A Flood Fill Algorithm That Closes Small Leaks

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Outline

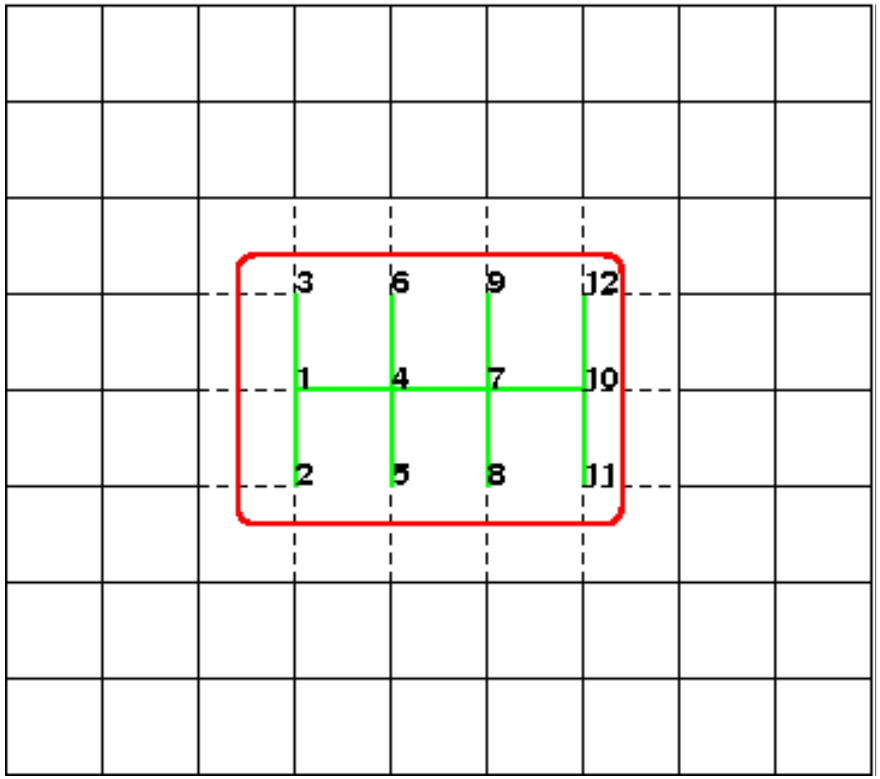
- Overview of different hole cut techniques
- Introduction to flood fill
- Examples of non-watertight geometries
- Proposed flood fill algorithm to heal leaks
- Results
- Summary

Hole Cutting Techniques
General Types

- Explicit Cut: User specified points are out
- Query Cut: Is this point inside a body?
  - "Thin cut" problem: geometry is sub-grid feature
- Direct Cut: Is element intersected by geometry face?
  - Requires a watertight set of surface faces
  - **Flood fill** operation used to mark interior vs. exterior
  - No "Thin cut" problem
- Implicit Hole Cut: What points are not needed by the solver?

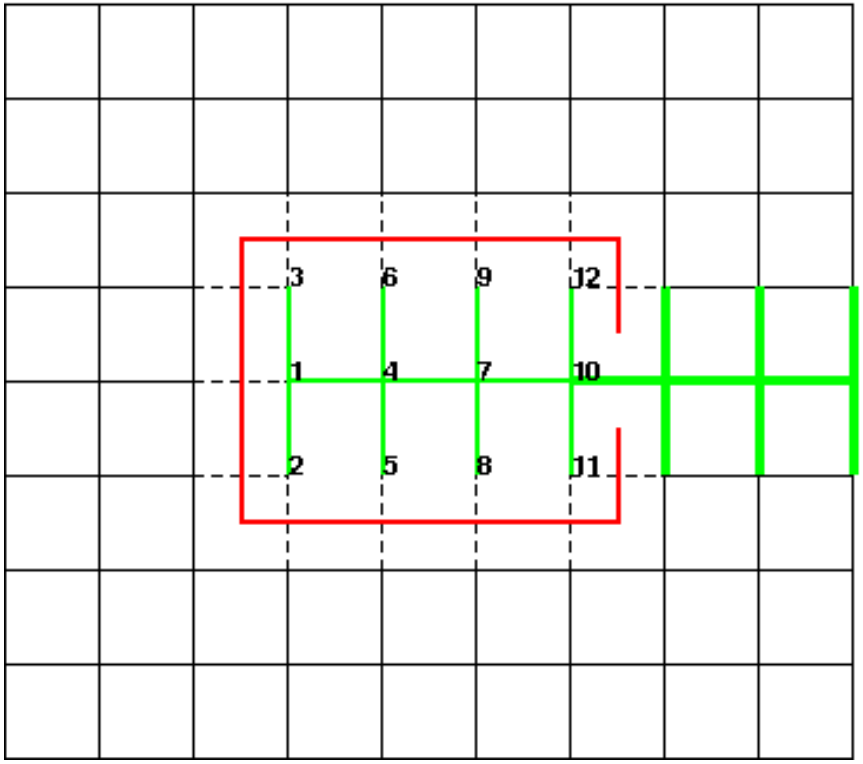
Flood Fill to Mark Interior Points As OUT

- Direct cut (and others) cut an outline of the geometry in the grid being cut
- A flood fill is performed to propagate the interior/exterior (or OUT/active) status of the grid points
- Initiate the flood fill from any known OUT points (seeds)
- Flood fill traverses from point to point along any uncut edges
- After the flood fill, nodes not marked as OUT are IN



Flood Fill Leaks

- Flood fill will "leak" if cut edges do not completely isolate OUT points from points that should be active
- Causes
  - Geometry is not **effectively** watertight
- Consequence – Every point in the grid will be marked as OUT
- Path can be output to visualize a leak

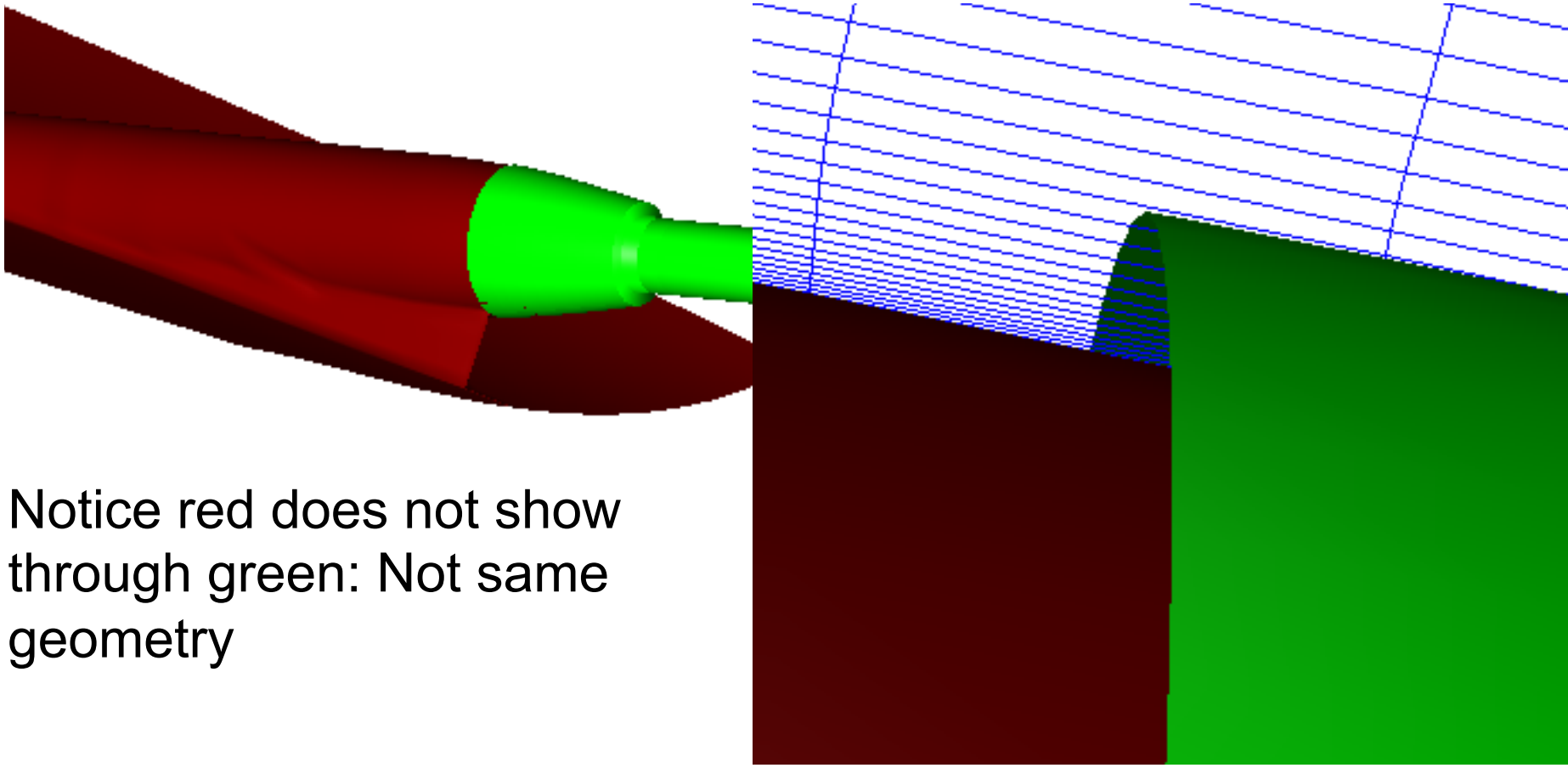


Why Is Geometry Not Effectively Watertight?

- Incorrect specification of overset assembly boundaries
  - Engine inlet face has farfield boundary condition in flow solver
  - Failure to assign a boundary surface
- Overlapping surface do not consistently represent the geometry

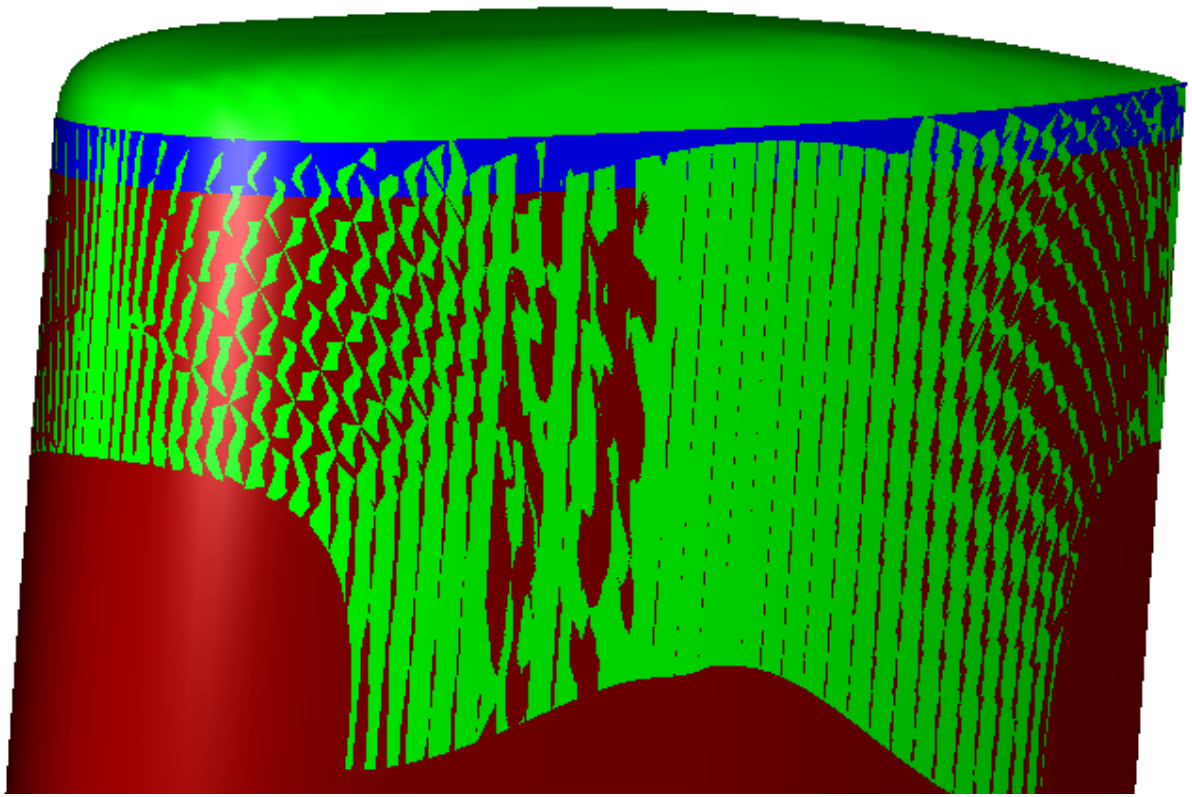
Overlapping Surfaces: Inconsistent Geometry Definition

- Solution: project onto same geometry

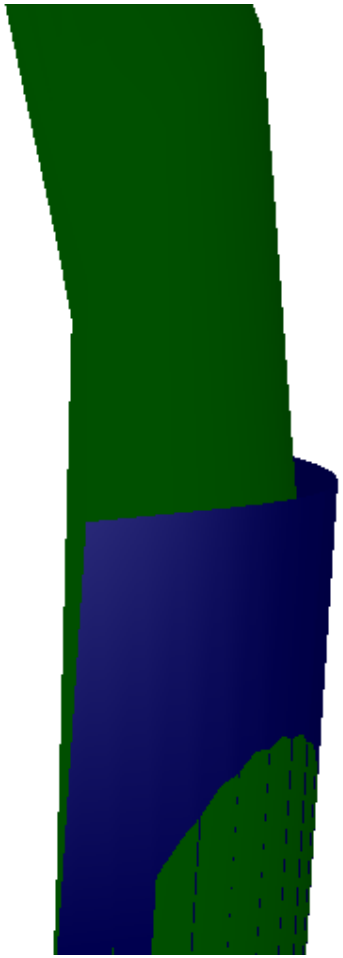


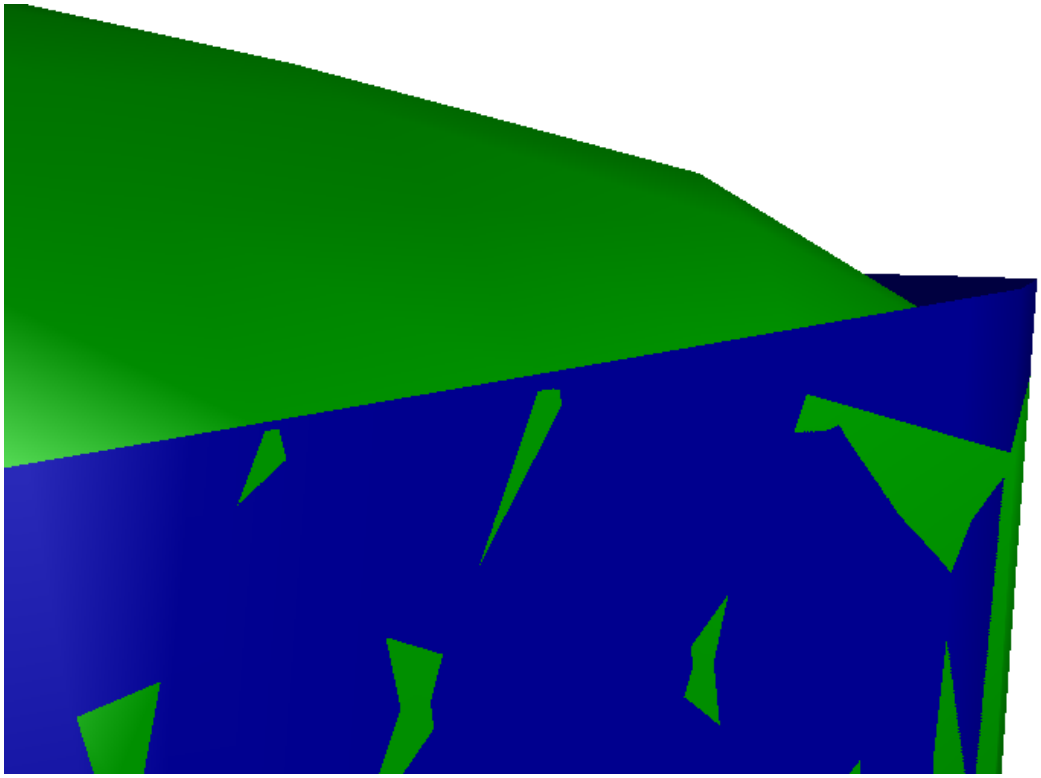
Notice red does not show through green: Not same geometry

Overlapping Surfaces: Inconsistent Geometry Definition



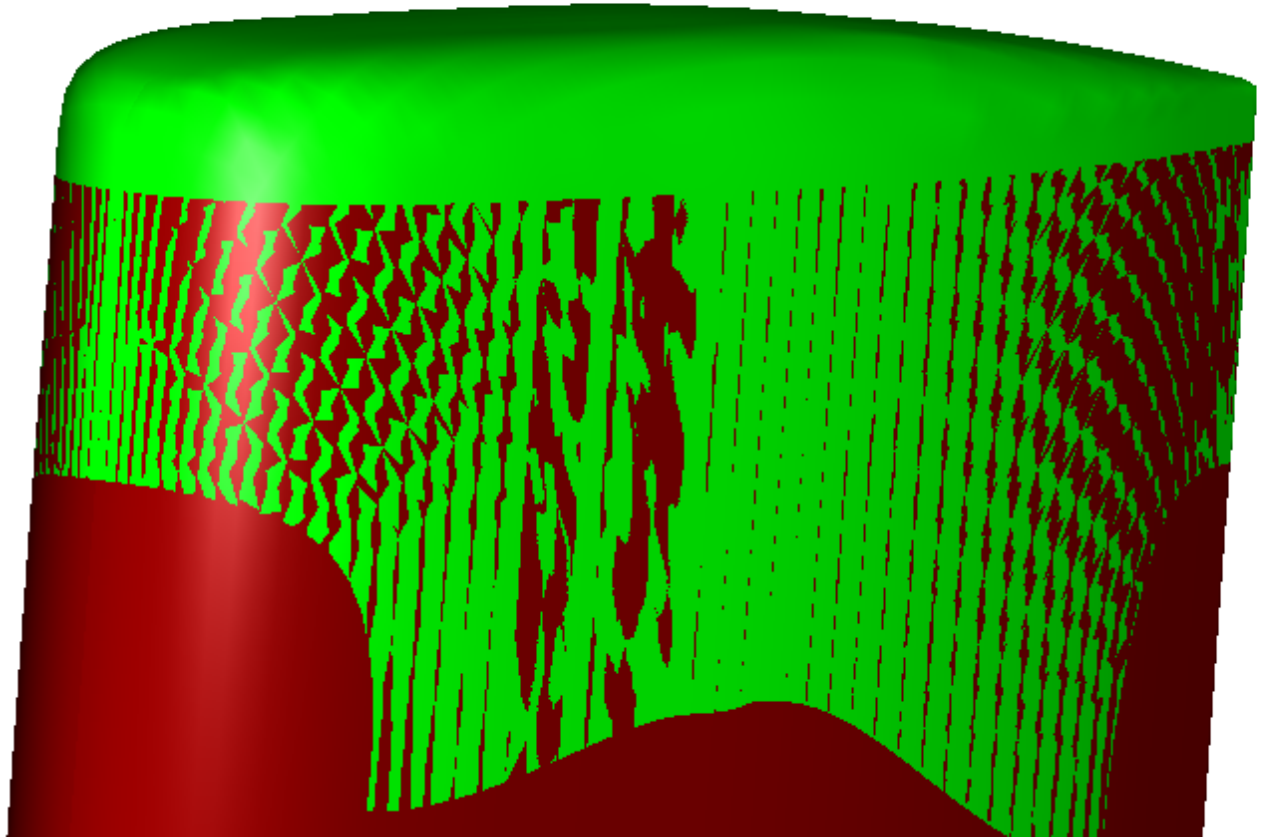
Overlapping Surfaces: Inconsistent Geometry Definition



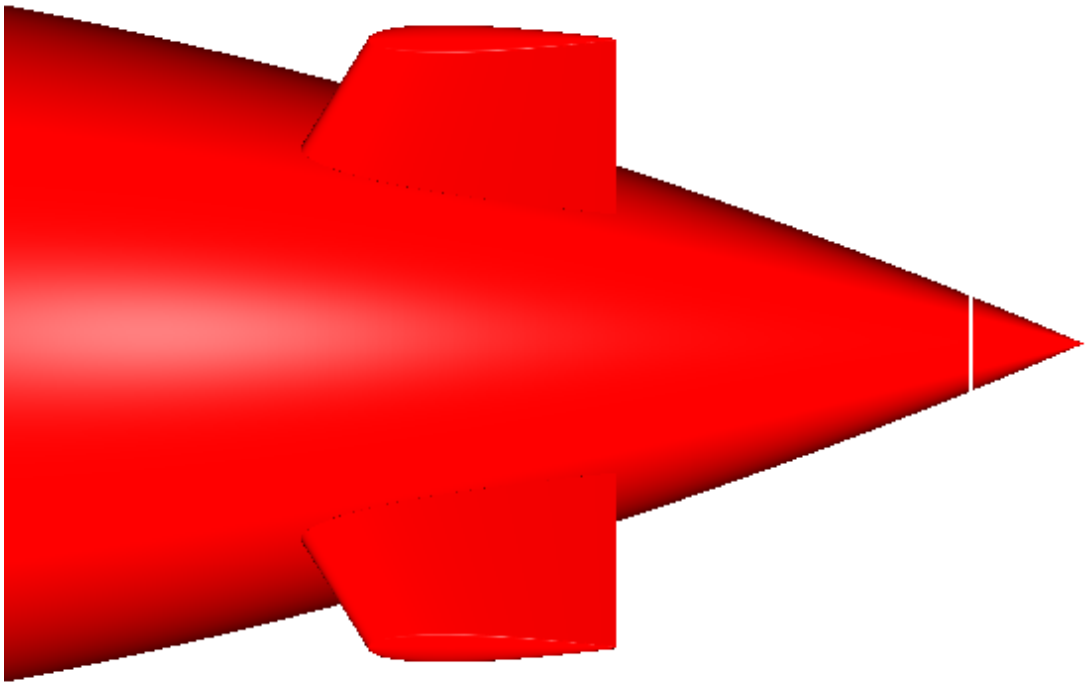


Overlapping Surfaces: Inconsistent Geometry Definition

- Solution: delete inconsistent portion of grid



Overlapping Surfaces: Inconsistent Geometry Definition



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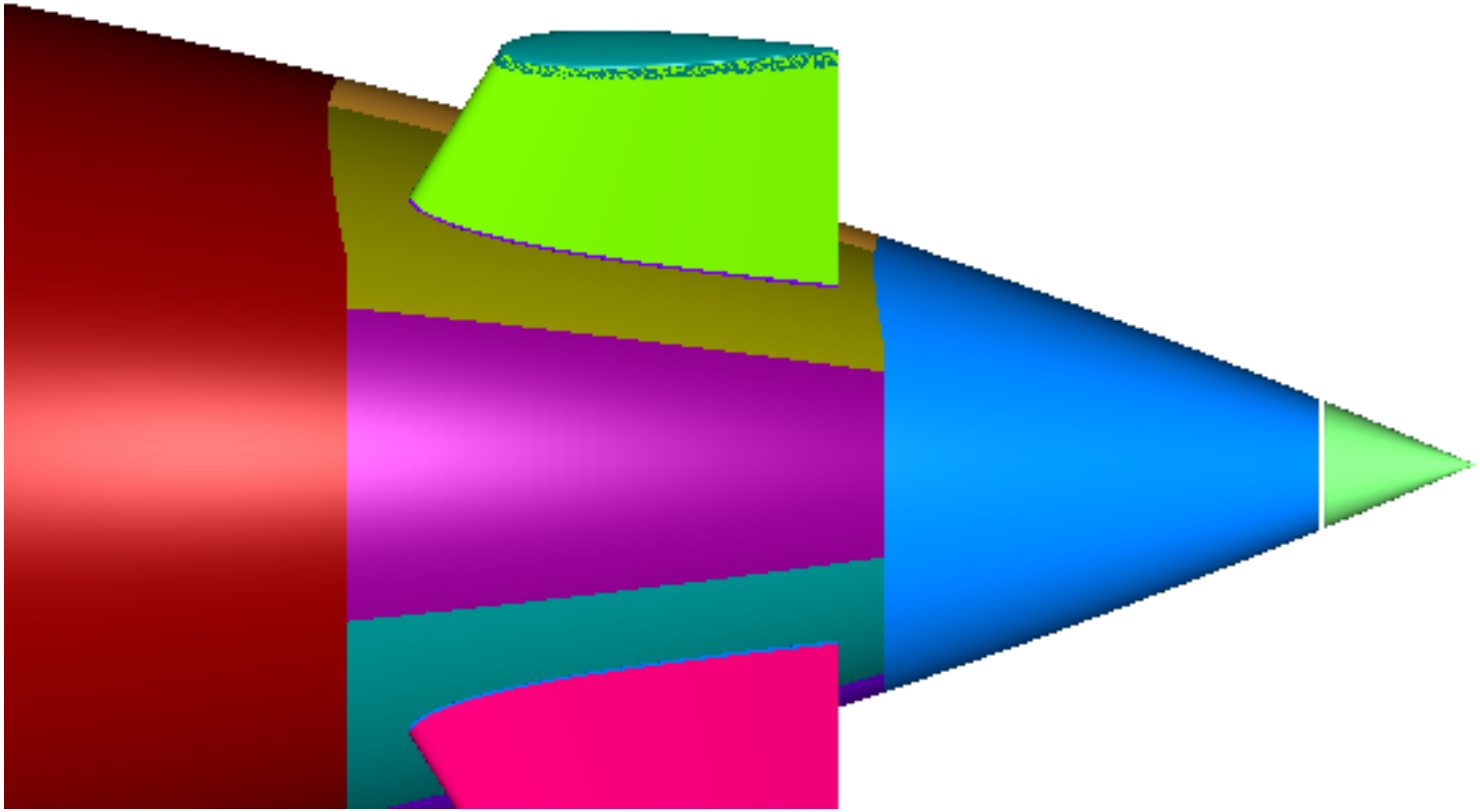

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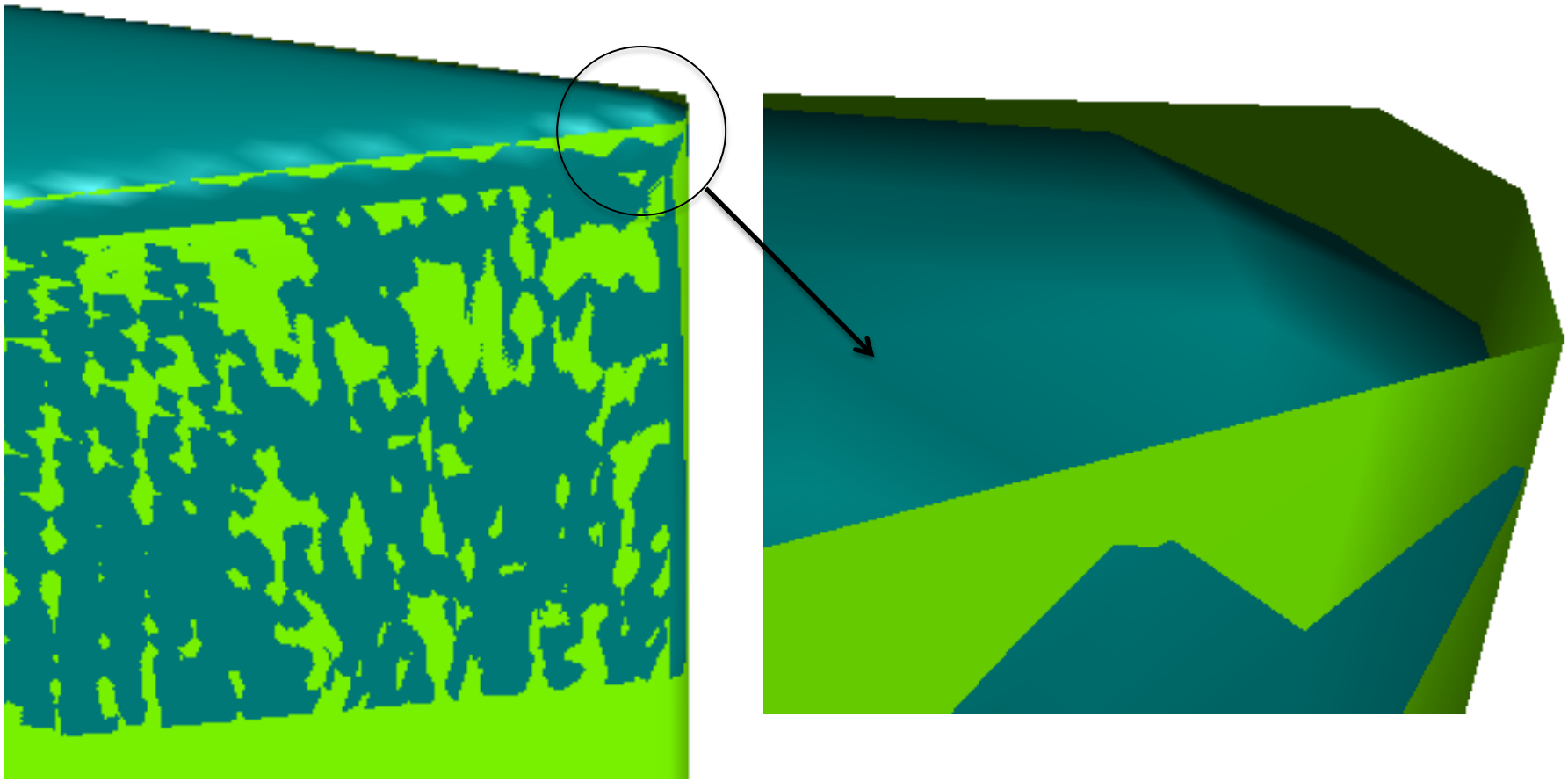
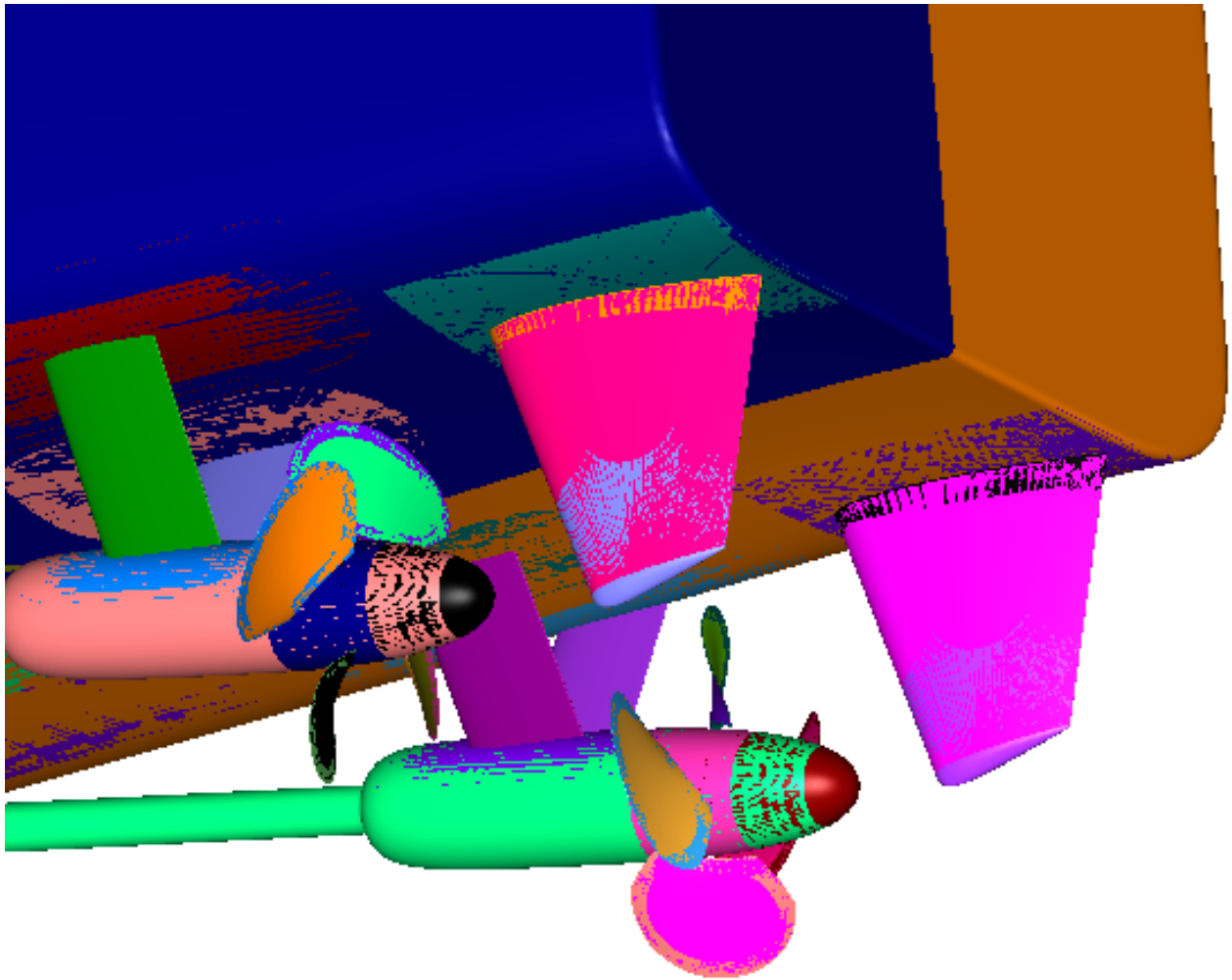


Overlapping Surfaces: Inconsistent Geometry Definition



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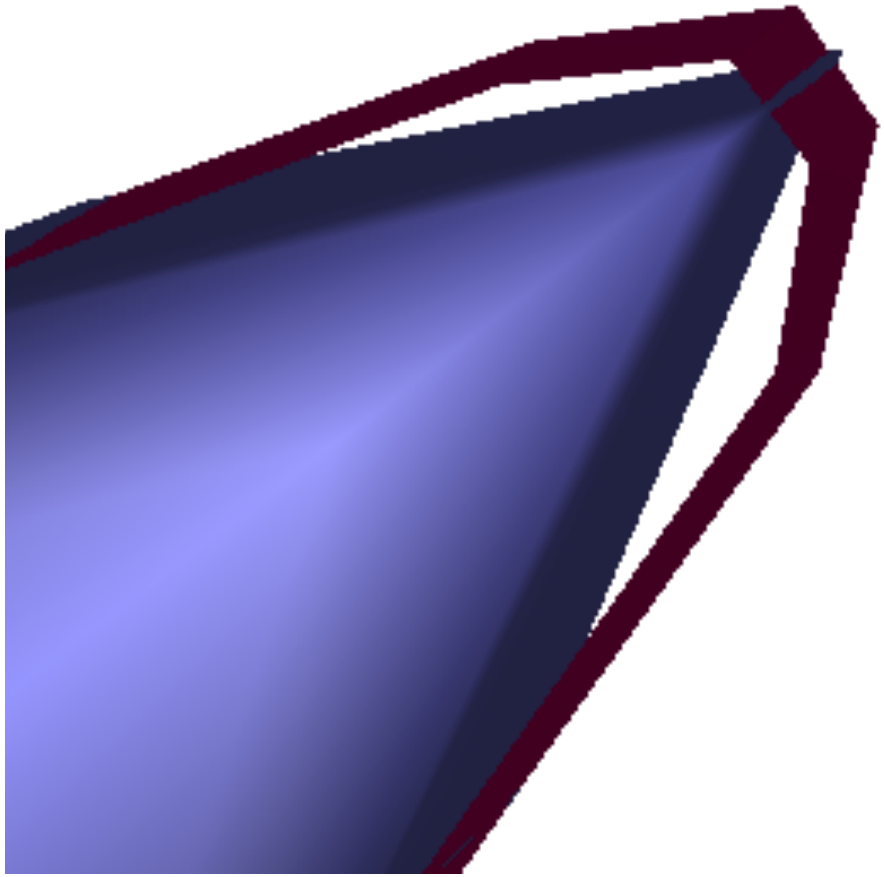


Small Inconsistent Geometry Definitions Poses Serious Problem

- Difficult for the user to see/fix
  - Even when told what to look for
- May not cause a problem until late in the simulation
  - Geometry is effectively water tight until grid aligns to probe in the fatal direction

How To Heal The Geometry

- Better users or grid generators
  - Not possible
- Reduce overlap
  - Use minimization
  - USURP, FOMOCO, zipper grids
  - May need a valid assembly with hole cuts
  - Difficult for inconsistency at trailing edge
- Different flood fill algorithm

Information Available At Start of Flood Fill

- Outlined the cutting geometry in the grid
  - Marked edges/elements as cut/OUT
  - Not 100% accurate: may have gaps in the outline if geometry is not watertight
- Points marked as behind or in front of the cutting geometry
  - Not 100% accurate: may have incorrectly marked point as behind/in front of the geometry

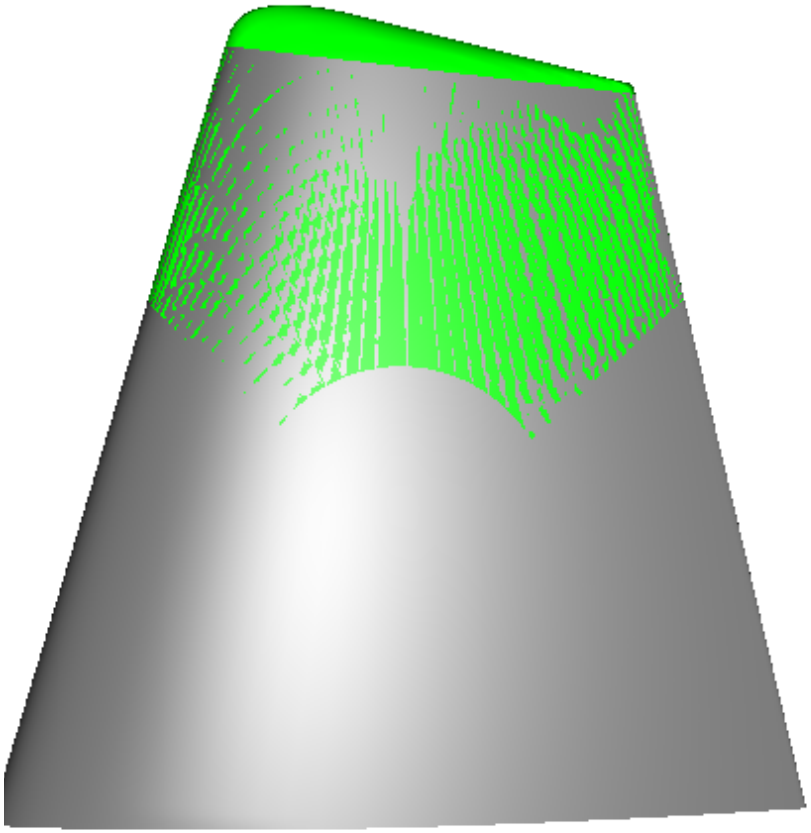
New Flood Fill Approach

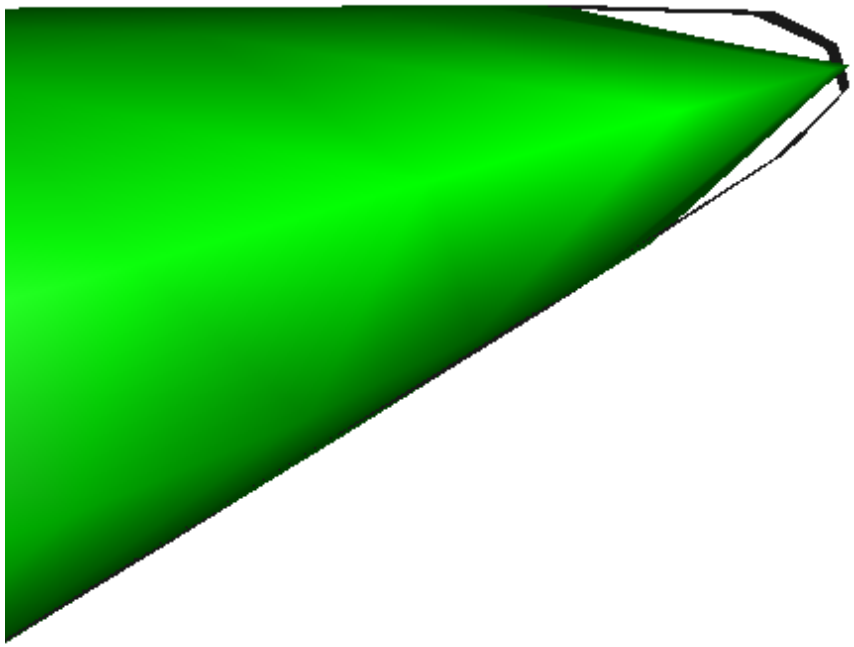
- Goal is to somehow smooth over gaps in the geometry
  - Stretch a membrane over the gaps
- Approach: Use Laplacian type smoothing of element marking

Smoothing Details

- Smoothing a scalar F at elements
  - Initial value = 1 (active)
- Element with node marked as out will have F=0
- Neighbor element marked as OUT will yield a zero gradient boundary condition
- Solve Laplacian of F
  - Gauss-Seidel iteration with over relaxation
- F < cutoff (0.75) is OUT

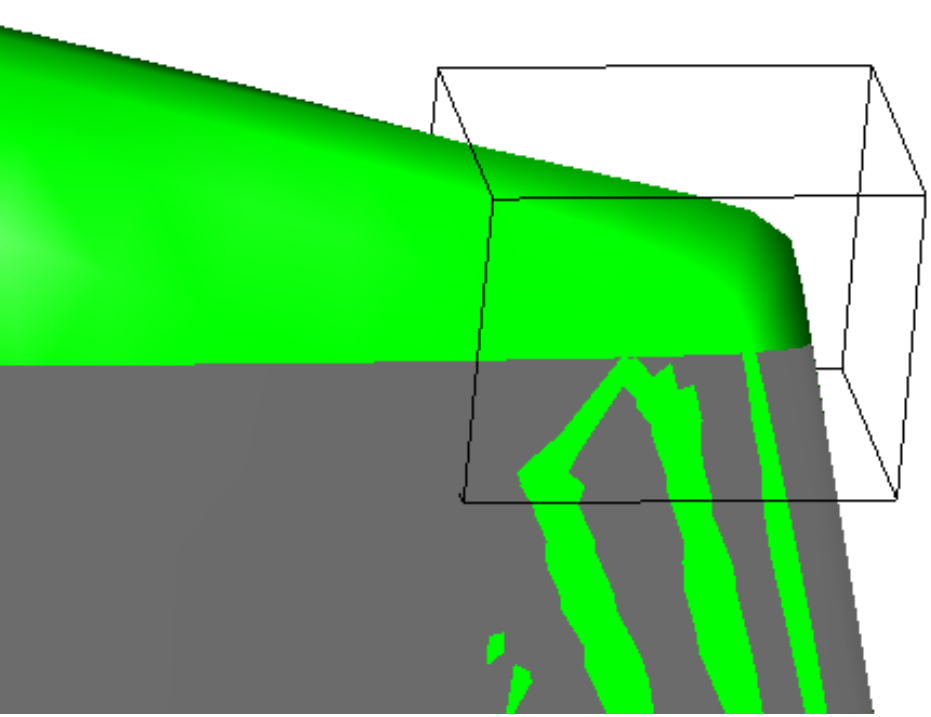
Test Case:
Ship Fin with Inconsistent Geometry

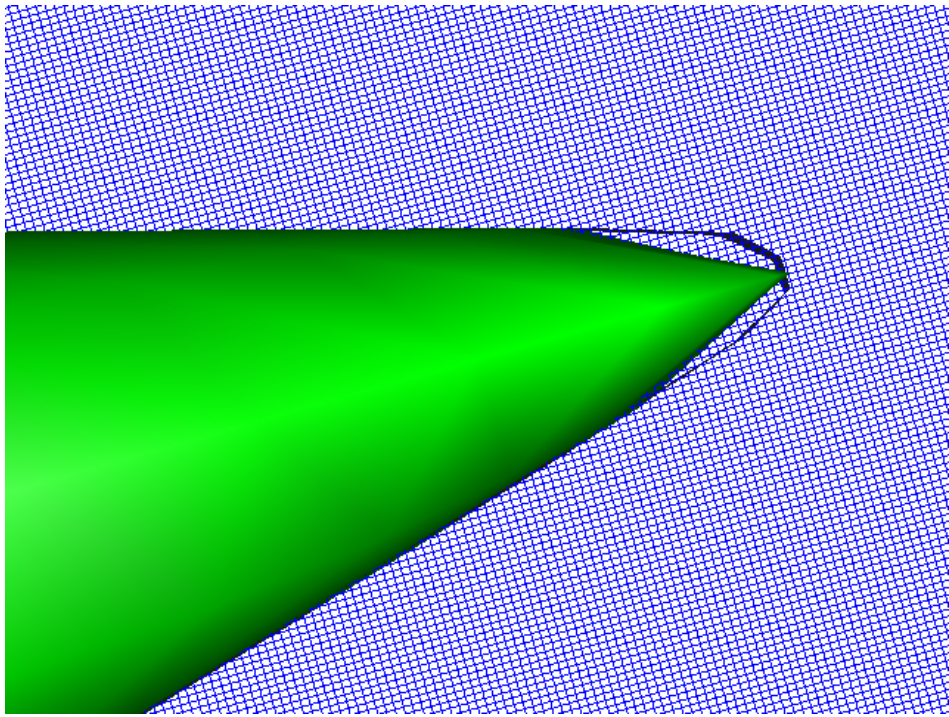




Probe Grid

- Add 169x145x61 Cartesian grid to cover leaky region

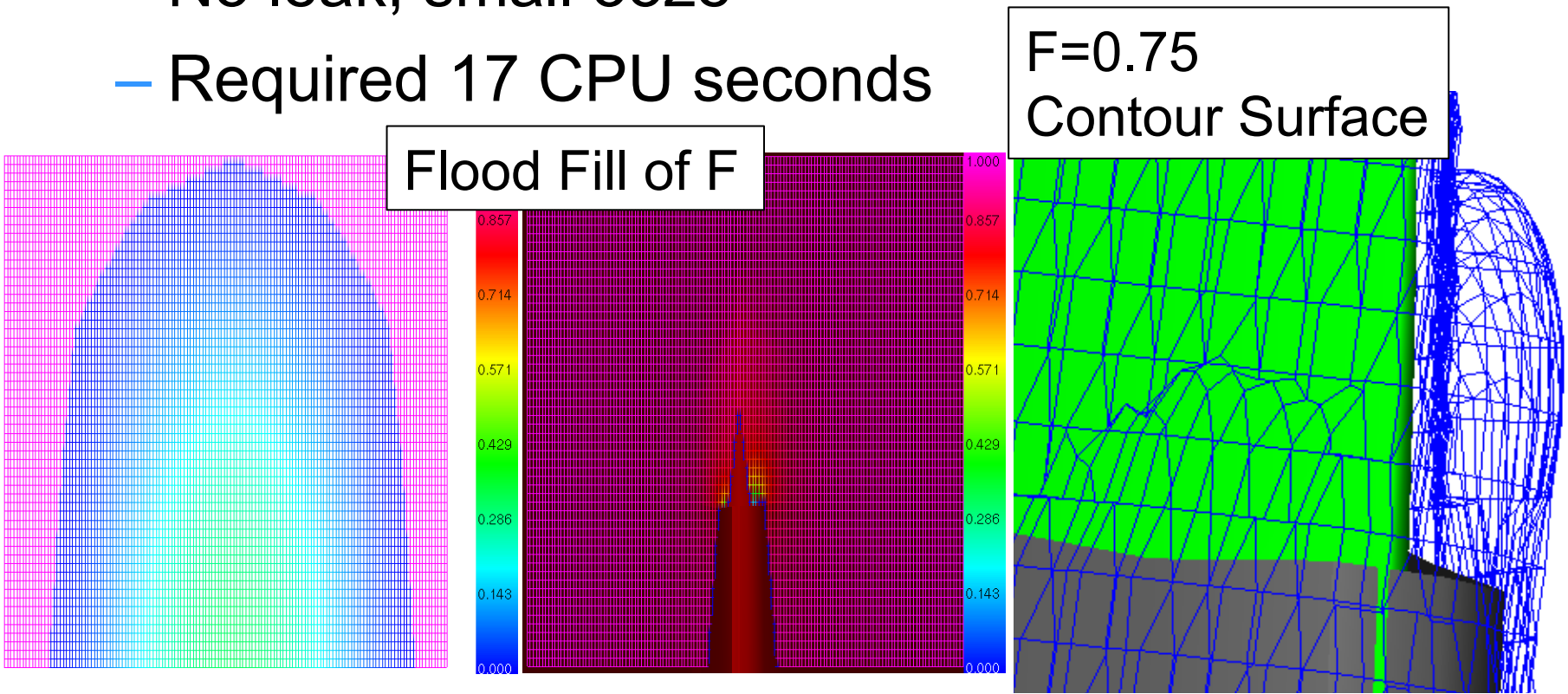




- Leak with conventional flood fill
  - Entire Cartesian grid is blanked OUT
  - Required 3.7 CPU seconds

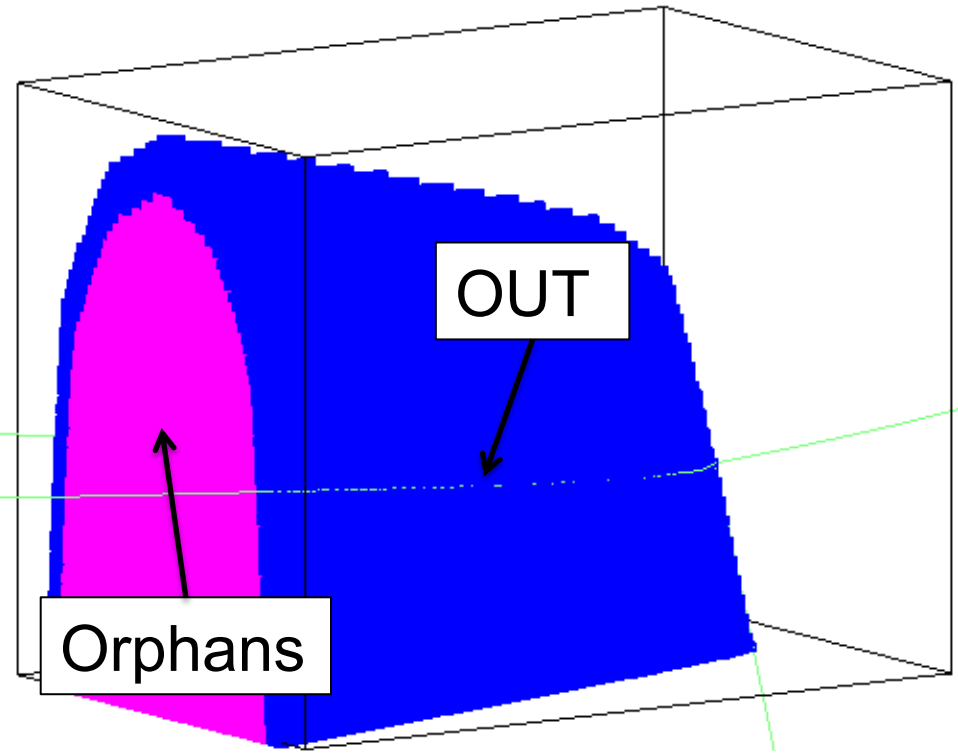
Laplacian Flood Fill: Converged

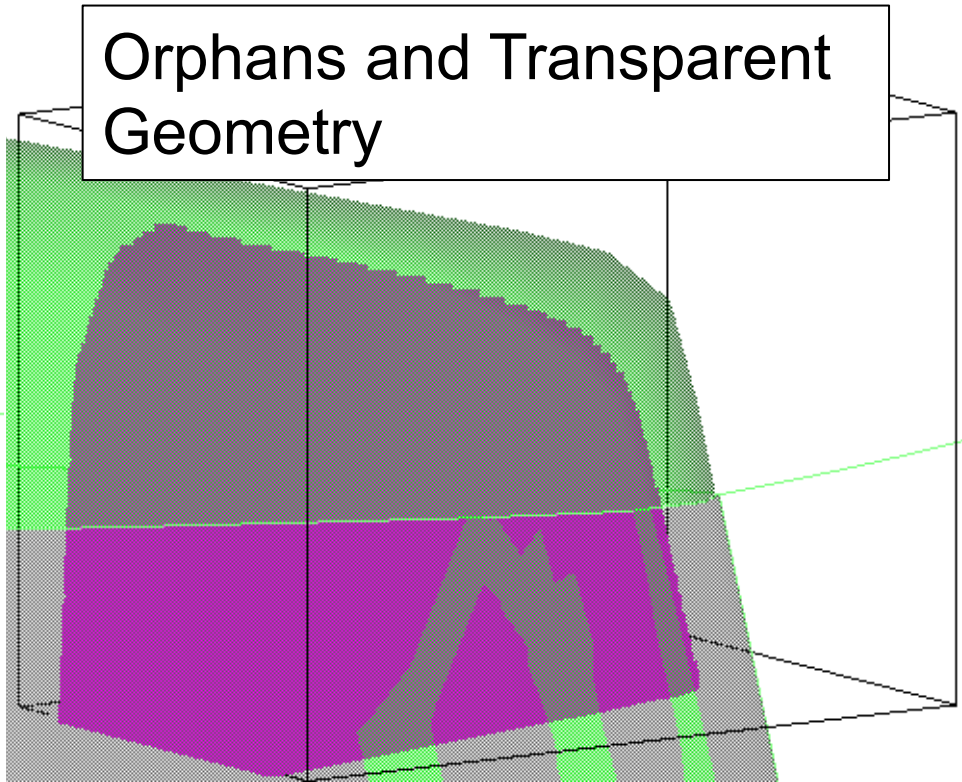
- Converged to tolerance in 760 iterations
  - No Orphans
  - No leak; small ooze
  - Required 17 CPU seconds



Laplacian Flood Fill: 10 Iterations

- Results after 10 iterations
  - 51000 Orphans: all inside the geometry
  - Required 3 CPU seconds





Summary of Very Preliminary Results

- Laplacian flood fill was successful in preventing leak
  - Simple Gauss-Seidel iteration is slow
    - Fast Poisson solver may help
  - Did have a slight ooze
- Incomplete convergence has orphans
  - All Orphans are inside the geometry for this case

What Is This Good For?

- Simple implementation is too slow for normal use
- Use few iterations to close gap, continue with regular flood fill
  - Need to find inside to start regular flood fill
- Possibly use in preprocessing step to get minimized overlap cutting surfaces
- Contour surface of F could be used as approximate geometry for hole cutting

Summary

- Flood fill is an integral part of many overset hole cutting methods
- Flood fill leak can occur when geometry is not effectively watertight
- A Laplacian smoothing approach to the flood fill was investigated
  - Preliminary investigation found it was successful in flood fill without leaking
  - Initial implementation is slow

Summary(2)

- Needs further investigation
  - Faster Laplacian solution
  - Use partial solution to start regular flood fill
- Possible use in preprocessing step
  - Attempt to remove geometric inconsistencies
  - Close non-watertight geometry

Questions?

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