NAVIER-STOKES MESHER (1)

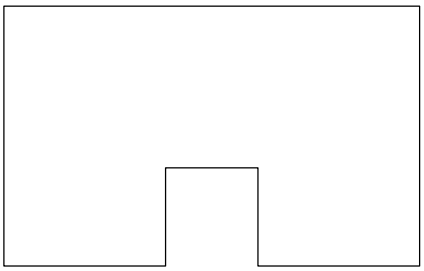
Observations:

- Size Not a Problem If $\delta_t/\delta_n = O(1)$
- Can Not Generate Unstructured Grids With Very High Aspect Ratio *Ab Initio*
    - Loss of Control for Aspect Ratio > 100
    - Vast Amount of Manual Input

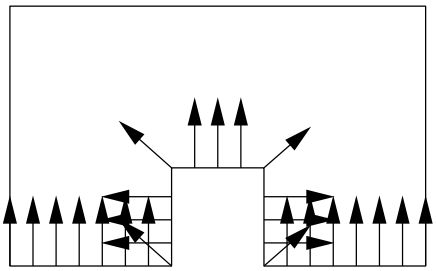
Strategy:

- Grid Regions With High Aspect-Ratio Elements Semi-Structured ('Navier-Stokes Region')
- Grid the Rest Unstructured ('Euler Region')
- Avoid the Uusual Problems at Corners
- Use Same Amount of Input Info as for Euler Grids

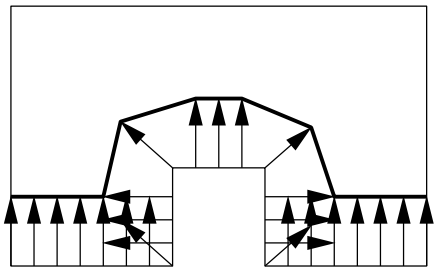
NAVIER-STOKES MESHER (2)



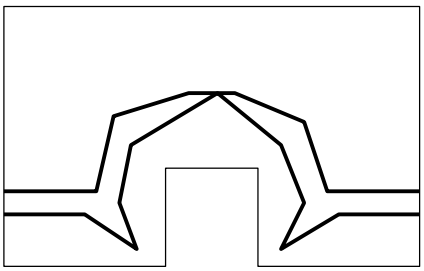
a) Define Surface



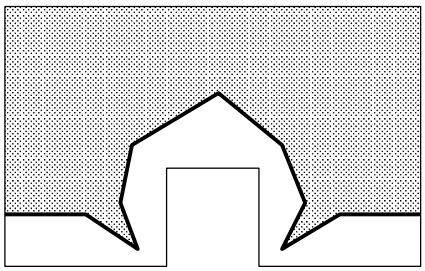
b) Compute Surface Normals



c) Obtain Boundary Layer Mesh



d) Remove Bad Elements



e) Complete Unstructured Mesh

Generation of Grids Suitable for Navier-Stokes Problems

NAVIER-STOKES MESHER (3)

Algorithmic Steps:

N.1 Use Unstructured Grid Generator to Mesh the Surface

N.2 Compute/Smooth Surface Normals

N.3 Generate Semi-Structured Grid at Wetted Surfaces

N.4 Remove Undesired Elements

- Negative/Too Large
- Crossing
- Isolated Islands

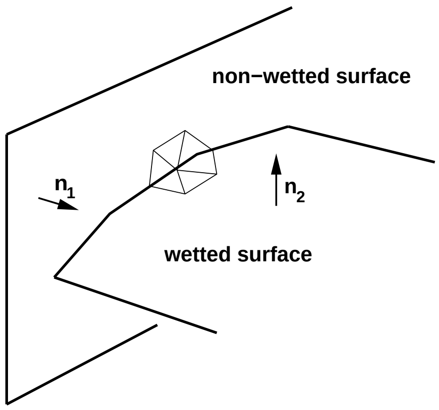
N.5 Use Unstructured Grid Generator to Complete the Mesh

NAVIER-STOKES MESHER (4)

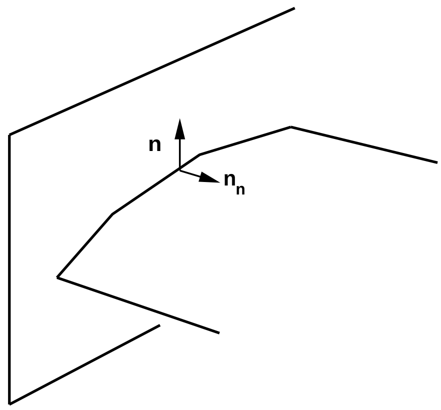
Major Areas of Work:

- Smoothing of Surface Normals
- Prism Generation (Compatibility)
- Fast Proximity Finder for Crossed Elements/Points (Octrees, Linked Lists)
- Good Filters to Avoid Extra Work (Cone of Visibility, Distance, etc.)
- Identification of Isolated Islands
- Initial Front for Unstructured Grid Region

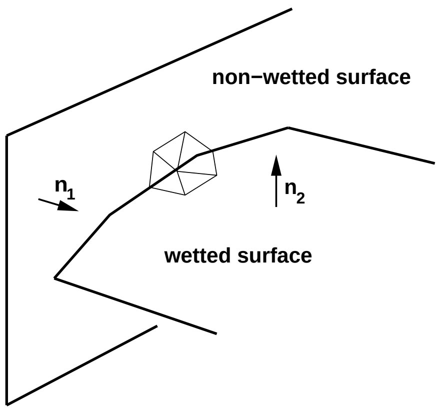
SMOOTHING OF SURFACE NORMALS (1)



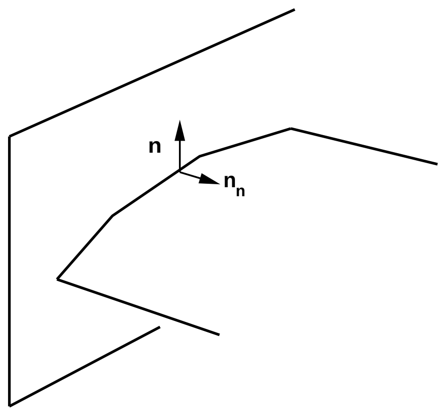
Wetted/Non−Wetted Interface



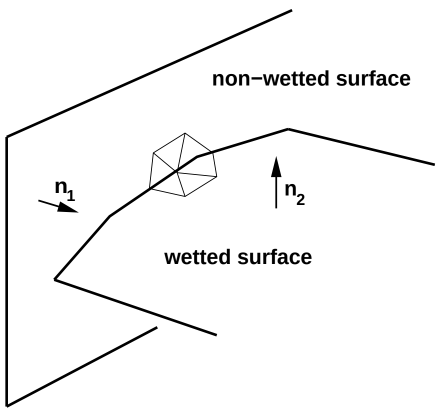
Normal forced to be on non−wetted surface



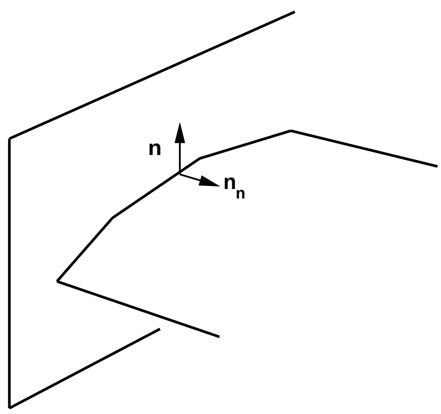
Wetted/Non−Wetted Interface



Normal forced to be on non−wetted surface



Wetted/Non−Wetted Interface



Normal forced to be on non−wetted surface

SMOOTHING OF SURFACE NORMALS (2)

Assume Given:

- Points of Surface
- Wetted/Non-Wetted Faces of Surface

a) Initialization Step:

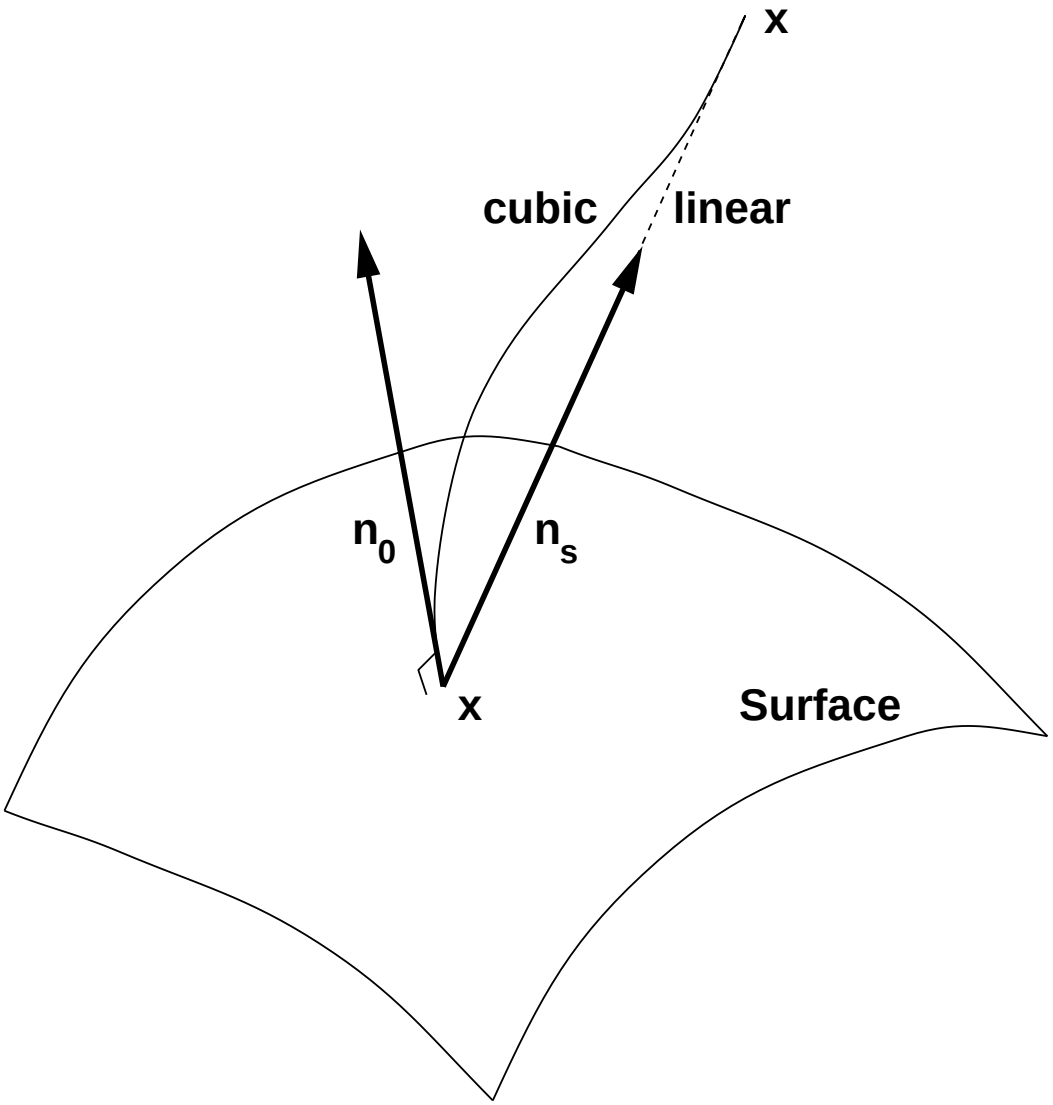
- Compute Wetted Face Normals
- Average at Points
- Obtain Boundary Conditions:
  - Wetted/Non-Wetted Interface: Normal from Non-Wetted Surface
  - Wetted/Wetted 2-Surface: Normal from Averages
  - Wetted/Wetted > 2-Surface: Prescibed Normal from Averages

b) Smoothing Step:

- Compute New Average Face Normal from Point Normals
- Average at Points
- Apply Boundary Conditions (Wetted/Non-Wetted Interface)

May require many passes (> 50)

POINT DISTRIBUTION ALONG NORMALS (1)



Blending of Smoothed and Unsmoothed Surface Normals

POINT DISTRIBUTION ALONG NORMALS (2)

Desired:

- Close to Body, Normals Perpendicular to Surface
- Away from Body, Normals Smoothed

Assume Given:

- Points of Surface $\mathbf{x}_0$
- Boundary Layer Thickness δ
- Normals Before/After Smoothing $\mathbf{n}_0, \mathbf{n}_1$

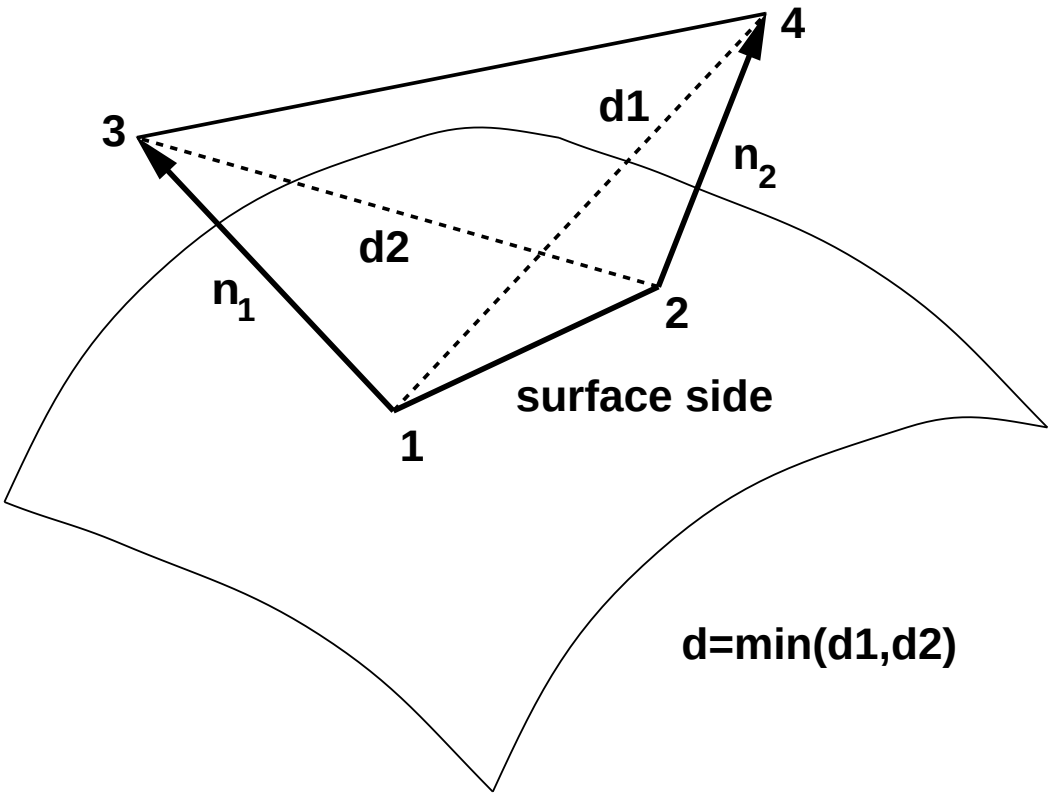
Then:

- Introduce Parameter: $\xi, \xi_{i+1} = \alpha\xi_i, \xi_n = 1$
- Use Hermitian Blend of Normals:

$$\mathbf{x} = \mathbf{x}_0 + \xi\delta\mathbf{n}_0 + \xi \cdot (2 - \xi) \cdot \xi\delta(\mathbf{n}_1 - \mathbf{n}_0)$$

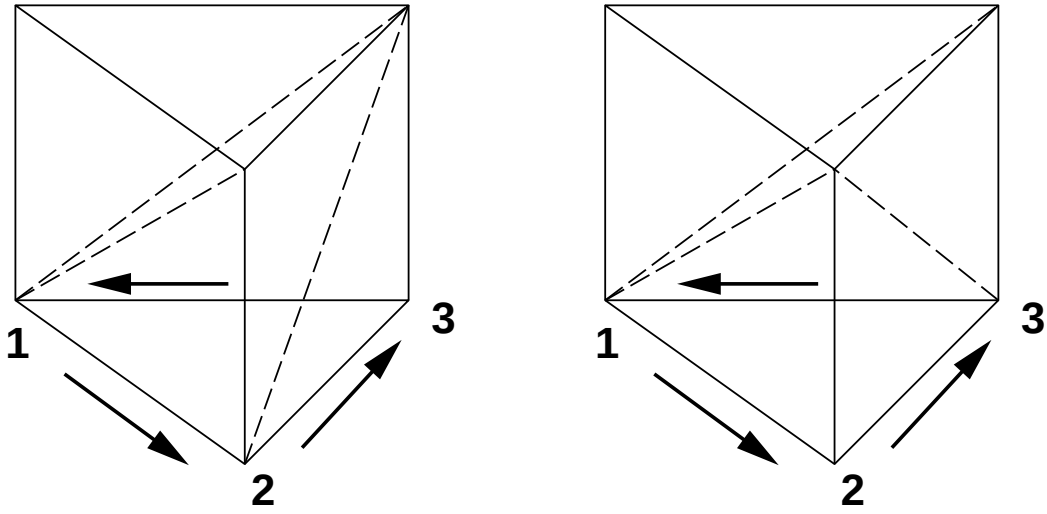
- Substitute: $\xi \cdot (2 - \xi) : \eta \cdot (2 - \eta) \quad , \quad \eta = \xi^{0.5}$

PRISM GENERATION (1)



Choice of Diagonal for Prism Faces

PRISM GENERATION (2)



Possible Subdivision Patterns for Prisms

PRISM GENERATION (3)

Problem: Compatibility Across Quad-Face Diagonals

Idea: As Sides of Each Face are Traversed,
Avoid Bad Combinations

D.0 Given:
- Sides of Surface Triangulation
- Sides of Each Face (Triangle)
- Neigbour Faces of Each Face

D.1 `DO`: Loop Over Faces
- `IF`: Current Side-Combination Invalid:
  - `DO`: Loop Over the Face-Sides
    - `IF`: Inversion of the Side/Diagonal Orientation Leads to Allowed Side-Combination in the Neighbour-Face:
      - Invert the Side/Diagonal Orientation
      - Goto Next Face

```
    ENDIF
  ENDDO
ENDIF
ENDDO
```

D.2 `IF`: Unallowed Combinations Left: `GOTO` D.1

FILTERS TO AVOID UNNECESSARY WORK

Why: Worst Case Scenario for Crossing Check $O(N^2)$

Filters:

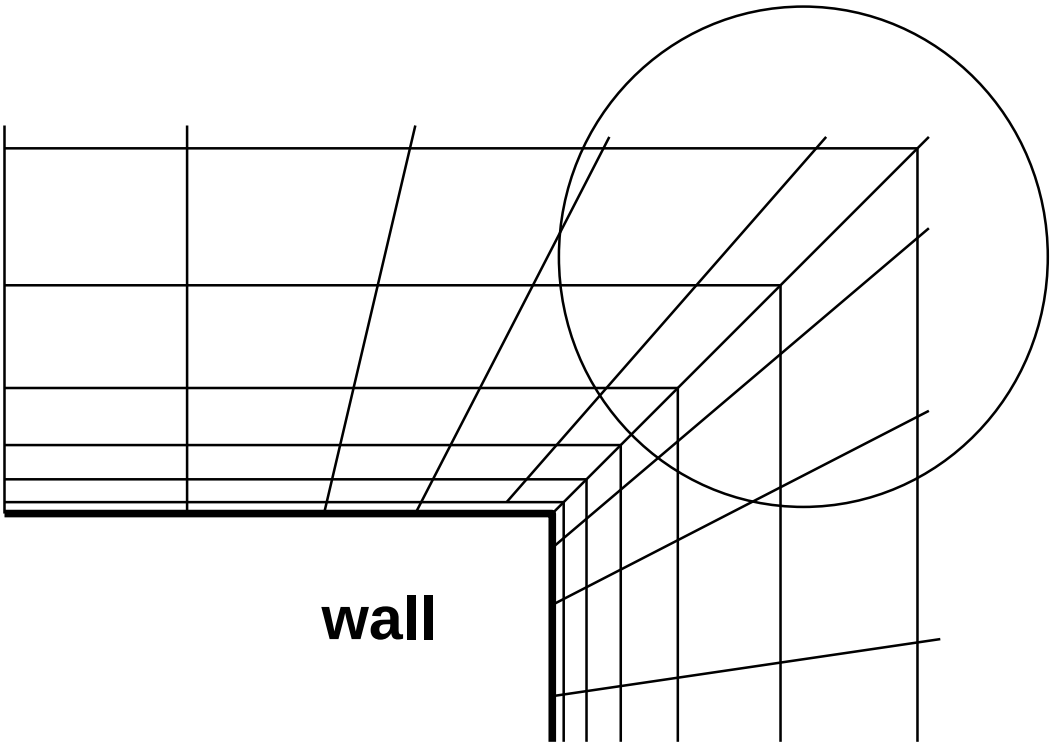
- Octrees for Localization
- Element Size (Large $\rightarrow$ Small)
- Column Marking
- Layers of Neighbours Not Considered
- Surface Patch ID
- Layered Testing
  - Point In Element
  - Point Too Close
- Prism Removal
- Only Top Element for Full Test
- Cone of Visibility
- Avoidance of Lower Layers

CHECKING THE INTERSECTION OF ELEMENTS

Problem: Tolerance

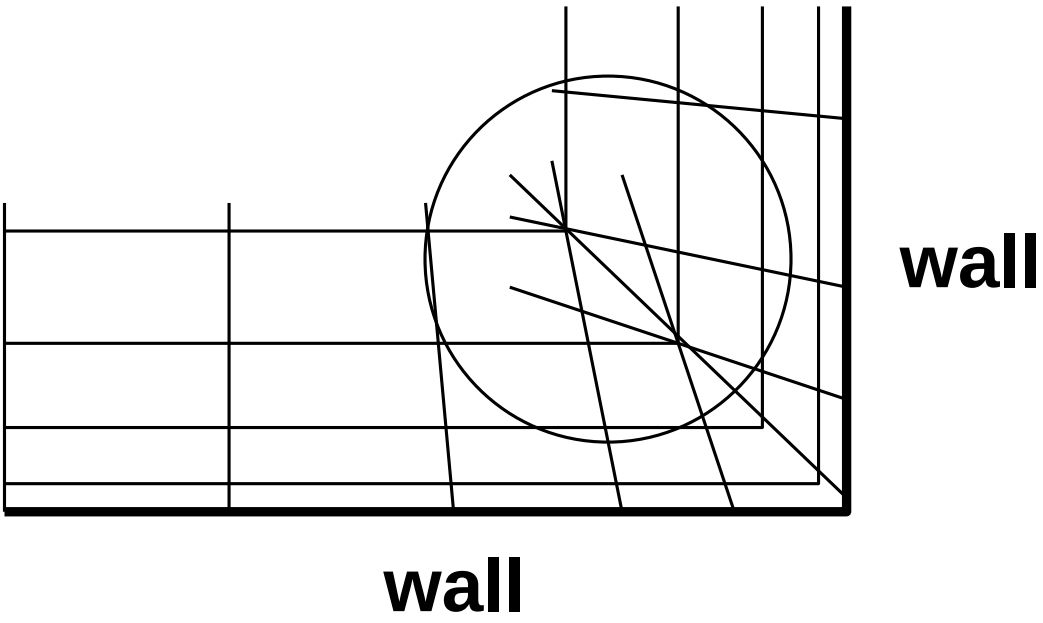
- Measure aspect ratio of elements $a = s_{min}/s_{max}$
- Take: $a_{12} = min(a_1, a_2)$
- Use: $toler' = toler * a_{12}$

REMOVAL OF LARGE ELEMENTS



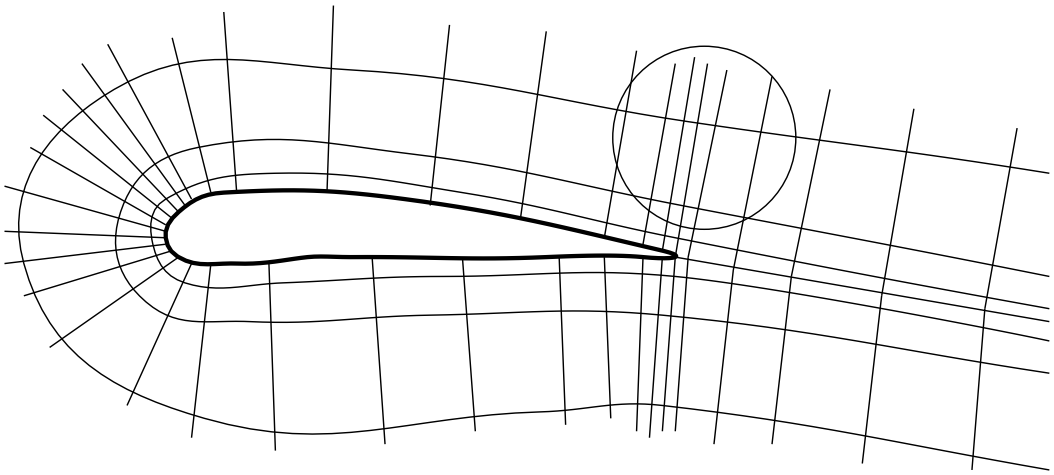
Removal of Large Elements

REMOVAL OF NEGATIVE ELEMENTS



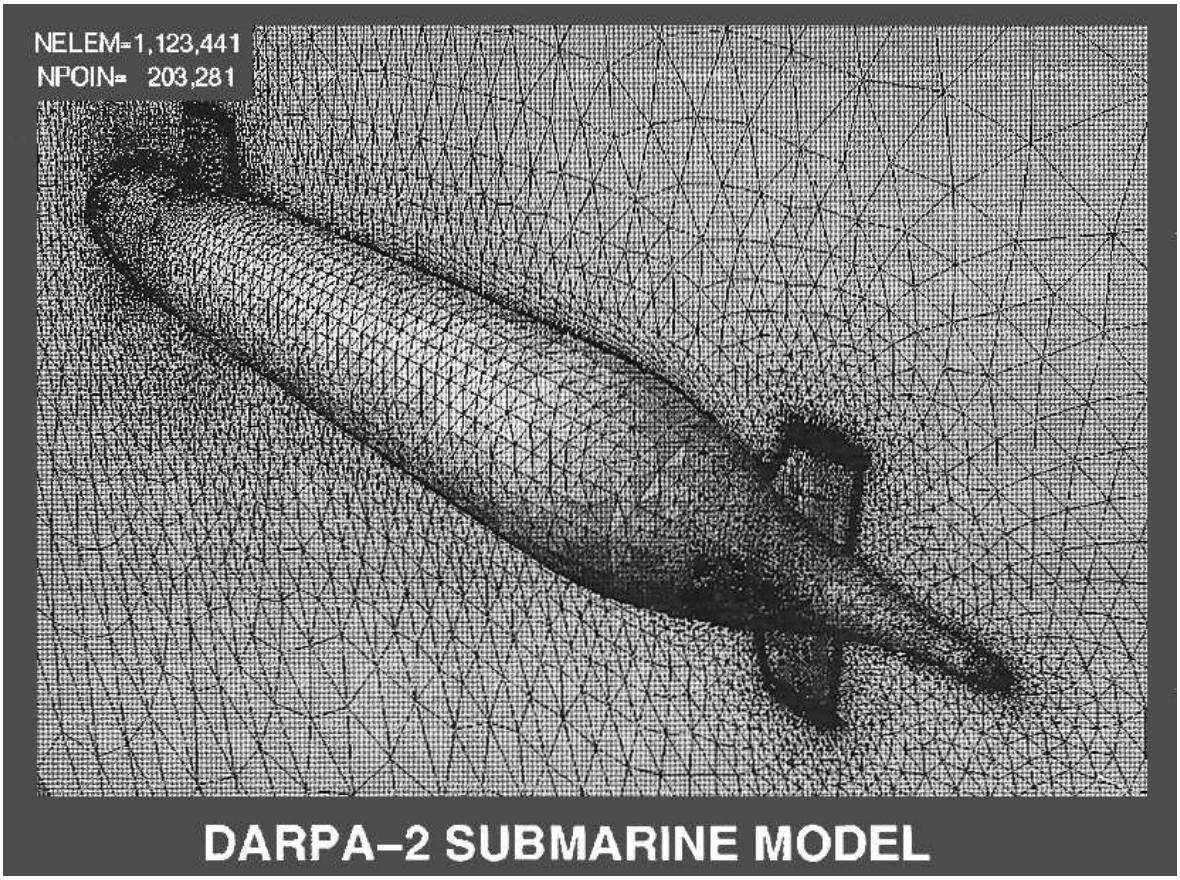
Removal of Negative (Folded) Elements

REMOVAL OF BADLY SHAPED ELEMENTS



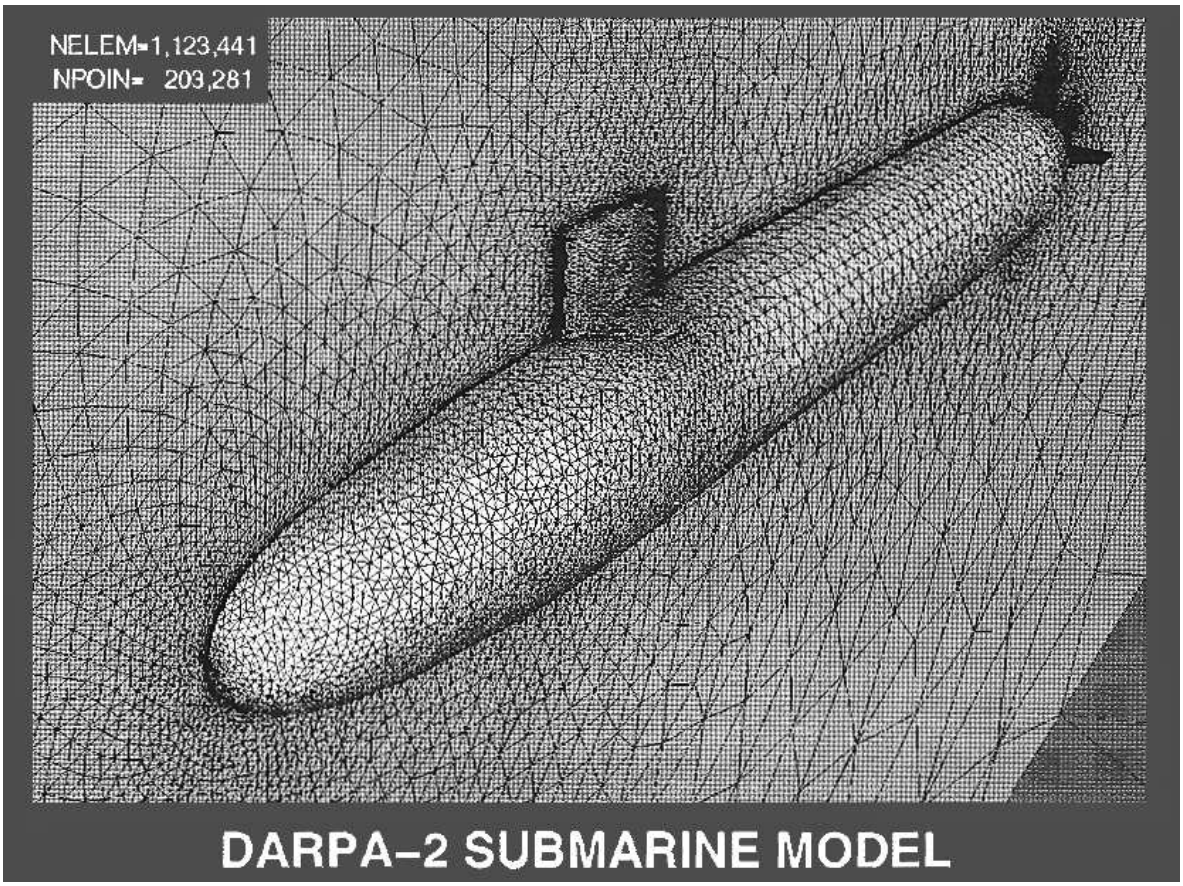
Removal of Badly Shaped Elements

DARPA-2 MODEL



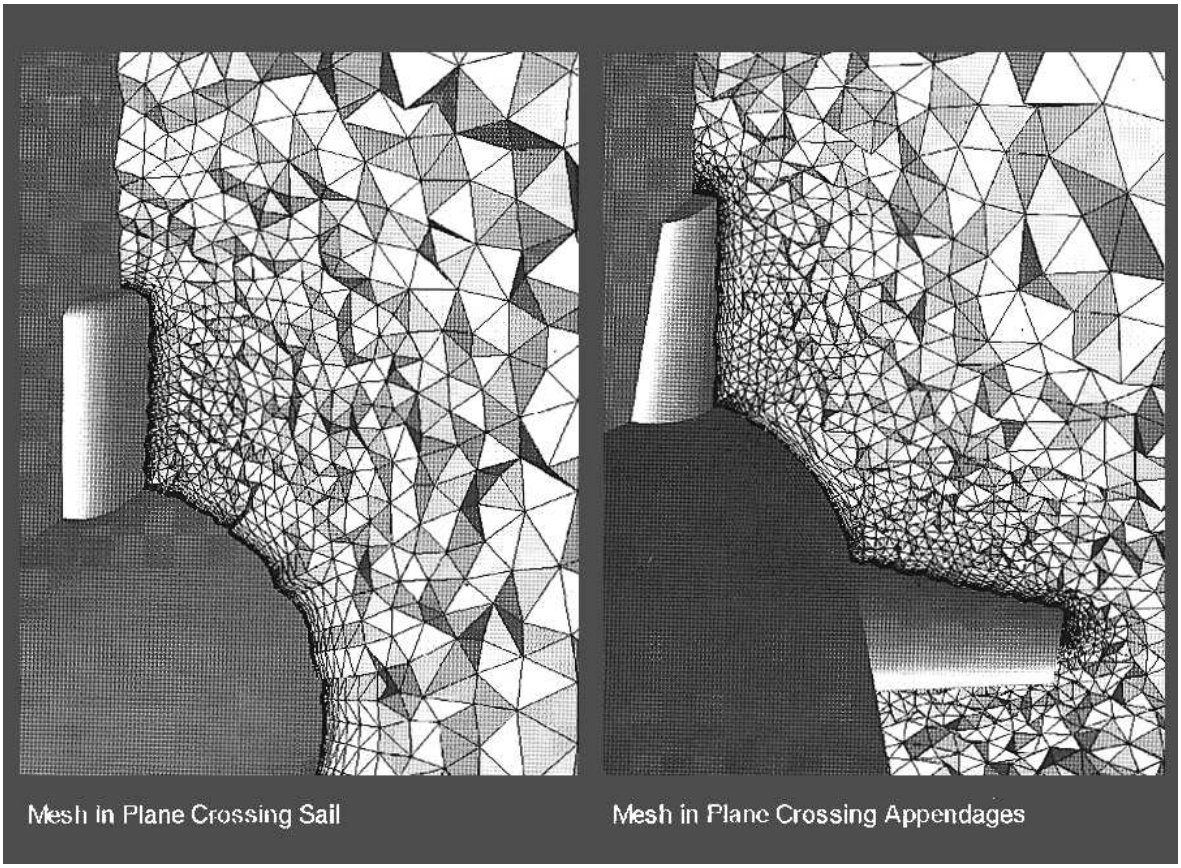
DARPA-2 Model: Surface Triangulation

DARPA-2 MODEL



DARPA-2 Model: Surface Triangulation

DARPA-2 MODEL



DARPA-2 Model: Cross-Sections in Mesh

TIMINGS (IBM-550)

Table 7.3: Timings for Cylinder Intake Case

Stage	NELEM	Time (min)	Rate (NELEM/min)
Navsto	335,843	5	67,168
Unstructured	108,813	10	10,881
Postproc.		5	
Total	444,656	20	22,232

Table 7.4: Timings for DARPA-2 Case

Stage	NELEM	Time (min)	Rate (NELEM/min)
Navsto	682,401	17	40,141
Unstructured	441,040	38	11,606
Postproc.		15	
Total	1,123,441	70	16,049

ADVANCING FRONT/LAYERS RANS MESHER

Status:

- Implemented and Working 2-D and 3-D
- Automatic (No User Intervention)
- Interactive
- Fast: >40Kels/min on IBM-550
- Can Be Improved Further:
  - Element Crossing Check for Highly Distorted Elements
  - More Control of Element Shape in Space
- Multiple Normals Case Problematic