OVERLAPPING UNSTRUCTURED GRIDS

- Introduction
- Distance to Wall
- Element Size as Criterion
- External Boundaries and Domains
- Interpolation: Initialization
- Treatment of Domains That Are Partially Outside
- Incremental Interpolation
- Diagnostics
- Changes in Flow Solver
- Examples
- Conclusions

INTRODUCTION (1)

Complex Geometries and/or Moving Bodies $\Rightarrow$

- Automatic Grid Generation
- Solvers for Moving Grids/Boundaries; and
- Treatment of Grids Surrounding Moving Bodies

INTRODUCTION (2)

Three Leading Techniques:

- Unstructured, Moving (ALE) Grids/Solvers
- Overlapping Grids/Solvers
- Adaptive Cartesian Grids

UNSTRUCTURED, MOVING GRIDS

- Guarantee Conservation
- Smooth Variation of Grid Size
- Locally Distorted Elements (Accuracy)
- Mesh Movement/Smoothing Techniques and Remeshing (Cost)

OVERLAPPING GRIDS

- No Remeshing
- Fast Mesh Movement Techniques
- Independent Component/Body Gridding
- Loss of Conservation
- Local Jump in Element Size (Accuracy)
- Interpolation (Cost)

ADAPTIVE CARTESIAN GRIDS

- No Mesh Movement
- No Remeshing
- Detection of Boundary Placement
- Small/Cut Cells (Accuracy)
- Mesh Refinement/Coarsening (Cost)
- RANS Difficult

RELATED WORK

- Overlapping/Chimera for Structured Grids
  - Whole Series of Conferences
  - Production Codes Pegsus, Overflow

- Overlapping for Unstructured Grids
  - Nakahashi, Sharov et al.
  - 'Distance to Wall' Criterion
  - Interpolation Via Nearest Neighbour/ Voronoi Fill

CONTRIBUTIONS OF PRESENT WORK

- Fast Distance to Wall Algorithm;
- Element Size as Dominant Mesh Criterion;
- Fast, General Interpolation Based on Octrees and Bounding Boxes;
- Treatment of Bodies that are Partially Outside

DISTANCE TO WALL (1)

Why:

- Decision if Point Should Be Interpolated from Other Grid

How: Combination of:

- Linked List to Store Points Surrounding Points;
- Faces on the Foundary;
- Linked List to Store Faces Surrounding Boundary Points; and
- Heap List for Points to Dynamically Store the Point Closest to Walls

DISTANCE TO WALL (2)

Part 1: Initialization

- Obtain the list of points surrounding points;
- Obtain the faces on the surfaces from which distance is to be measured;
- Obtain the list of faces surrounding faces;
- Set all points as unmarked

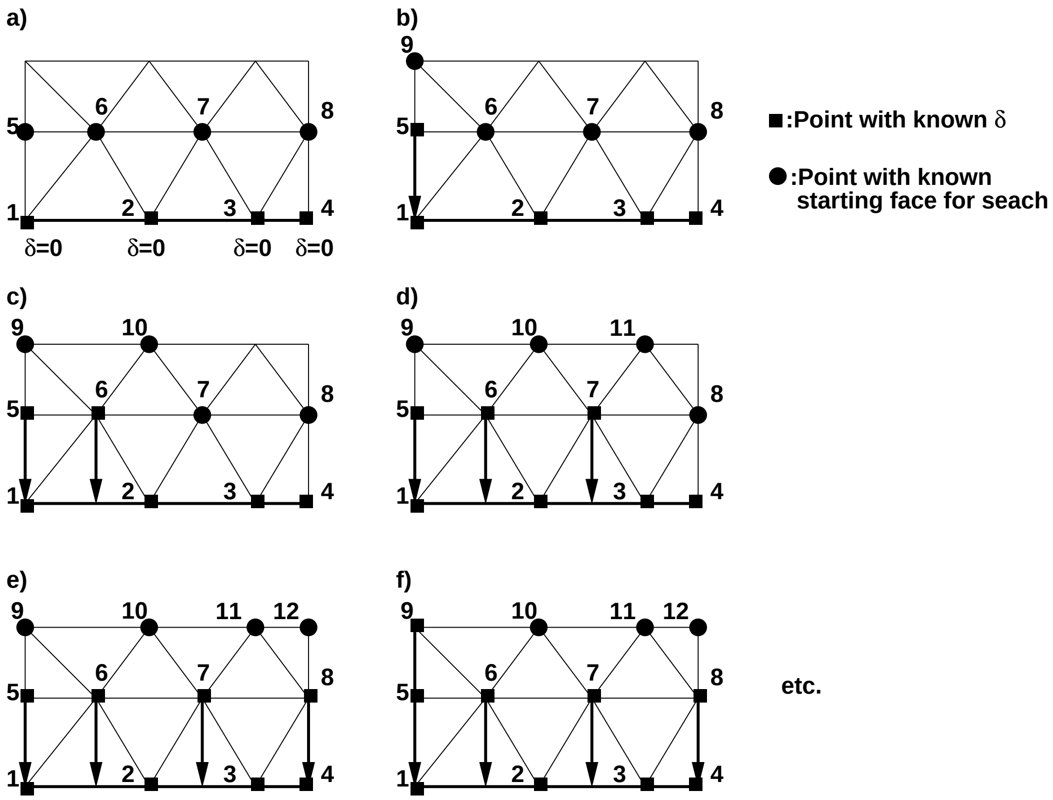
- `do`: loop over the faces
    - `do`: loop over the points of a face
        - Set distance to wall = 0
        - Mark the point
        - Introduce point into heap list
    - `enddo`
- `enddo`

DISTANCE TO WALL (3)

<u>Part 2</u>: Domain Points

- `while`: heap not empty
    - Retrieve the point `ipmin` with smallest distance to wall
    - Obtain boundary face of `ipmin`
    - Find the points surrounding `ipmin`
    - `do`: loop over the neighbours of `ipmin`
        - `if`: point unmarked
            - Find the shortest distance to the wall
            - Introduce point into heap list
            - Mark unmarked nearest neighbours
        - `endif`
    - `enddo`
- `endwhile`

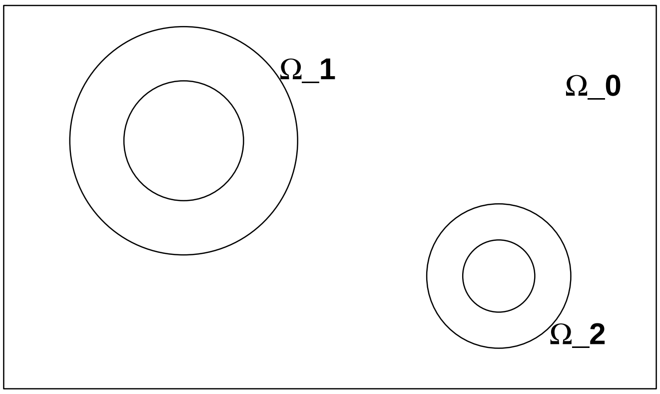
DISTANCE TO WALL (4)



EXTERNAL BOUNDARIES AND DOMAINS (1)

<u>Why</u>:

- Bodies in Flowfield Surrounded by Local (Own) Grid Embedded in External, 'Background Grid' $\Rightarrow$
- Need to Define 'Distance to Wall' for External Grid



EXTERNAL BOUNDARIES AND DOMAINS (2)

Compute extent of Whole Domain:

$$d = max(x_{max} - x_{min}, y_{max} - y_{min}, z_{max} - z_{min})$$

- Assign d To All point of External Grid
- For External Boundary of Local Body Grids:
  - Set $d_{out} = 10\ d$
  - If Desired: Use Several Layers

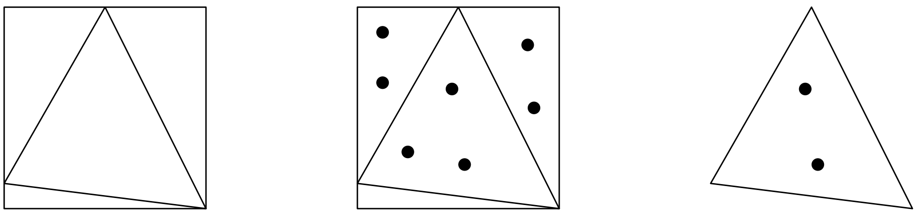
INTERPOLATION: INITIALIZATION

Desired: Given Element:

- Which Point of Different Grid Falls Into It ?

How: Combination of:

- Marker for Domain-Nr. of Each Point;
- Octree of all Gridpoints



a) Bounding Box   b) Points (Octree)   c) Retain Points:
− Different Domain
− Inside Element

Part 1: Initialization

- Mark the domain-nr. of each gridpoint;
- Construct an octree for all gridpoints;

Part 2: Interpolation

- `do`: loop over the elements
- Obtain the bounding box for the element;
- From the octree, obtain the points in the bounding box;
- Retain only the points that:
  Correspond to other (allowed) domains/grids;
  Are located inside the element;
  Have a distance/size larger than the one in the element;
- `enddo`

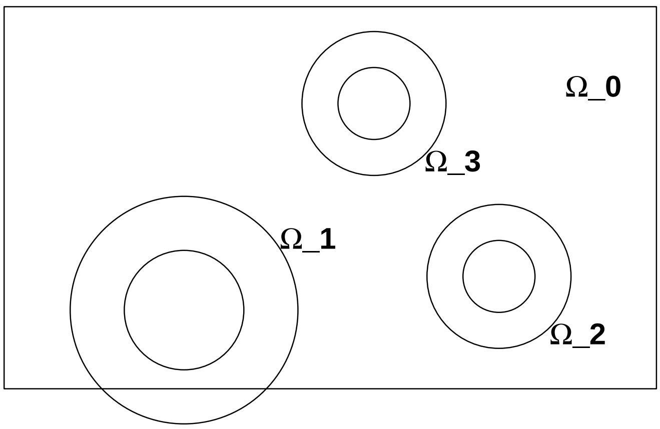
Re:

- No Recursion/Memory Contention
  $\Rightarrow$ Easy to Parallelize

TREATMENT OF DOMAINS THAT ARE PARTIALLY OUTSIDE (1)

Why:

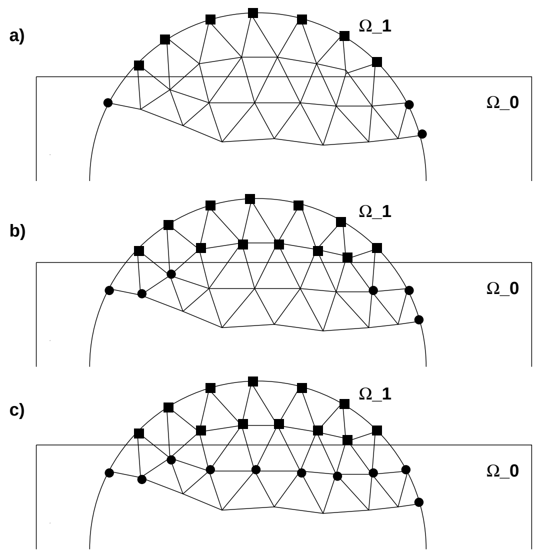
- External Boundaries of Body Grids May Lie Outside 'Background Grid'
  $\Rightarrow$ Interpolation Impossible



TREATMENT OF DOMAINS THAT ARE PARTIALLY OUTSIDE (1)

Recursive Loop:

- While Exterior Points Without Hosts Present:
  - For Neighbours of Points Without Hosts: Set Distance to Body to Large Value
  - Interpolate Again
- End While

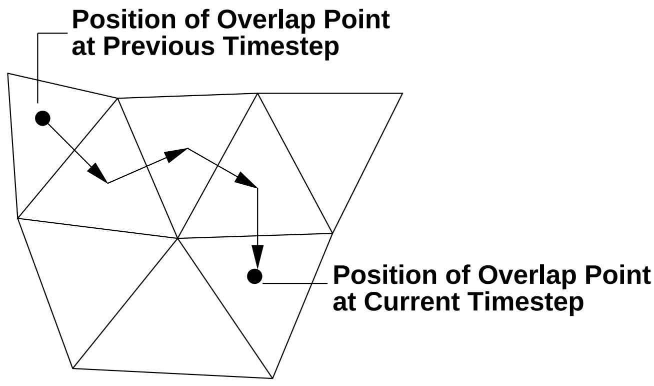


INCREMENTAL INTERPOLATION

Why: Small Movement per Timestep

How:

- Mark Points Surrounding Present Set of Interpolated Points
- Use Nearest Neighbour Search



Re:

- No Recursion/Memory Contention
  $\Rightarrow$ Easy to Parallelize

DIAGNOSTICS

Why: Overlap Technique no Panacea

- Interpolated Points That Interpolate
- Size-Difference in Interpolation Region
- Insufficient Number of Layers

How:

Write Files for Graphical Display of Problems

CHANGES TO FLOW SOLVER

- Masking Array for Points: `lmskpo(1:npoin)`
  - `0`: $\Rightarrow$ Inactive
  - `1`: $\Rightarrow$ Active, Being Interpolated
  - `2`: $\Rightarrow$ Active

- After Each Timestep/Iterative Step:
  - Set $\Delta\mathbf{u} = 0$ if `lmskpo(ip)`<2
  - Interpolate
  - Update the Solution/Krylov Space

SPHERE IN CHANNEL

- Equations Solved: Compressible Euler
- $Ma = 0.67$

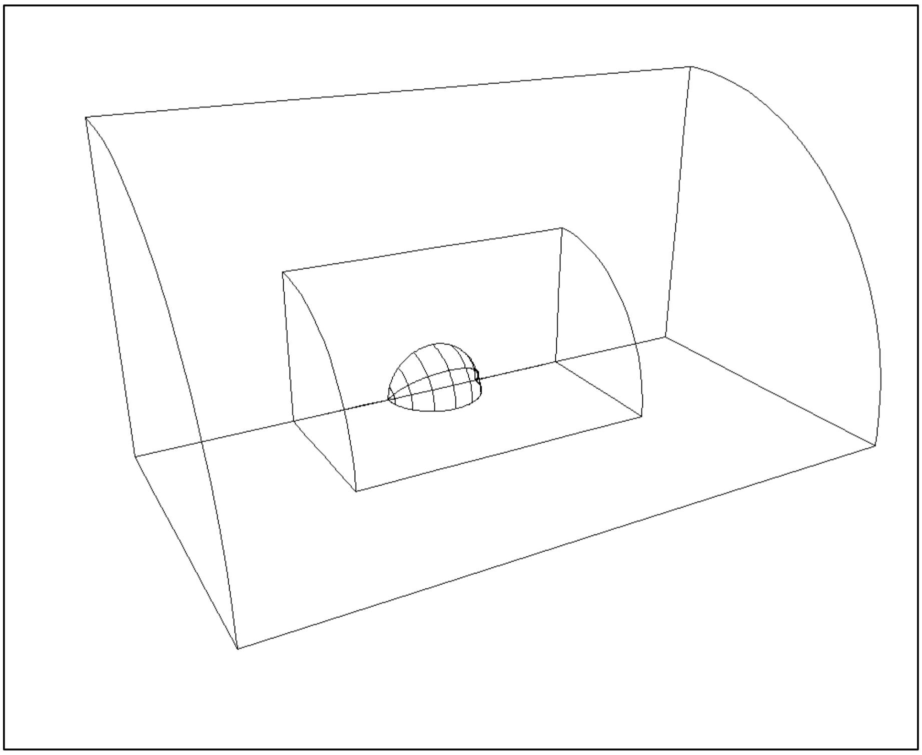


Figure 6.1 Sphere in Channel: CAD Data

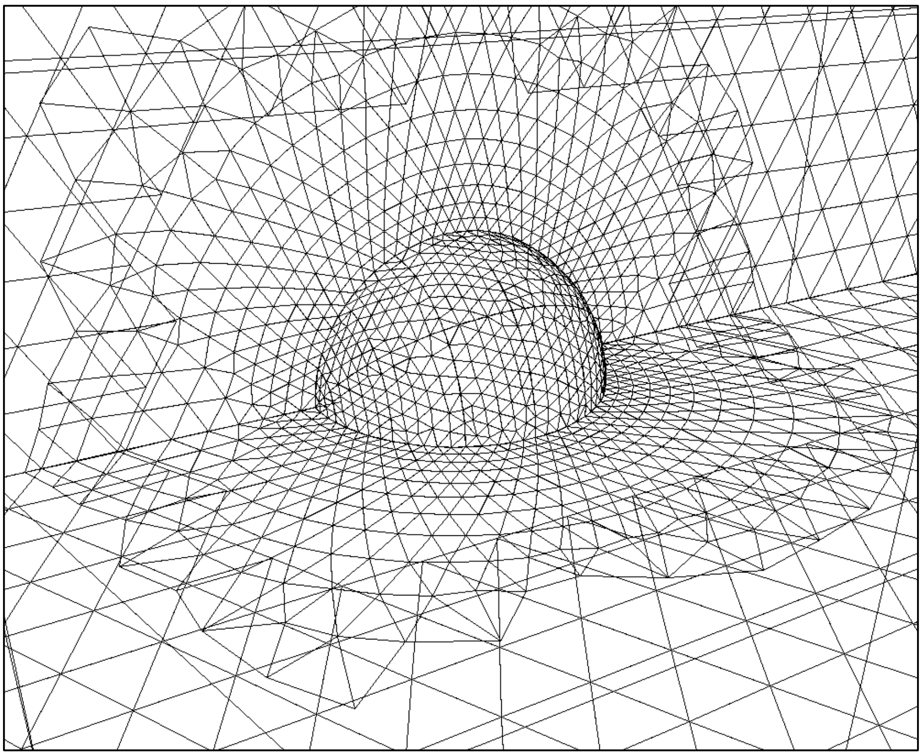


Figure 6.2 Sphere in Channel: Surface Grids

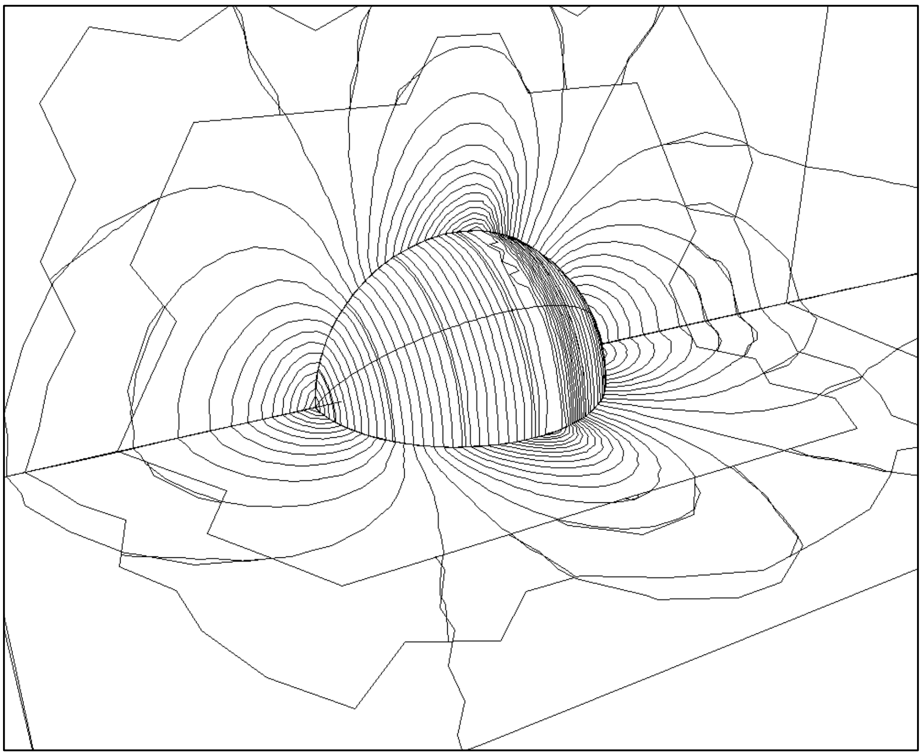


Figure 6.3 Sphere in Channel: Surface Mach-nr.

DROSOPHILA

- Equations Solved: Incompressible Navier-Stokes

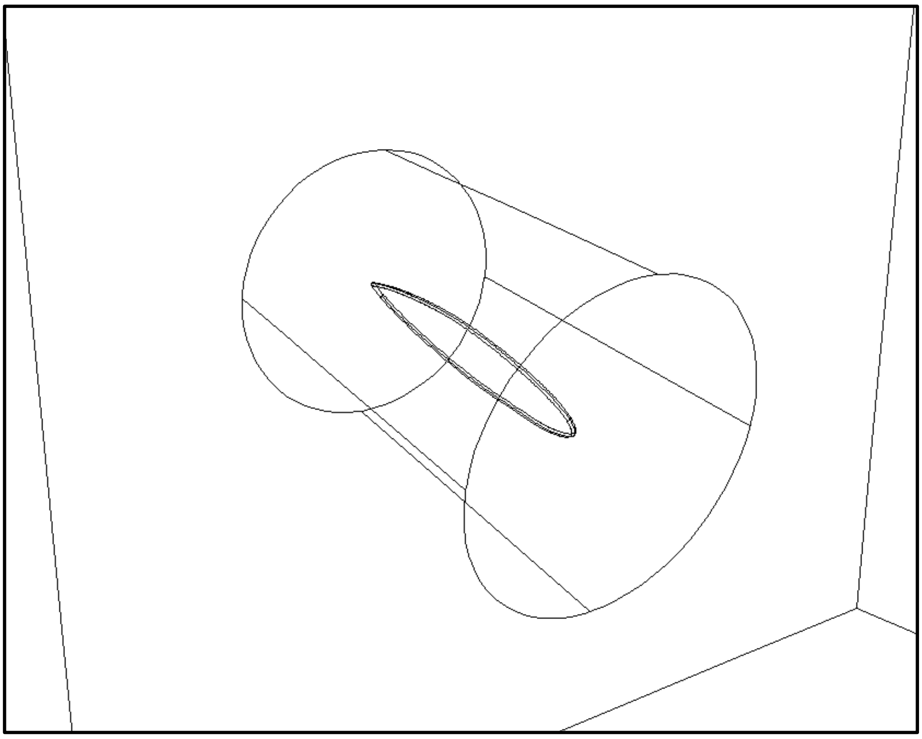


Figure 7.1 Drosophila: CAD Data

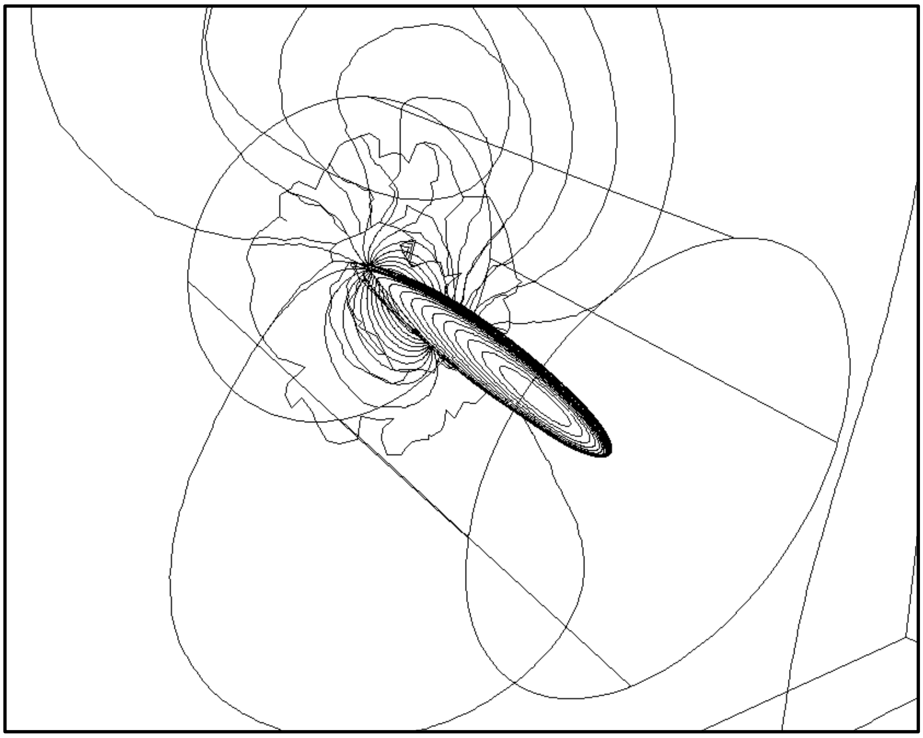


Figure 7.2 Drosophila: Pressures

CONCLUSIONS

- Overlapping, Unstructured Grids
- Fast Distance to Wall Algorithm;
- Element Size as Dominant Mesh Criterion;
- Fast, General Interpolation Based on Octrees and Bounding Boxes;
- Treatment of Bodies that are Partially Outside
- Implemented for:
    - Compressible (Explicit/Implicit)
    - Incompressible