Robust Meshes from Multiple Range Maps

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Surface Reconstuction

Step 1: Data acquisition

Obtain range data that covers the object. Filter, remove background.

Step 2: Registration

Register the range maps into a common coordinate system.

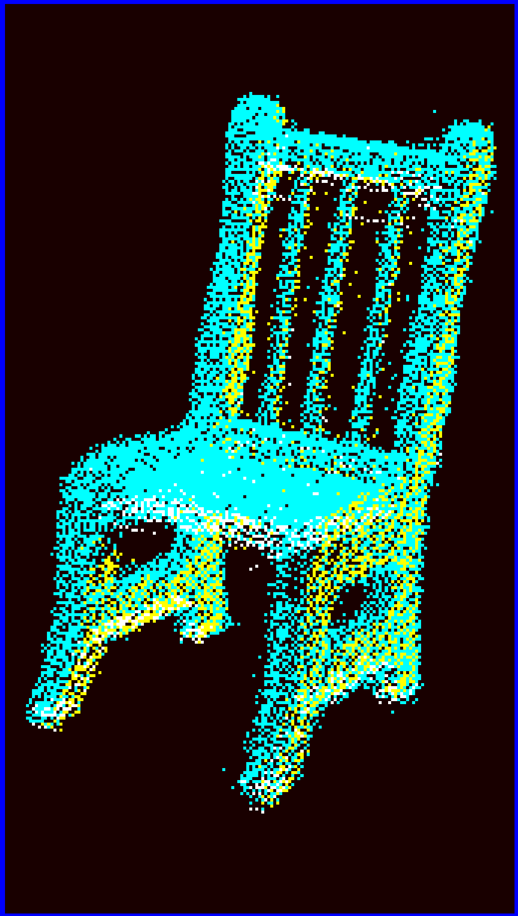
Step 3: Integration

Integrate the registered range data into a single surface representation.

Step 4: Optimization

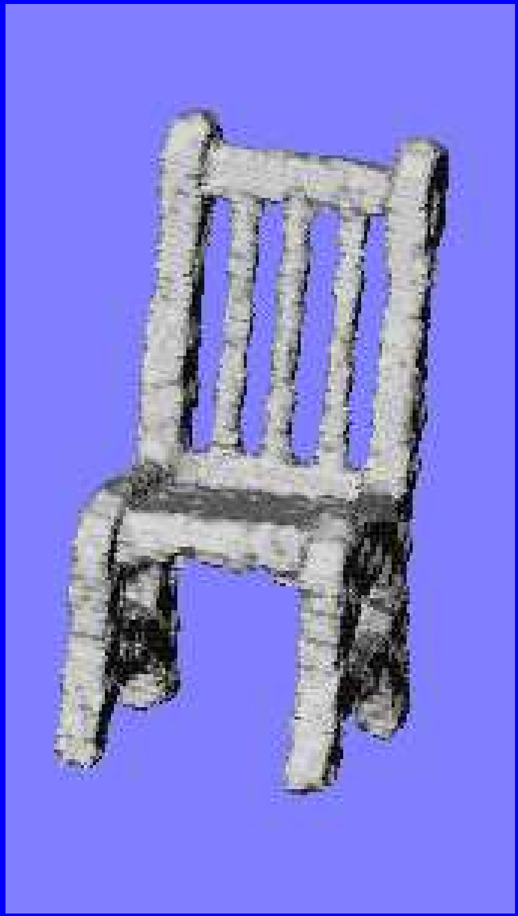
Fit the surface more accurately to the data, simplify the representation.

Problem



Noisy registered data

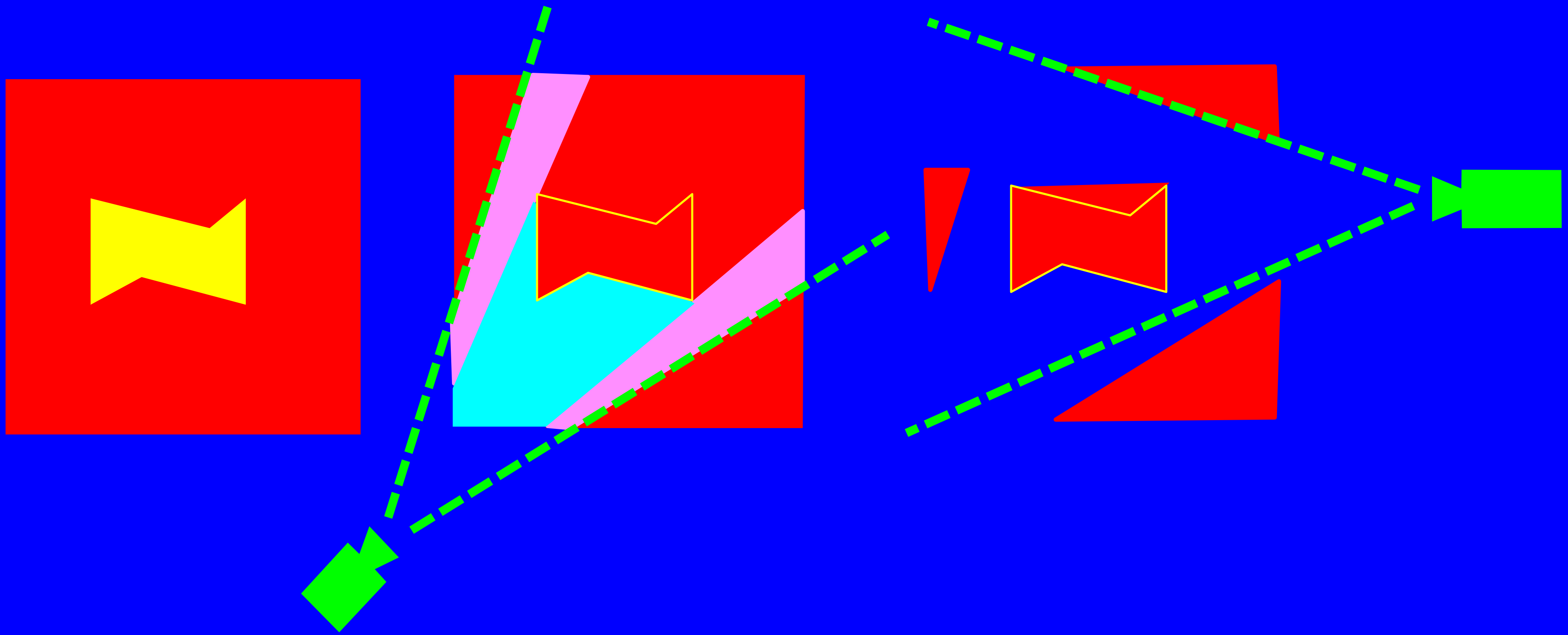
Signed distance fn & marching cubes



Hierarchical & directional space carving

Space carving

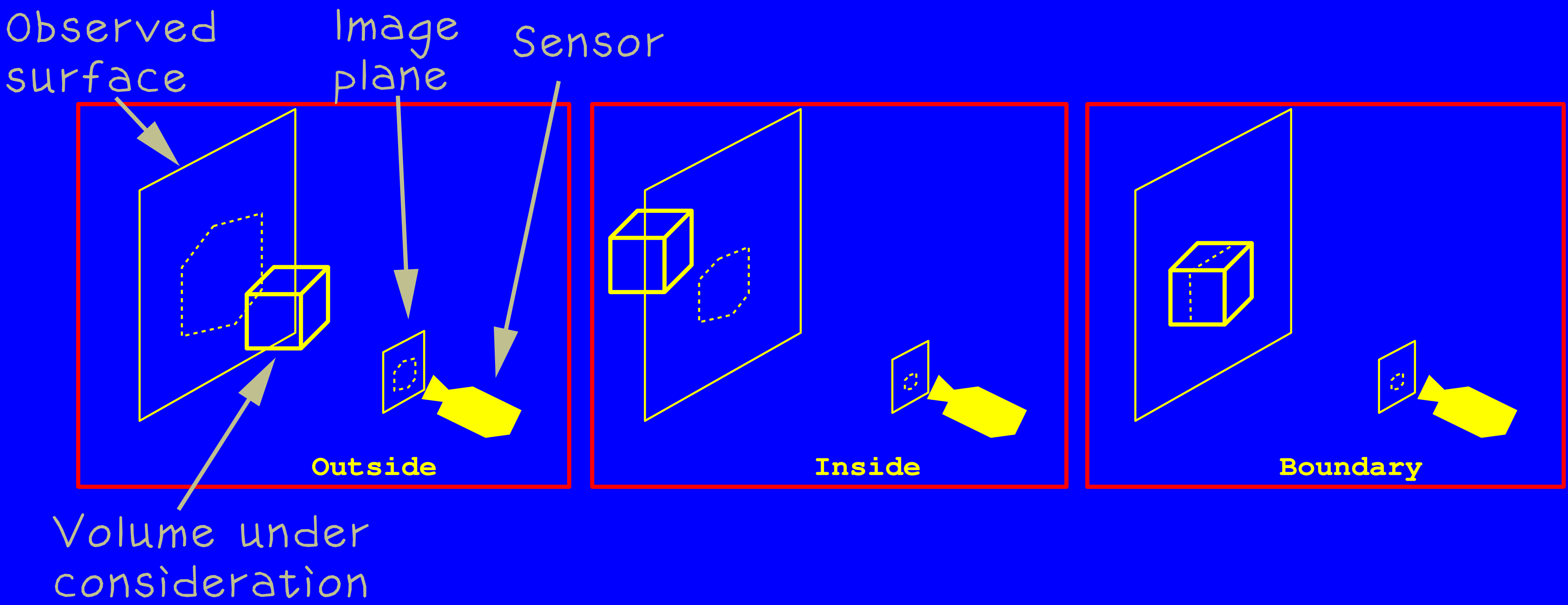
- Curless & Levoy SIGGRAPH '96
- Concentrate in volumes



Our approach

- A simple implementation of space carving
- Use only robust methods
  - interval analysis
  - thin surfaces
- Hierarchical approach
  - speed
  - storage
- Assume
  - range maps, known calibration, registered data

Carve space in cubes



- Project cube to image plane (hexagon)
- Test against data in the hexagon

Several scanners

Processing order:

FOR EACH cube

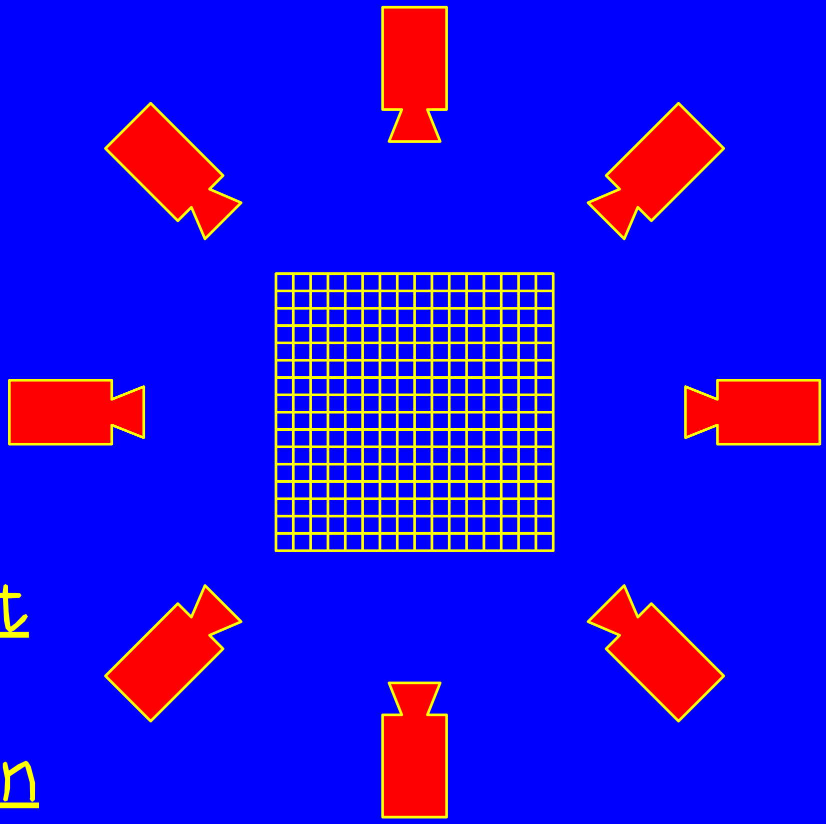
FOR EACH scanner

Rules:

any view thinks cube's out
=> it's out

every view thinks cube's in
=> it's in

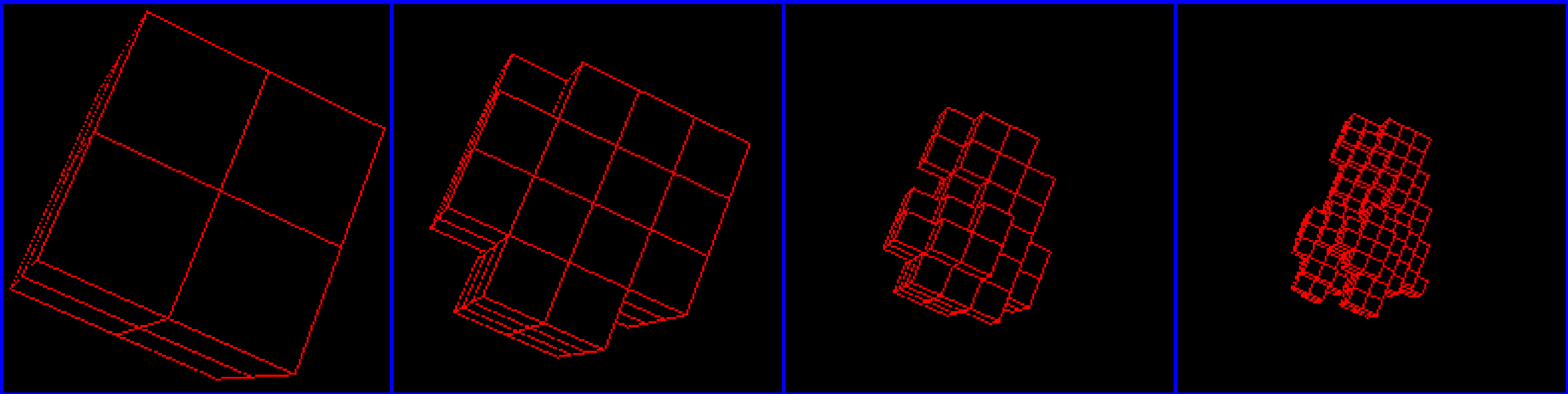
else
=> it's at boundary



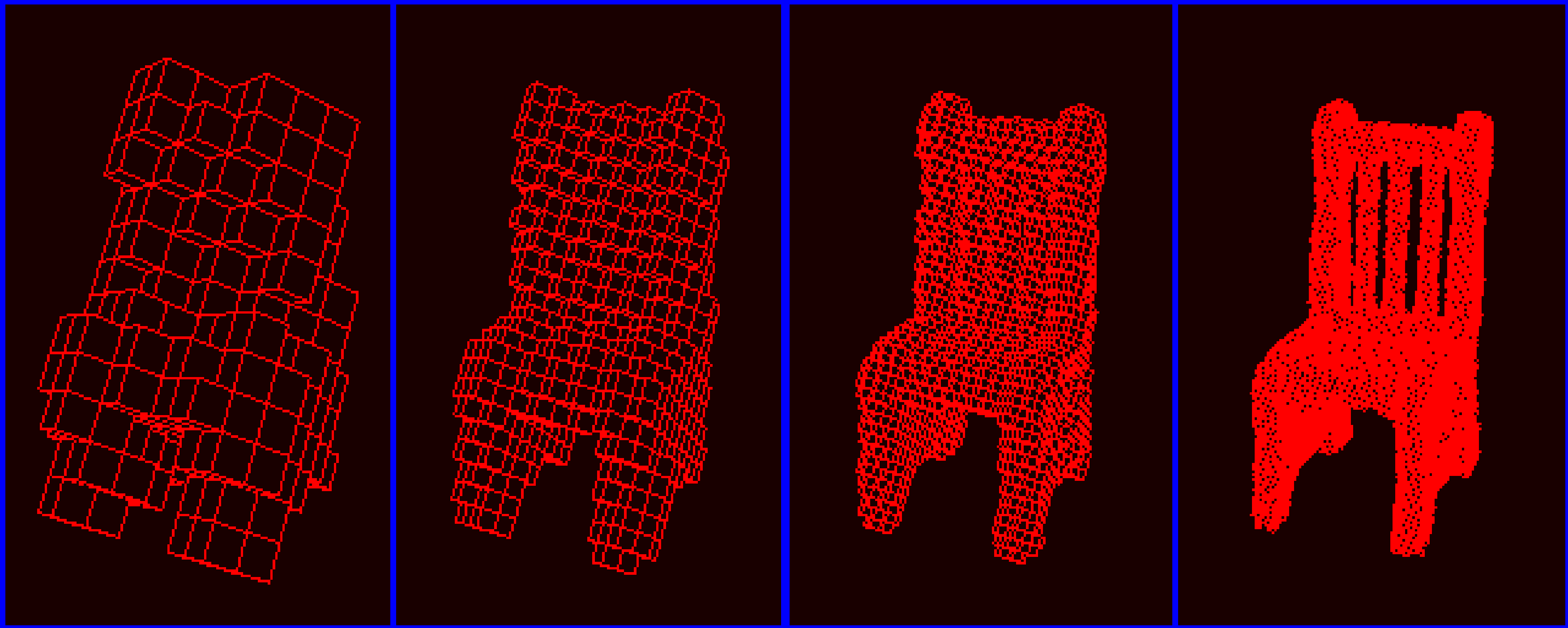
Hierarchical space carving

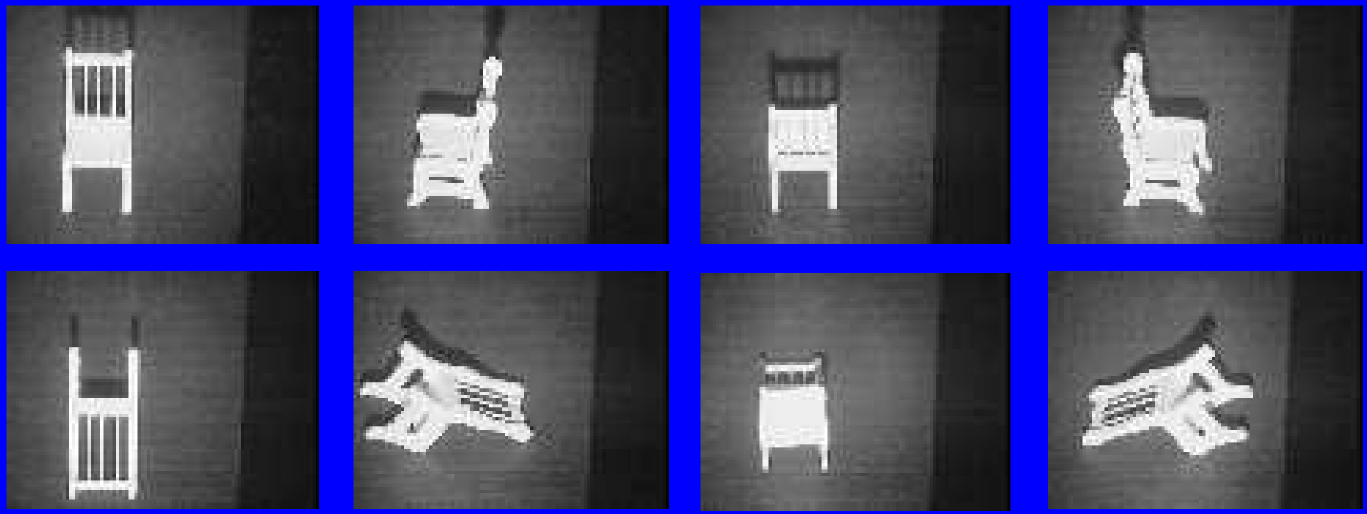
- Big cubes => fast, poor results
- Small cubes => slow, more accurate results
- Combination = octrees

RULES:
- cube's out => done
- cube's in => done
- else => recurse



The rest of the chair

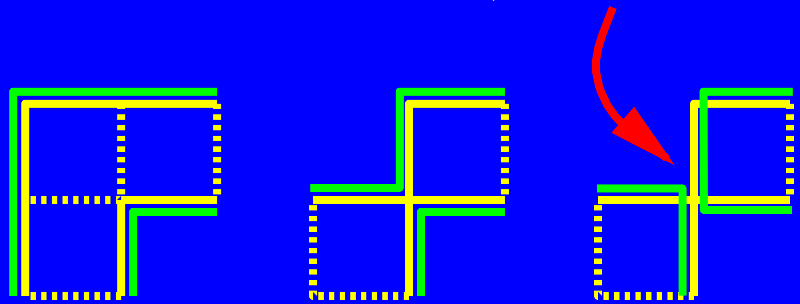




Mesh extraction

- Traverse the octree
  - * Ignore outside cubes
  - * For every face between a boundary and outside cube output 2 triangles
  - * Cover the intersection of inside and outside cubes with triangles
- Mesh connectivity

replicate a vertex

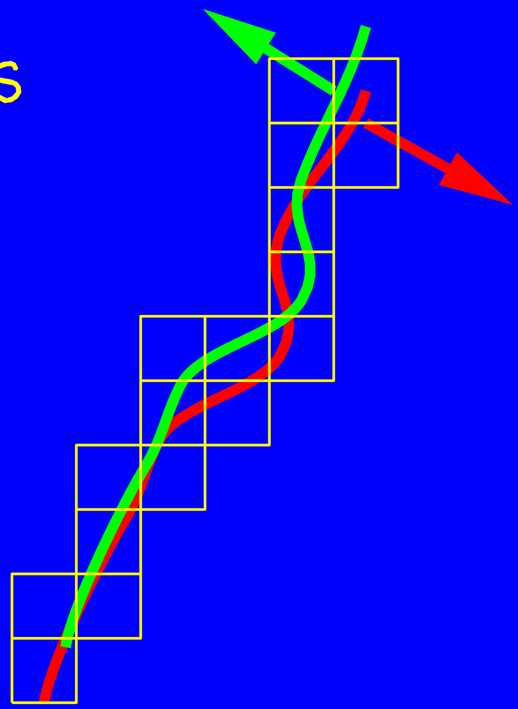


easy wrong correct

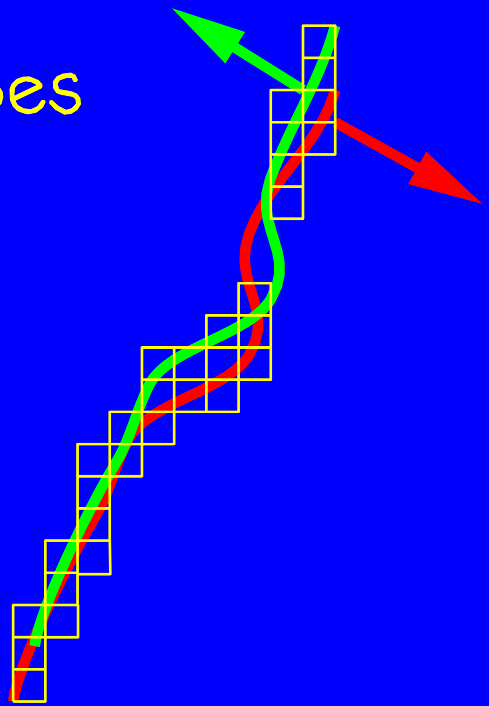
Thin surfaces

- Use of directional information
  allows reconstructing thin objects

- Surface seen from left and right
  Reconstruction:
  a shell around the surface



- Don't use too small cubes
  Size > max of
  * registration error
  * sampling error
  * sampling density

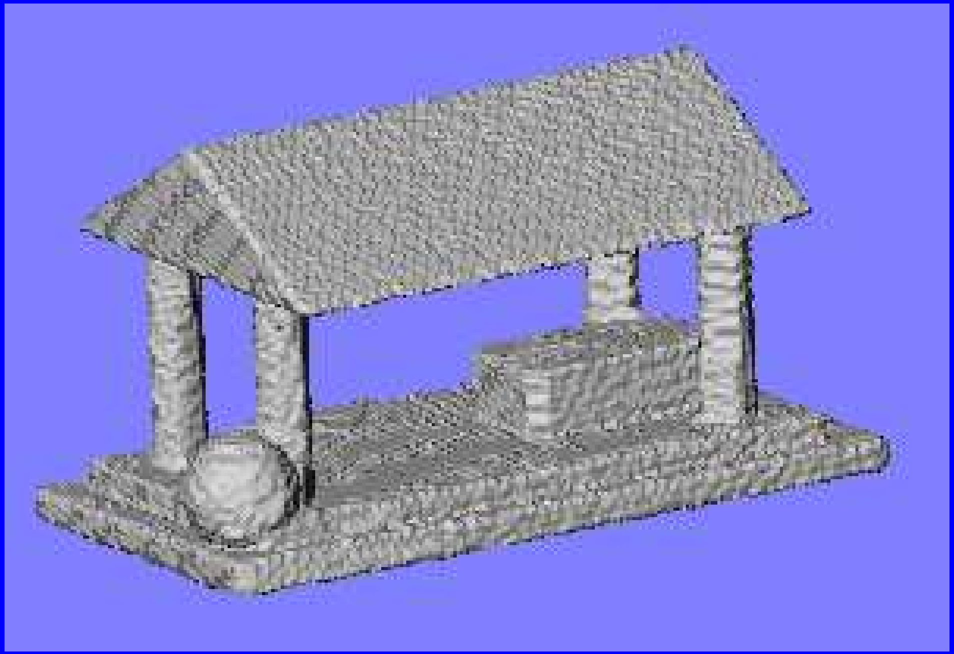


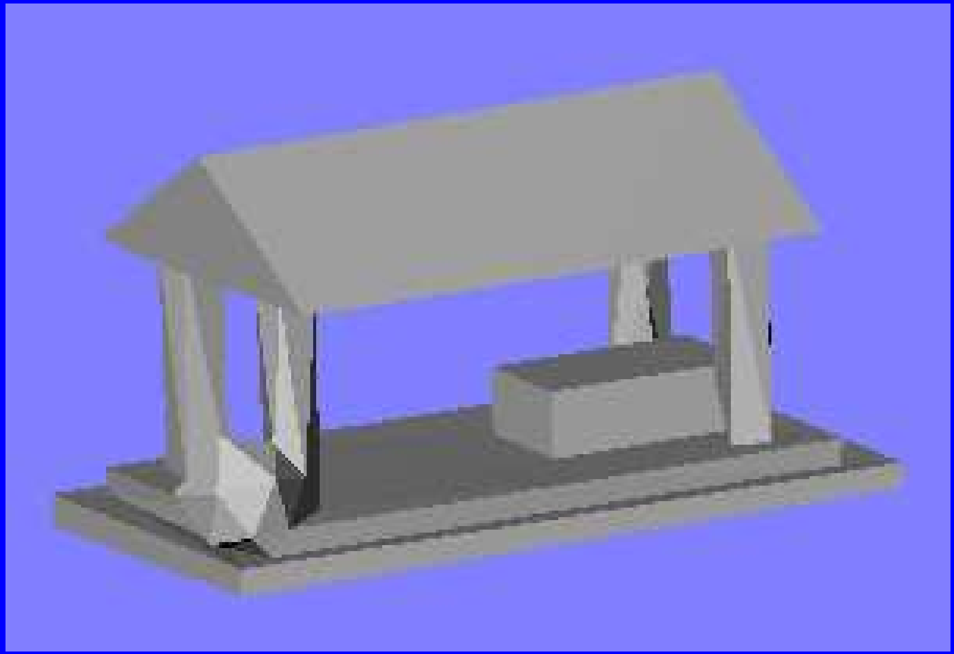
Robustness: discussion

- Automatically watertight
  - * boundary between "ins" and "outs" fills holes
- Interval analysis
  - * analyze space conservatively
  - * more refined analysis at uncertain locations
- Use of direction
  - * implicit outlier removal
  - * thin surfaces

= Propagate and manipulate constraints, optimize later

Optimization example





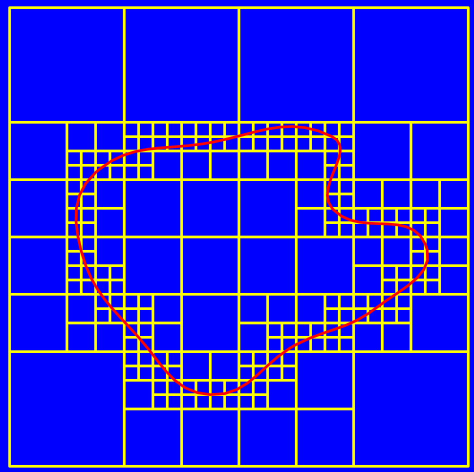
Our result (smoothed)

Fitted and simplified (Hoppe '93)

A previous approach

Connolly ('84) projected from image to space

* range images into quadtrees
* carve space corresponding to a node towards surface
* space organized in an octree



Problem:

* typically cannot match quadtree and octree nodes well
  - nodes close in size ->inaccurate carving
  - use small octree nodes ->no more hierarchical processing