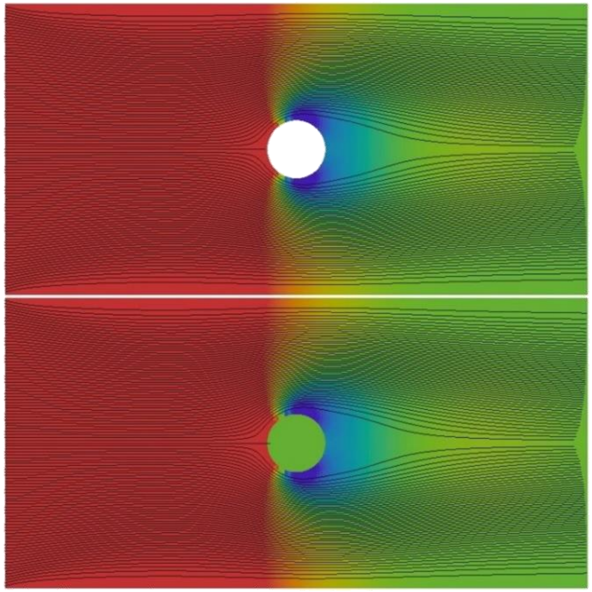
FURTHER DEVELOPMENTS ON THE GEOMETRIC IMMERSED BOUNDARIES (GIB)

OpenFOAM Workshop 2016

26th – 20th June

Guimarães, Portugal

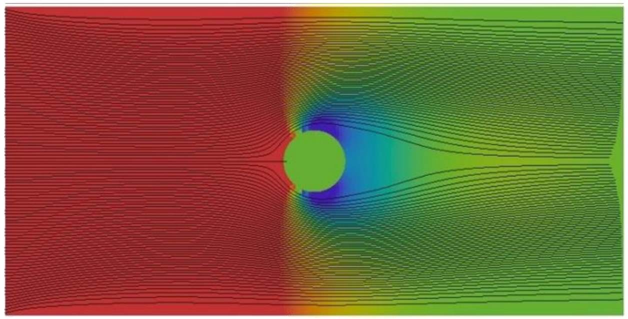


Georgios Karpouzas, ENGYS Ltd.

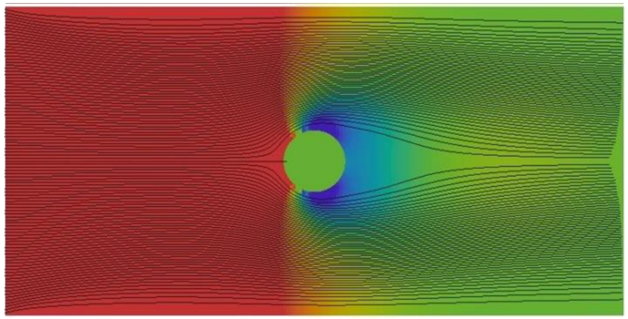
Eugene de Villiers, ENGYS Ltd.

Contents

- Motivation
- Methodology
- Validation
- Applications
- Closing Comments

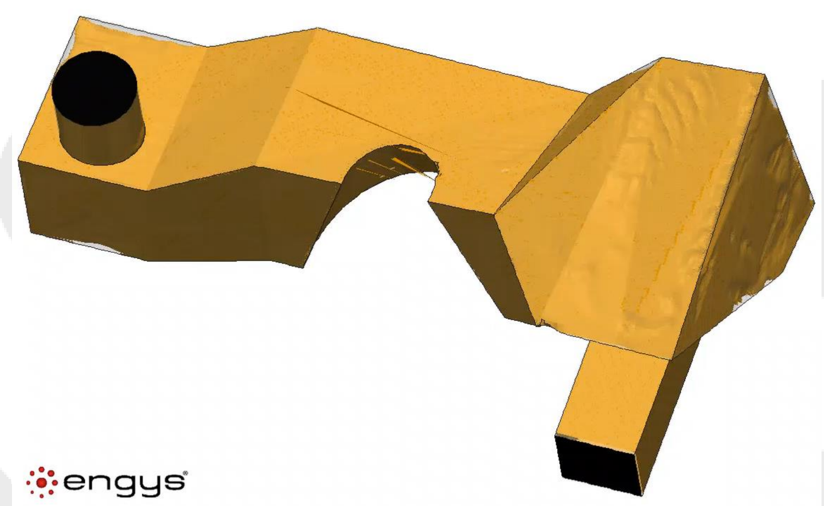


Contents

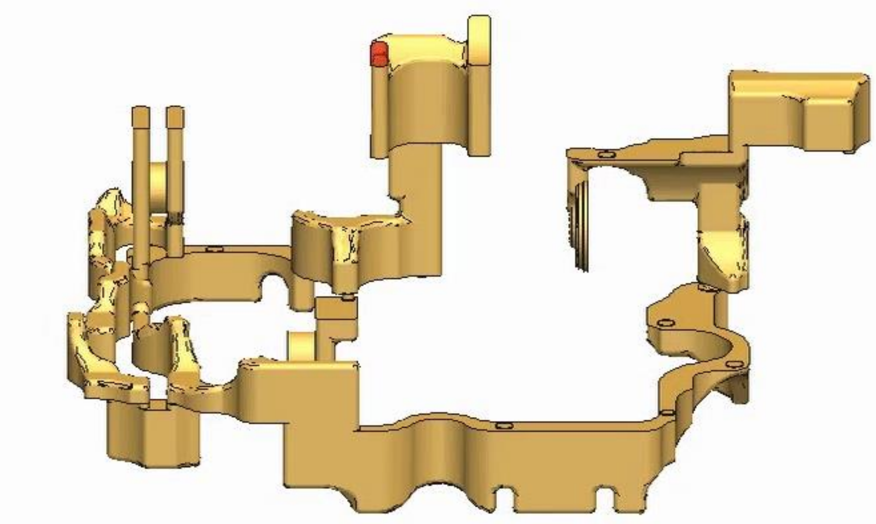


Motivation

- Topology optimization
- Level-set coupled with the continuous adjoint method



53.5% power losses reduction

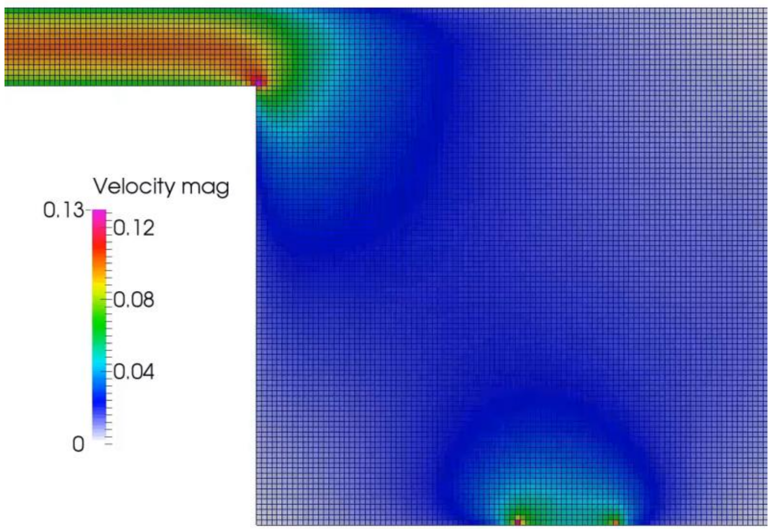


~30% power losses reduction

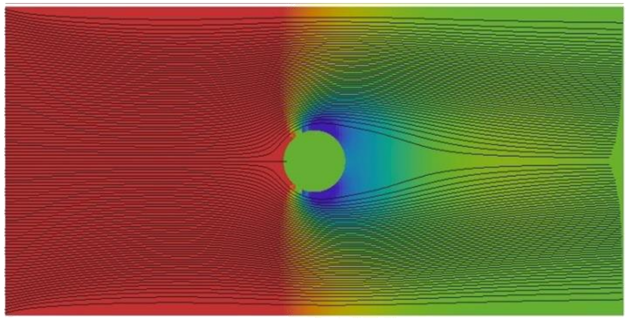
- *G.K. Karpouzas, E.M. Papoutsis-Kiachagias, T. Schumacher, E. de Villiers, K.C. Giannakoglou, C. Othmer. "**Adjoint Optimization for Vehicle External Aerodynamics",** JSAE 2016*
- *G.K. Karpouzas, E De Villiers, "**Level-set based topology optimization using the Continuous Adjoint Method**", OPTi2014, 2014, Kos, Greece*
- *I.S. Kavvadias, G.K. Karpouzas, E.M. Papoutsis-Kiachagias, D.I. Papadimitriou, K.C. Giannakoglou: "**Optimal Flow Control and Topology Optimization Using the Continuous Adjoint Method in Unsteady Flows**", EUROGEN 2013*

Motivation – Current Problems

- Currently simple immersed boundaries (IB) are applied on the fluid-solid interface
- Resistance/porosity is added to the solid cells of the matrix which blocks the velocity
- Lacks of accuracy especially in the turbulent cases
- In-situ IB primal results do not exactly match boundary fitted equivalent
- Results in approximate objective/optimal
- Solution: Implement immersed boundaries with the same accuracy as a real boundary



Contents



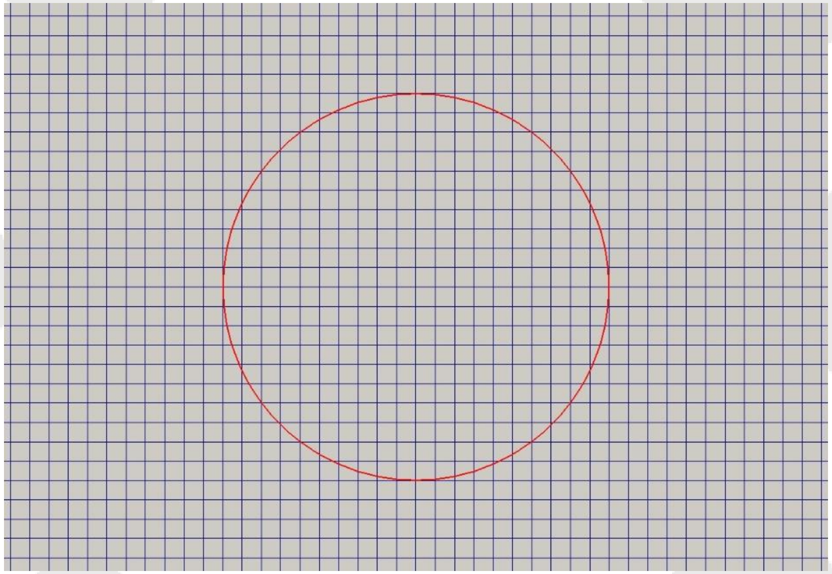
Methodology | Goals

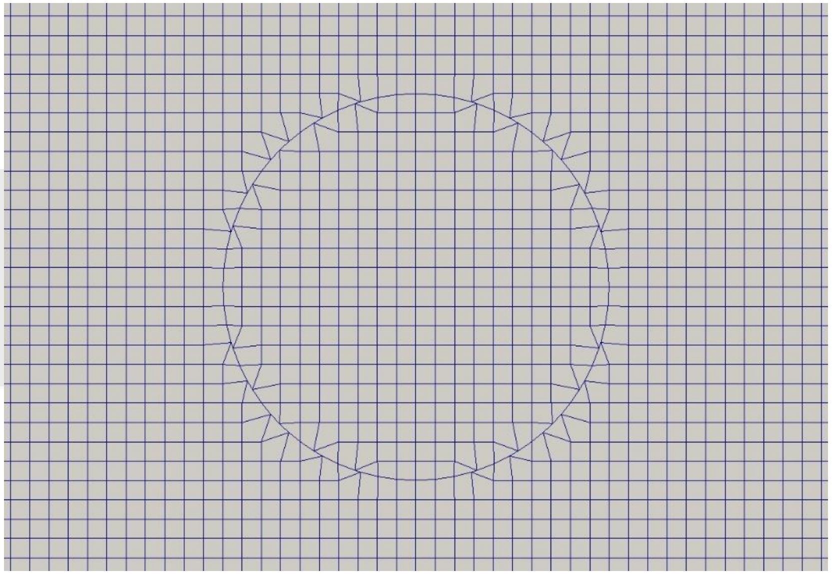
- Same accuracy as body fitted meshes
- Automation: Work with every
  - solver (compressible/incompressible)
  - operation (field operations, implicit/explicit, etc)
- Apply the existing boundary conditions (`diriclet`, `Neumann`…) on the immersed boundaries
- Same interface as the other boundaries
- No double coding allowed

engys

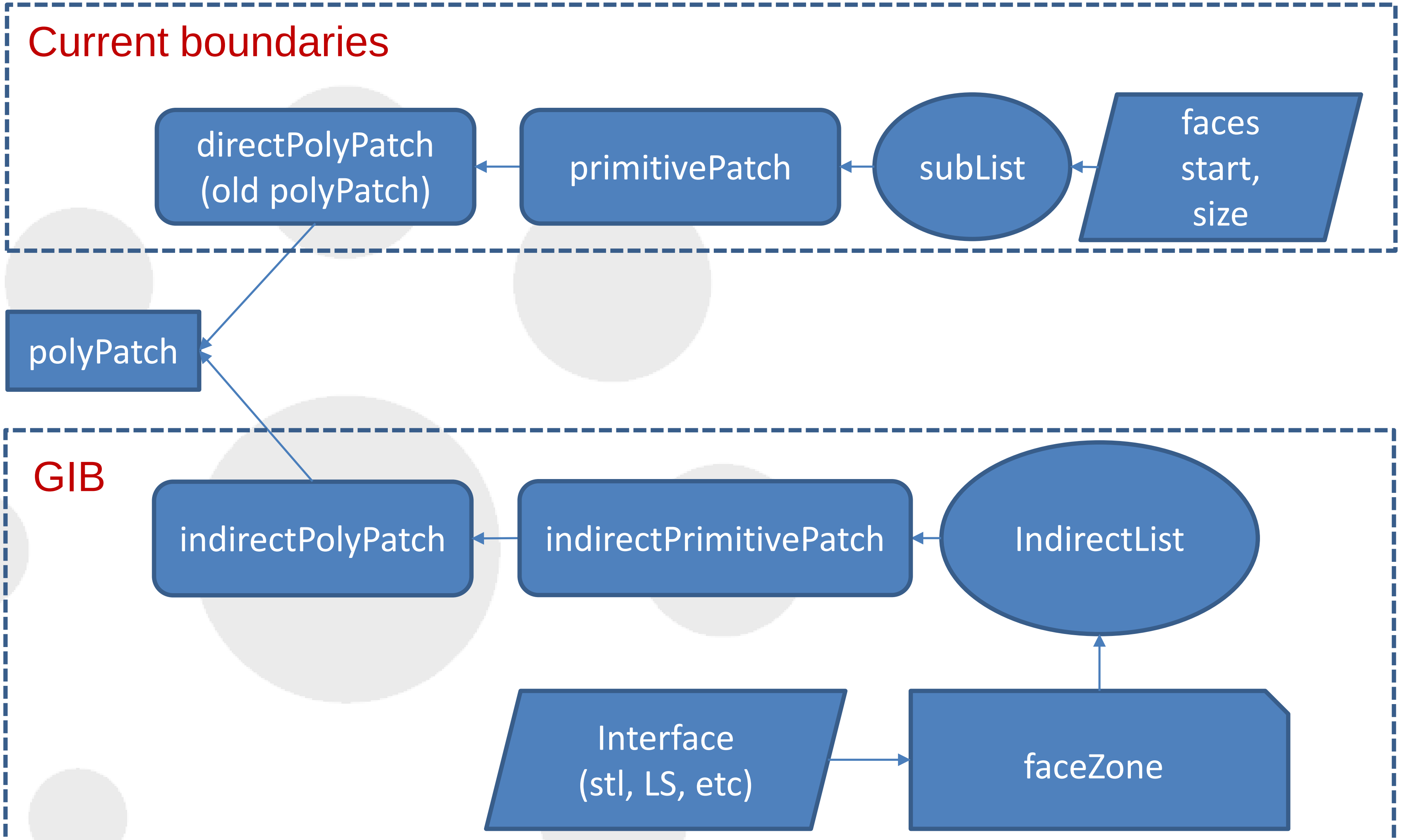
Methodology | Concept

- Perform snapping on the interface (LS, .stl, etc.)
- After snapping some of the faces are located on the interface.
- All the quantities needed from the finite volume are updated
- Problem: There is not a code structure in OpenFOAM® to apply boundary conditions in internal faces.





Methodology | Implementation

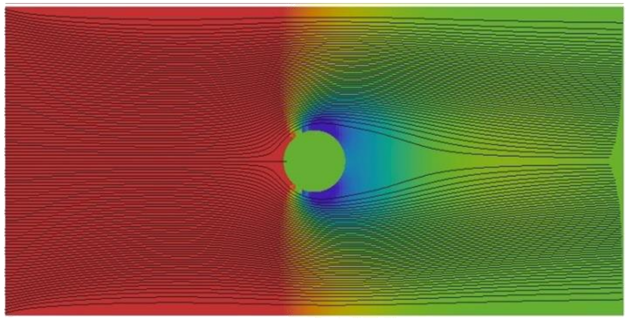


Methodology | Implementation

- 30 new classes added
- Changes in ~ 100 existing classes
- OpenFoam library:
  - `polyMesh/patch` to insert the GIB classes
  - GeometricField macros to automate the operators
  - GAMG agglomerator
- finiteVolume library:
  - `fv(s)PatchField, fvPatch`
  - `fvm, fvc` operators
- Parallelization
- dynamicFvMesh libraries (static, stl, level-set)

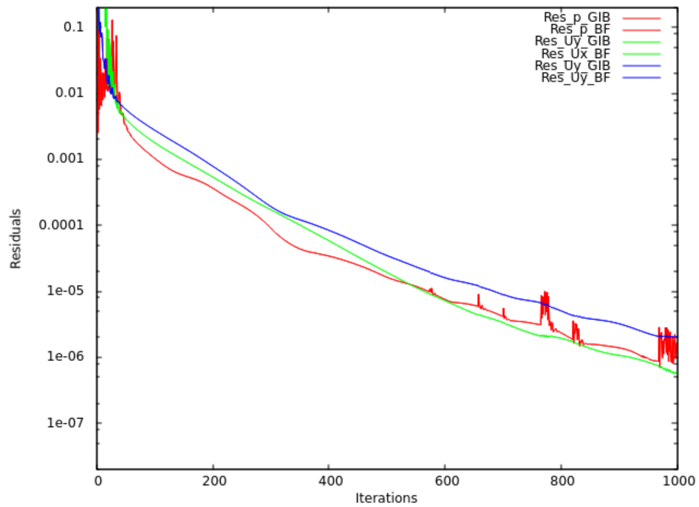
Contents

- Motivation
- Methodology
- Validation
- Applications
- Closing Comments



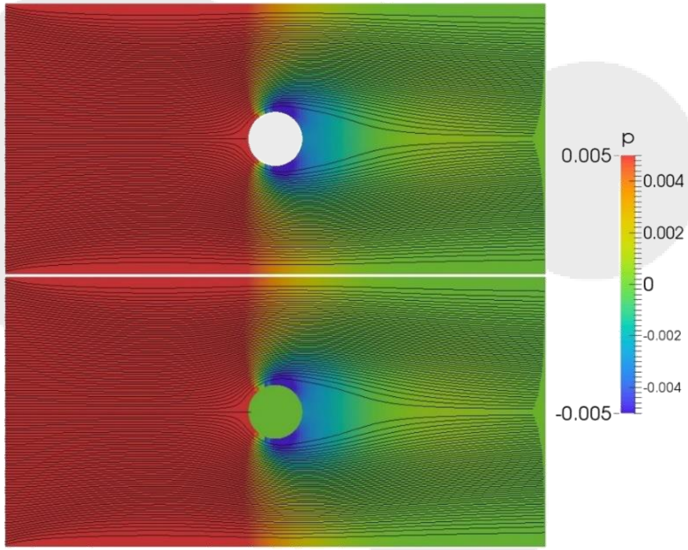
Validation | Cylinder

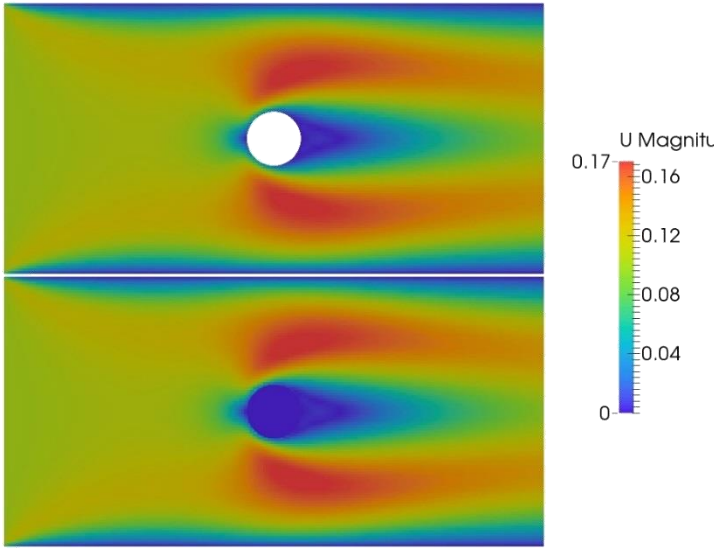
- Bodyfitted vs GIB cylinder results
- Identical results (machine accuracy)



Body-Fitted

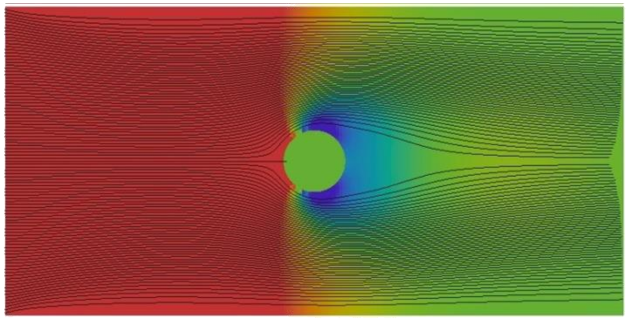
GIB





Contents

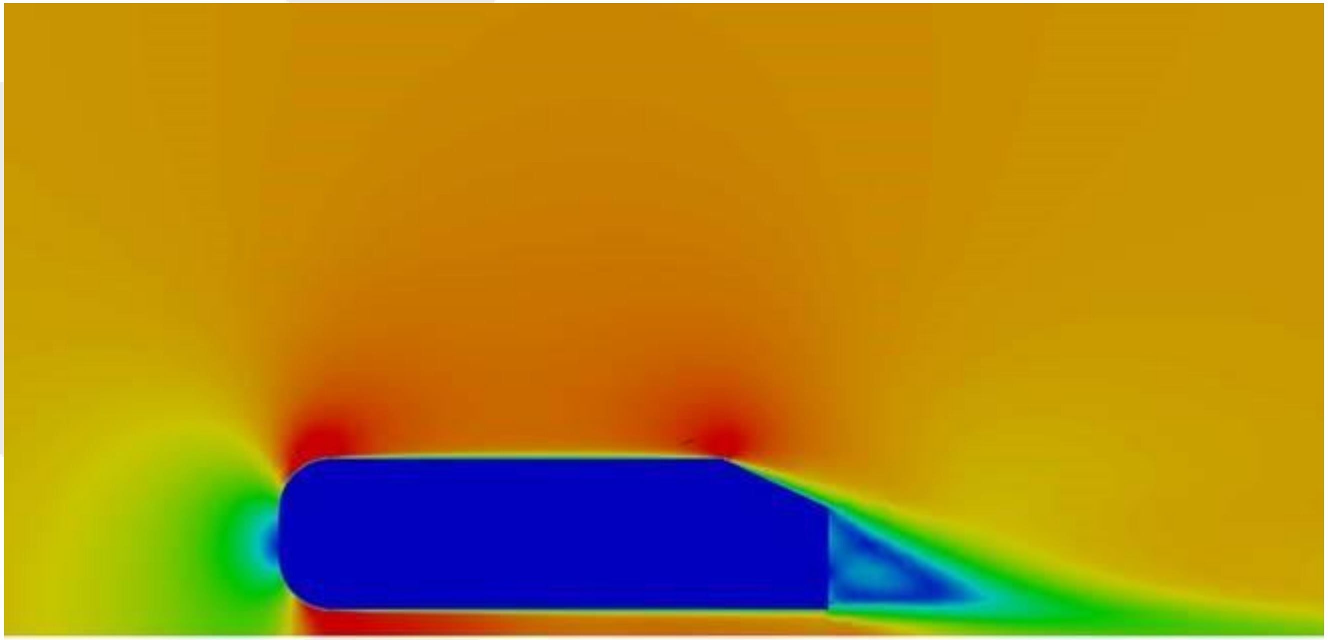
- Motivation
- Methodology
- Validation
- Applications
- Closing Comments



Applications | Ahmed | Parallelization

- Fully parallel
- Works with turbulence
- No top level change is required in the standard solvers

simpleFoam



Topology optimization requirements

- Dynamically changeable immersed boundaries
- Clever update of the required fields
- Steady-state solver for the primal (dU/dt doesn’t exist)
- The calculation of the old time values for the freshly solid/fluid cells is not needed

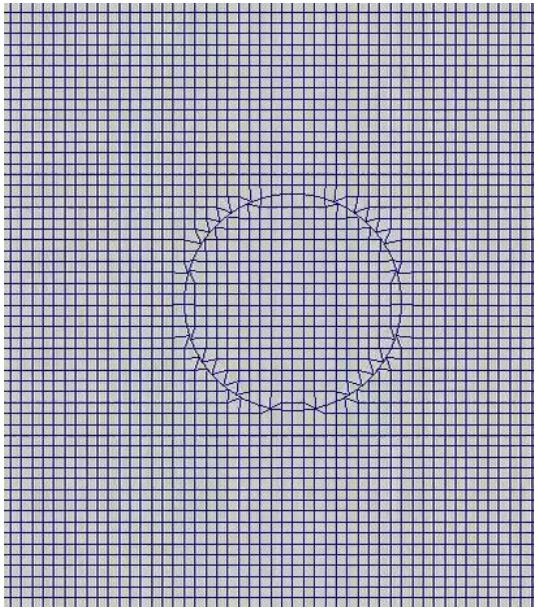
But:

- Bad initialization of these cells can slow down the convergence

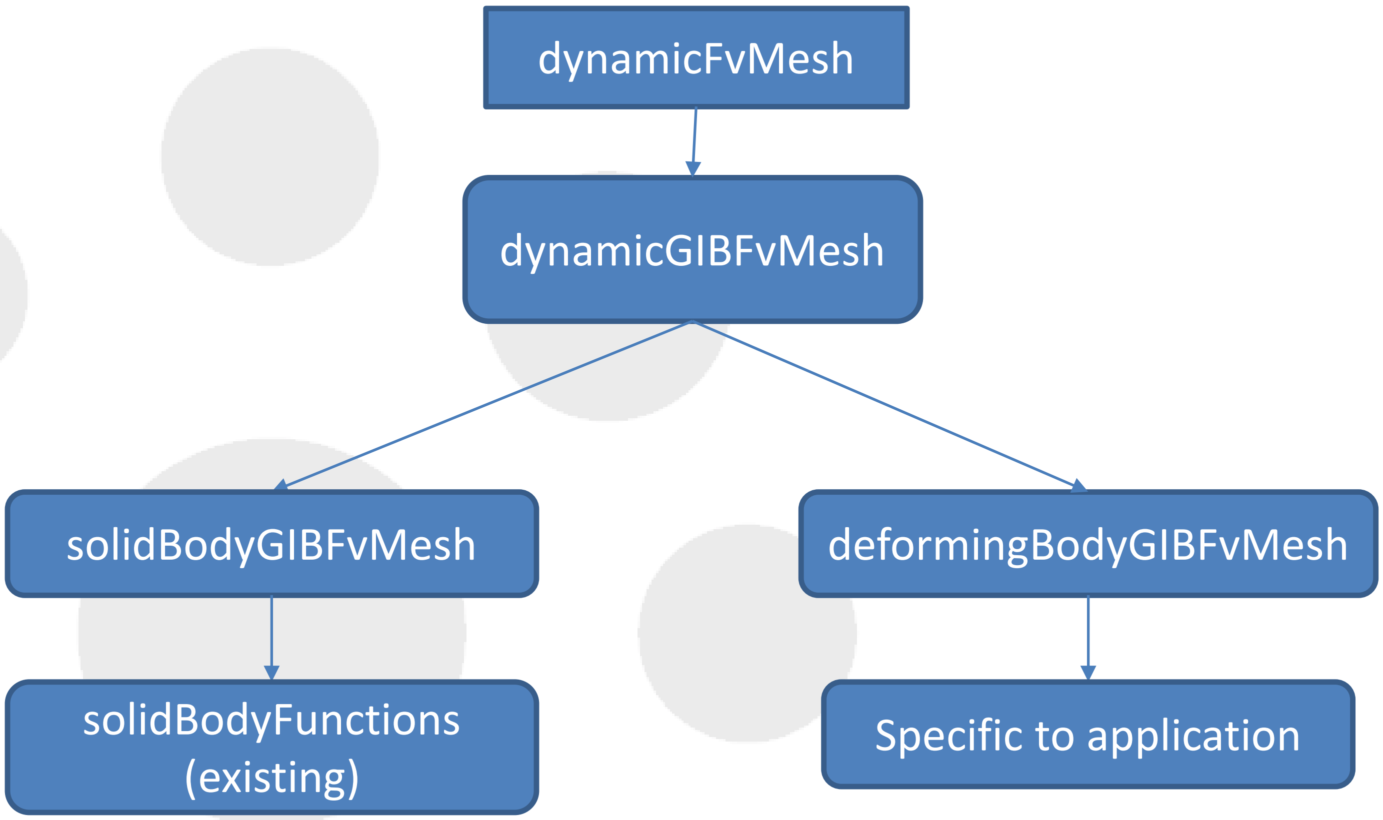
Development of the moving immersed boundaries is needed

Moving GIB | Basic steps

- New location of the interface
- Perform snapping from the base mesh to the new interface
- faceZone update
- polyPatches class update
- GIB patch Fields update
- Special treatment for the freshly solid/fluid cells (pop cells)
- ALE (Arbitrary Langarian-Eulerian) framework



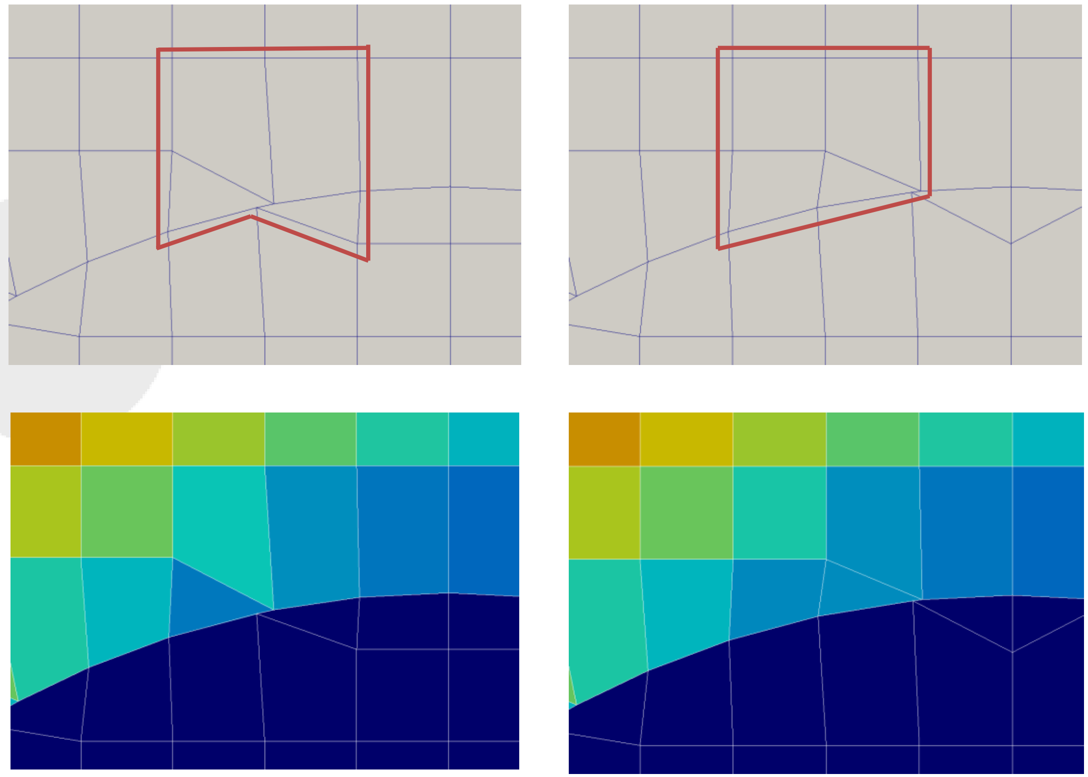
Moving GIB | dynamic classes



Moving GIB | Current Pop treatment

- Calcualtion of the Uold (dU/dt term)
- Treatment has two steps
  - Calculate the pop mesh fluxes based on the previous and current interface location
  - Perform explicit conservative redistribution of the old field values of the pop up cell from/to the neighbour cells based on the pop mesh fluxes
- After calculating the required old time fields, the remaining mesh phi of the boundary is used in the ALE framework for the new iteration

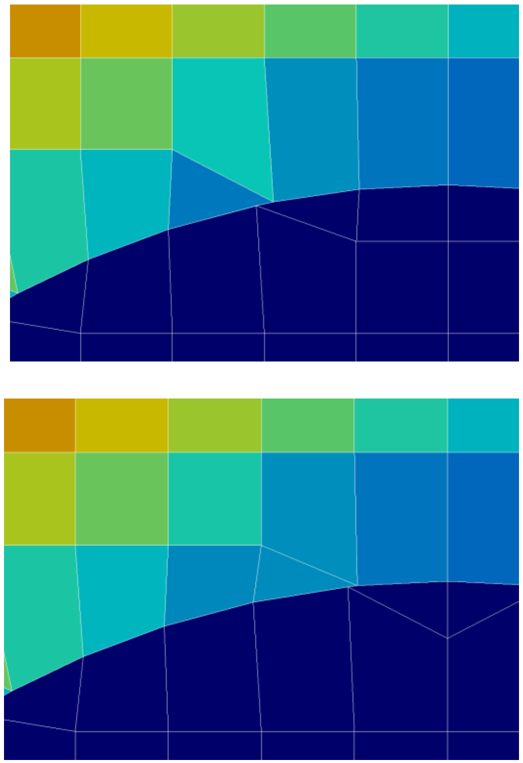
prePop postPop



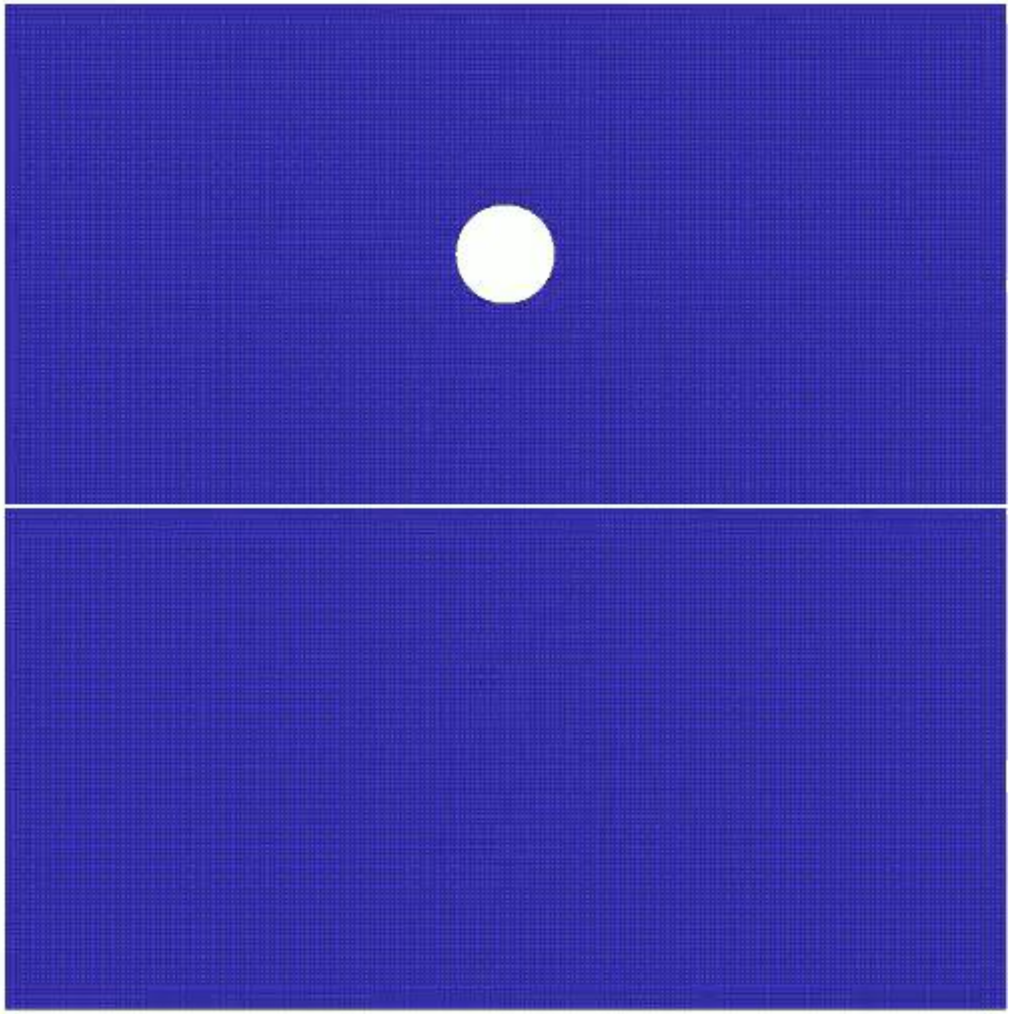
Uold Uold

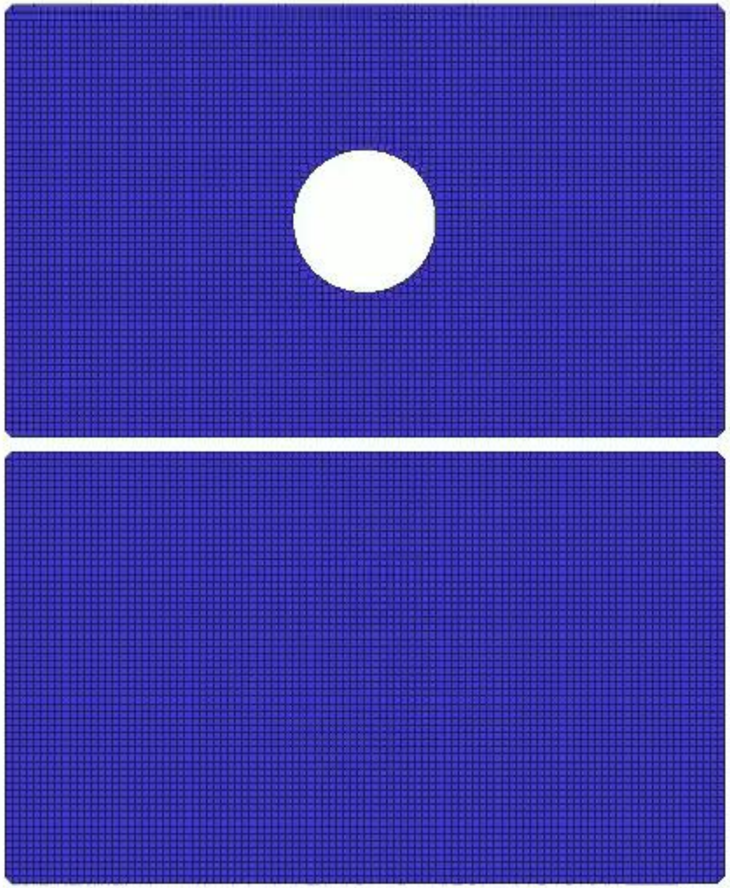
Moving GIB | Pop treatment

- Only conservative doesn't mean is satisfying the state equations
- Many ways to distribute the quantities by keeping the conservation constant
- If the mesh close to the interface is coarse small oscillations in the forces might appear

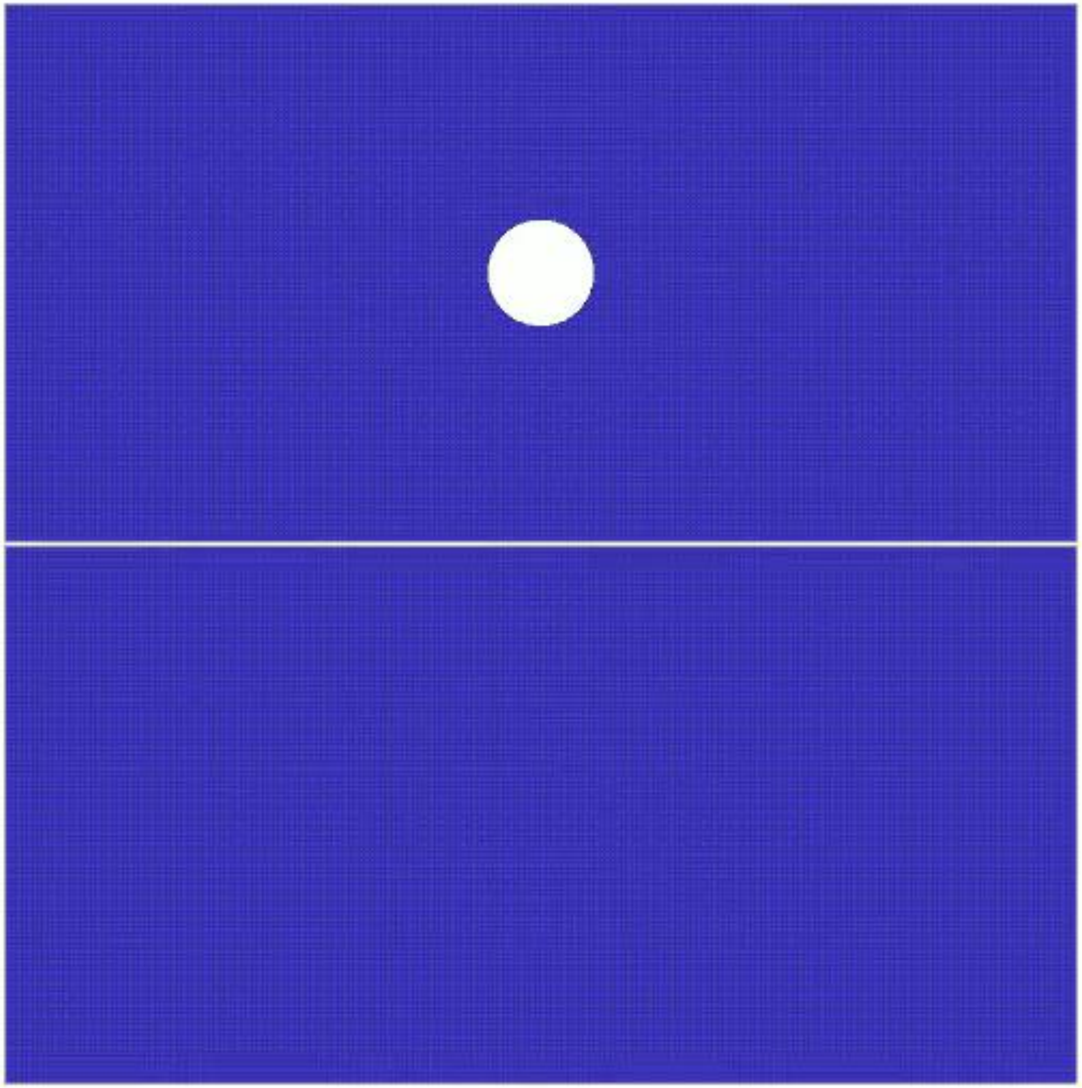


Moving GIB | movingCylinderBenchmark

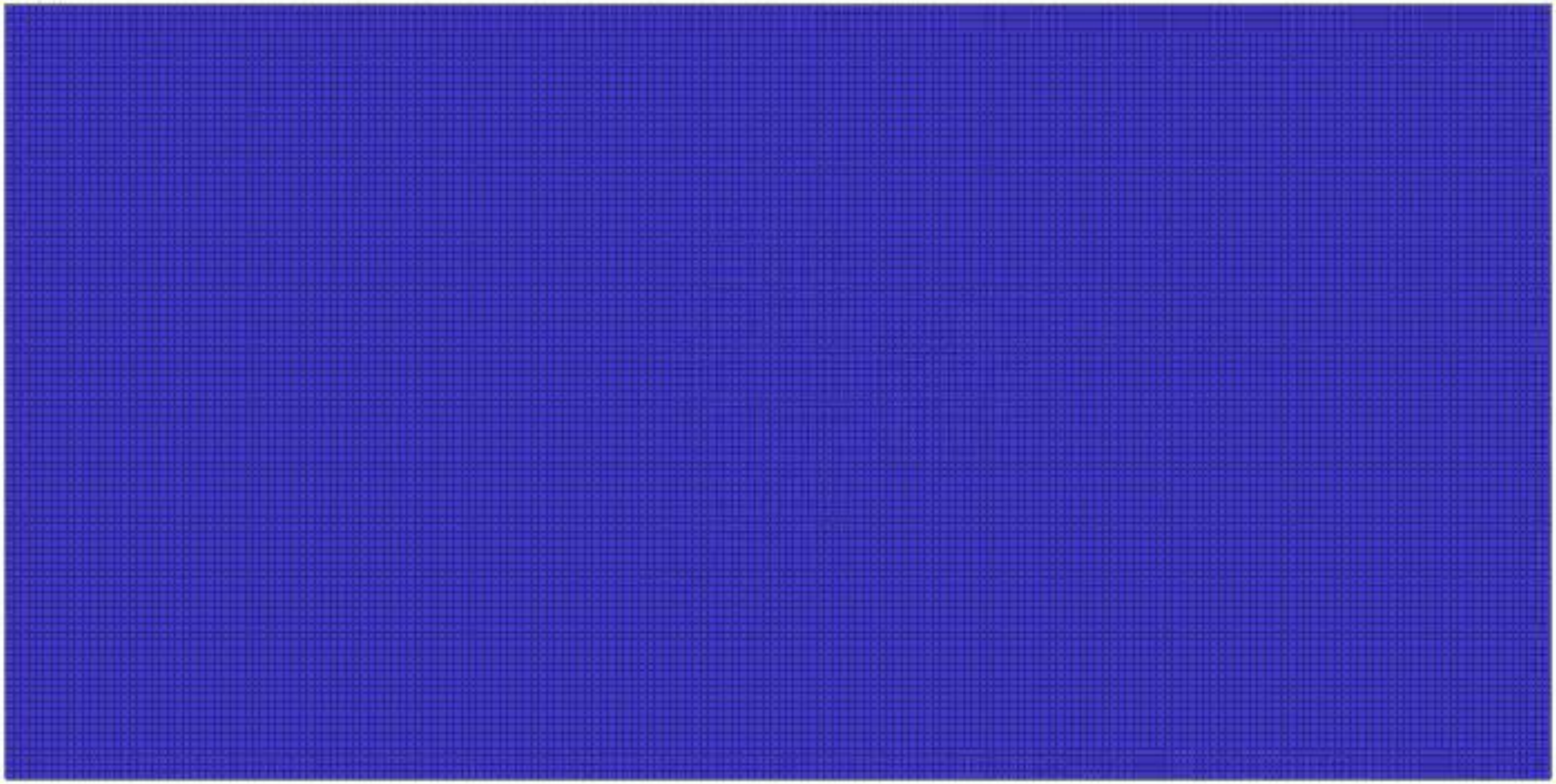




Moving GIB | Cylinder crash test

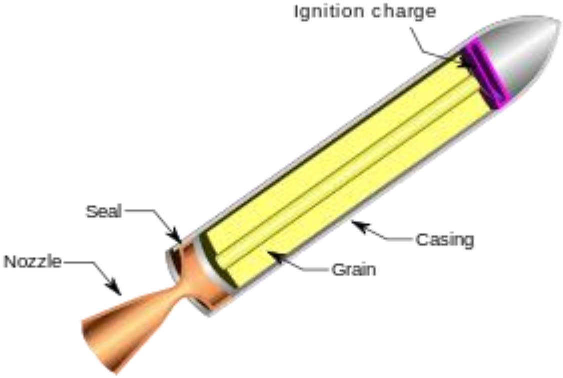


Moving GIB | Growing cylinder



Internal Ballistics | Rocket motor

- A simple solid rocket motor consists of a casing, nozzle, grain (propellant charge), and igniter.
- The grain behaves like a solid mass, burning and producing exhaust gases
- Unsteady compressible high speed flow
- Difficulty:
  - The grain interface is changing during the burn
  - Large deformation of the grain boundary
  - Mesh deformation tools impossible to work without breaking the mesh
- Current approach: Solve the equations for static boundaries and then morph experimentally → inaccurate
- Solution: Simulate the burning interface with GIB



engys

Internal Ballistics

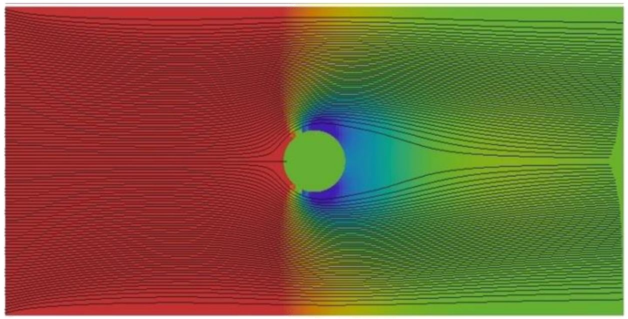
Sensitive material

Results

Sensitive material

Contents

- Motivation
- Methodology
- Validation
- Applications
- Closing Comments



Closing comments | Next steps

- Closing comments:
  - New framework for applying boundary condition in internal group of faces is implemented
  - General implementation. Top level change is not required.
- Next steps:
  - Coupling with the adjointFoam engine
  - Revisit the full ALE approach

Looking forward

- It can be applied in every application with a static/moving interface.
- Applications such as:
  - FSI
  - multiphase
  - Gear pumps
  - 6 DoF
- Adjoint version of them
- Challenges: Add layers to the GIB with overset grids

Questions?

Thanks for your time!

WEB: http://engys.com

E-MAIL: info@engys.com