Reconstructing Consistent 3D Models From Polygon Soup

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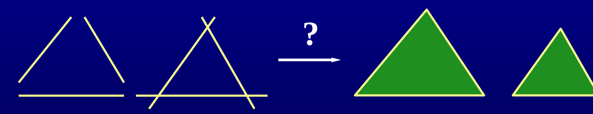
Goal

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

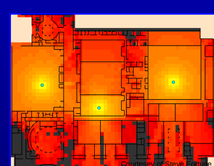


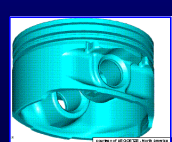
Arbitrary Set of Polygons

Consistent Solid and Boundary Representations

Applications

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

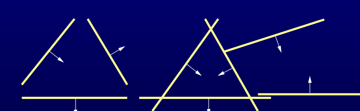




Challenges

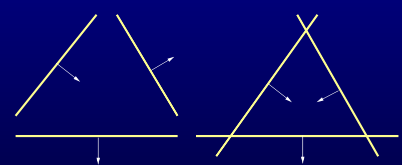
Model may be non−manifold:

- Missing polygons
- Intersecting polygons
- Unoriented polygons
- Overlapping polygons
- Unconnected polygons
- T−junctions



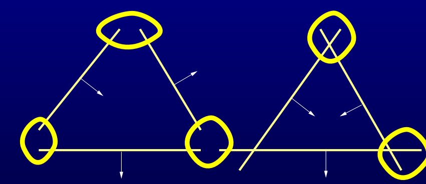
Three Approaches

- Boundary stitching
- Boundary resampling
- Solid region labeling



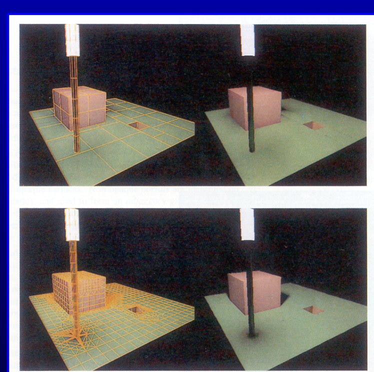
Three Approaches

- **Boundary stitching** ←
  - Baum et al. '91
  - Bohn & Wozny '93
  - Makela & Dolenc '93
  - Sheng & Meier '95
  - Baraquet & Sharir '95
  - Butlin & Stops '96
  - Baraquet & Kumar '97
  - Gueziec et al. '97
- Boundary resampling
- Solid region labeling



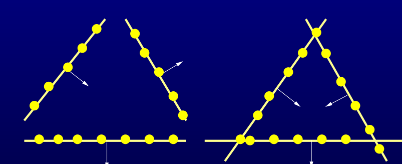
Boundary Stitching

Baum et al. '91



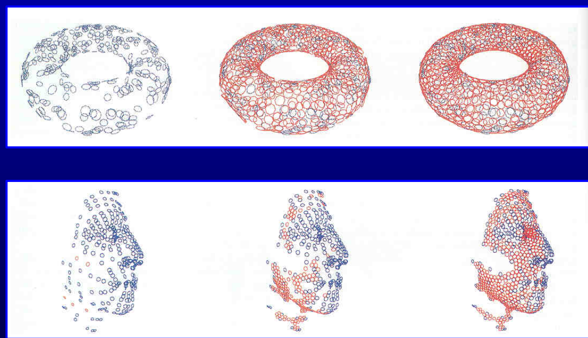
Three Approaches

- Boundary stitching
- **Boundary resampling** ← • Szeliski '93
- Solid region labeling



Boundary Resampling

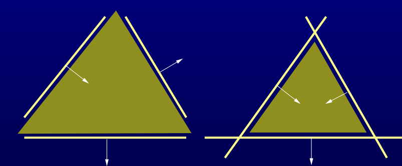
Szeliski et al. '93



Three Approaches

- Boundary stitching
- Boundary resampling
- **Solid region labeling**

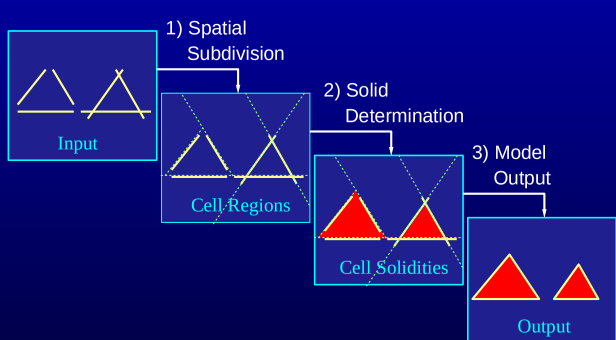
• Thibault & Naylor '87
• Teller '92
• Murali et al. '97



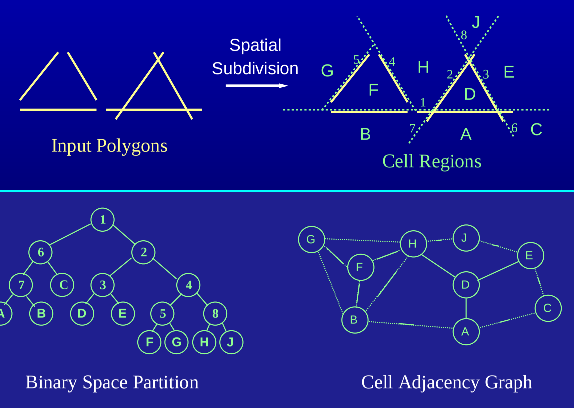
Solid Region Labeling

Murali et al. '97

Three Steps:



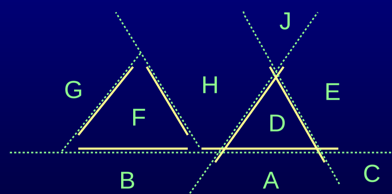
Spatial Subdivision



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



Solid Determination

Formalism:

- Cell "solidity" relationship for bounded cells:

$$S_i = \frac{\sum_j (t_{i,j} - o_{i,j})\, S_j}{A_i}$$

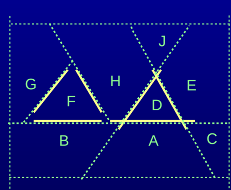
- For unbounded cells:

$$S_i = -1.0$$

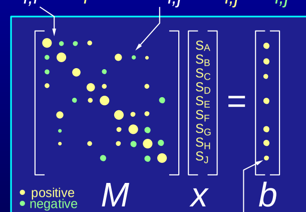
> S_i = Solidity of cell C_i [−1.0 : 1.0]
> $L_{i,j}$ = Boundary between C_i and C_j
> $t_{i,j}$ = transparent area of $L_{i,j}$
> $o_{i,j}$ = opaque area of $L_{i,j}$
> $A_i = \Sigma j\, (t_{i,j} + o_{i,j})$

Solid Determination

Linear system of equations:



$M_{i,i} = A_i$ $M_{i,j} = o_{i,j} - t_{i,j}$

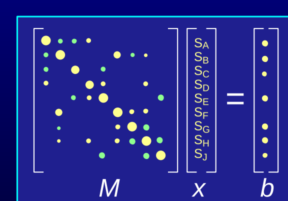


$b_i = \Sigma_k\, (t_{i,j} - o_{i,j})$ for all k where C_k is unbounded

Solid Determination

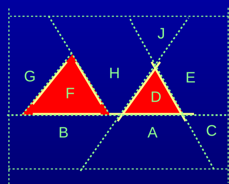
Linear system of equations:

- $M_{i,i} > 0$
- $M_{i,j} > 0.0$ indicates $L_{i,j}$ is mostly opaque
- $M_{i,j} < 0.0$ indicates $L_{i,j}$ is mostly transparent
- M is weakly diagonal dominant, $M_{i,i} \geq \Sigma_j\, |M_{i,j}|$
- M is symmetric, $M_{i,j} = M_{j,i}$

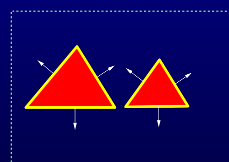


These properties imply that M has an inverse, and the system of equations is solvable!

Model Output

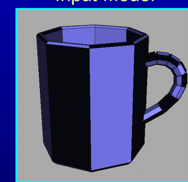


Output a polygon for each boundary separating a solid cell from a non−solid cell (oriented away from solid)

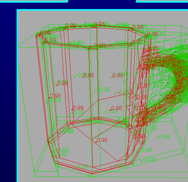


Results

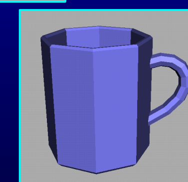
Input Model



Solid Cells



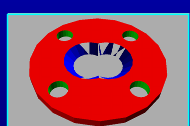
Cell Solidities



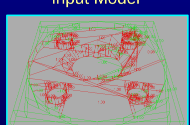
Output Model

Results

Honda Clutch

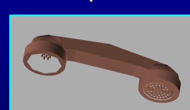


Input Model

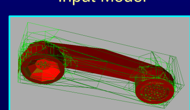


Cell Solidities

Telephone

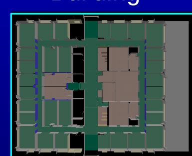


Input Model

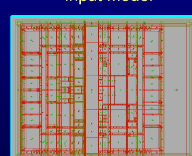


Cell Solidities

Building



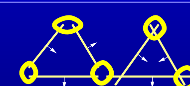
Input Model



Cell Solidities

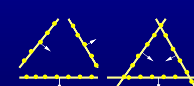
Summary

Boundary stitching:



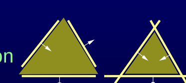
+ Relatively simple, local operations
+ Works for non−physical objects
− Uses heuristics based on distance tolerances
− Does not find global solution

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

General Idea

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