculate the average distance between spine vertex directly connected to the vertices of external edges
2. elevate proportionally

Each internal edges excluding spine edges => convert to a quarter oval

Construct polygonal mesh
Construct polygonal mesh

• Copy elevated mesh to the other side
  – Make mesh closed and symmetric
• Refine mesh
  – Remove short edges
  – Remove small triangles
Painting on the Surface

- Find intersections between the plane and each polygon of the object
- Splices the 3D line segments together
Extrusion

- Project and Produce 3D extruding line
- Base ring sweep along the 3D extruding line
- Construct polygonal mesh
1. Find the best matching plane of the ring
2. Projection plane pass through the base ring’s center of gravity and lying parallel to the normal of the base ring
3. Project the 2D extruding stroke onto the plane
4. Produce the 3D extruding stroke
Choose: advance the left pointer, the right pointer, or both.

Goodness value: angle between red line and direction of strokes => closed 90 degree
Sewing adjacent rings

=> Done!

Bad result caused by bad input:
unexpected extruding strokes, base surface is not sufficiently planar
Cutting

• Based on painting algorithm
• Project onto the front and back facing polygons
• Connect endpoints to construct a planar polygon
• Cutting, remove all polygons to the left of the cutting stroke
Connect the endpoints and construct a planar polygon.

Project to the front facing polygon

Project to the back facing polygon

Screen

Camera

Object
Smoothing

- Translate the object into a coordinate system, and Z-axis is parallel to the normal of the ring
- Project the ring onto XY-plane
- 2D triangulation (CDT) and refine
- Elevate each vertex
Calculate Z-value

Interpolate the new z value of elevated vertex

Bezier curve on the plane

Plane is parallel to Z-axis

Elevate vertex

Midpoint
Result
Conclusion

• Teddy is quite intuitive and encourages them to explore various 3D designs
• 5mins tutorial, 5mins practice
• Chameleon: 3D Paint for Teddy
• Commercial Products based on Teddy:

Magic sketch 2