Goal

Aim to reconstruct consistent solid and boundary representations for the objects modeled by a set of polygons.

Arbitrary Set of Polygons

Consistent Solid and Boundary Representations

Challenges

Model may be non-manifold:
- Missing polygons
- Overlapping polygons
- Intersecting polygons
- Unconnected polygons
- Unoriented polygons
- T-junctions

Applications

- Finite element methods
- Physical simulation
- Collision detection
- Lighting simulation
- Visualization
- CAD/CAM

Reconstructing Consistent 3D Models From Polygon Soup

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Courtesey of Steve Fortune
Three Approaches

- Boundary stitching
- Boundary resampling
- Solid region labeling

Boundary Stitching

Baum et al. '91

Three Approaches

- Boundary stitching
- Boundary resampling
- Solid region labeling

- Baum et al. '91
- Bohn & Wozny '93
- Makela & Dolenc '93
- Sheng & Mere '95
- Baraquet & Sharir '95
- Butlin & Stoops '96
- Baraquet & Kumar '97
- Gueziec et al. '97
- Szeliski '93
Three Approaches

• Boundary stitching
• Boundary resampling
• Solid region labeling

Szeliski et al. ‘93

• Thibault & Naylor 87
• Teller 92
• Murali et al. ‘97

Solid Region Labeling

Three Steps:

1) Spatial Subdivision
2) Solid Determination
3) Model Output

Spatial Subdivision

Input Polygons

Cell Adjacency Graph

Binary Space Partition

Cell Regions

Spatial Subdivision

Cell Adjacency Graph

Binary Space Partition

Input

Cell Regions

Output

Spatial Subdivision

Three Approaches

Boundary Resampling

Szeliski et al. 30

Murali et al. 37

Boundary Resampling

Input Polygons

Cell Adjacency Graph

Spatial Subdivision

Binary Space Partition

Input

Cell Adjacency Graph

Solid Region Labeling

Three Steps:
Solid Determination

**Intuition:**
- Adjacent cells sharing a transparent boundary should have the same solidity
- Adjacent cells sharing an opaque boundary should have opposite solidities
- Unbounded cells are not solid

**Formalism:**
- Cell “solidity” relationship for bounded cells:
  \[ S_i = \sum_j (t_{ij} - o_{ij}) S_j \]
- For unbounded cells:
  \[ S_i = -1.0 \]

**Linear system of equations:**
- Positive \( M_{ij} > 0 \) indicates \( L_{ij} \) is mostly opaque
- Negative \( M_{ij} < 0 \) indicates \( L_{ij} \) is mostly transparent
- \( M \) is weakly diagonal dominant, \( M_{ij} \geq \sum_j |M_{ij}| \)
- \( M \) is symmetric, \( M_{ij} = M_{ji} \)

These properties imply that \( M \) has an inverse, and the system of equations is solvable!
Model Output

Output a polygon for each boundary separating a solid cell from a non-solid cell (oriented away from solid).

Results

Honda Clutch

Boundary stitching:
+ Relatively simple, local operations
+ Works for non-physical objects
  - Uses heuristics based on distance tolerances
  - Does not find global solution

Boundary resampling:
+ Global solution
+ Finds topology automatically
+ Works for non-physical objects
  - Approximate reconstruction

Solid region labeling:
+ Global solution
+ Finds topology automatically
+ Constructs consistent solid representation
  - Does not work for non-physical objects
  - Depends on spatial subdivision constructed

Summary

Input Model
Solid Cells

Cell Solidities
Output Model

Input Model

Cell Solidities
General Idea

- Apply sequence of filters
  - Example: Baum et al. '91
  - Group vertices, edges, polygons
  - Split intersecting polygons
  - Merge coplanar polygons
  - Subdivide large polygons