Ambiguous Input and Layered Manufacturing

Sara McMains
ME 290 D
U.C. Berkeley
Winding Numbers

• What’s “in” self-intersecting polygons?
• Winding numbers
  – Defined for point P not on boundary
  – Boundary elastic rubber band
  – If it contracts, number of CCW wraps around P
  – CW wraps count negative
Winding Numbers
Winding Numbers

[OpenGL Programming Guide]
Winding Numbers

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Winding Numbers

[OpenGL Programming Guide]
Winding Number Rules

[OpenGL Programming Guide]
Winding Number Rules

[OpenGL Programming Guide]
Winding Number Rules

[Winding Number Rules Diagram]

[OpenGL Programming Guide]
Ambiguous Input
Ambiguous Input

- Implicit union
Ambiguous Input

- Implicit union

(2D slice)
Ambiguous Input

- Implicit union

(2D slice)
Ambiguous Input

- Implicit union

(2D slice)
Ambiguous Input

- Implicit union

(2D slice)
Ambiguous Input

• Implicit difference

(2D slice)
Ambiguous Input

- Implicit difference
Ambiguous Input

• Implicit difference
Ambiguous Input

- Implicit difference
Ambiguous Input

- Implicit difference
Ambiguous Input

- Implicit difference
Ambiguous Input

- Self-intersecting contour
Ambiguous Input

- Self-intersecting contour
Ambiguous Input

- Self-intersecting contour
Self Intersections

• May even be introduced during “clean-up”
Self Intersections

- May even be introduced during “clean-up”
  - Cow model’s tail intersected body
- Some interpretations produce non-manifold part
  - Structurally weak
- Preferred interpretation is unary union
Implicit Booleans

- Even if exchange format doesn’t include *explicit* CSG, *implicit* Booleans will arise
- Manufacturers don’t categorically reject
  - 2D Booleans are relatively easy to resolve
  - OpenGL winding number rules can compute them
Winding Number Booleans

- What winding number rule(s):
  - will treat intersecting CCW contours as implicit unions?
  - will treat self-intersecting CCW contours as unary unions?
  - will correctly calculate implicit differences?
Winding Number Booleans

• Unions
  – Non-zero rule
  – Positive rule

• Self-intersections
  – Non-zero rule
  – Positive rule

• Differences
  – (CW orientation for subtractands)
  – Positive rule
Winding Number Booleans

• What’s with the “Absolute value $\geq 2$” rule?
  – Gives intersection of 2 CCW contours
• Combined w/ positive rule, allows all Booleans to be displayed w/out evaluating