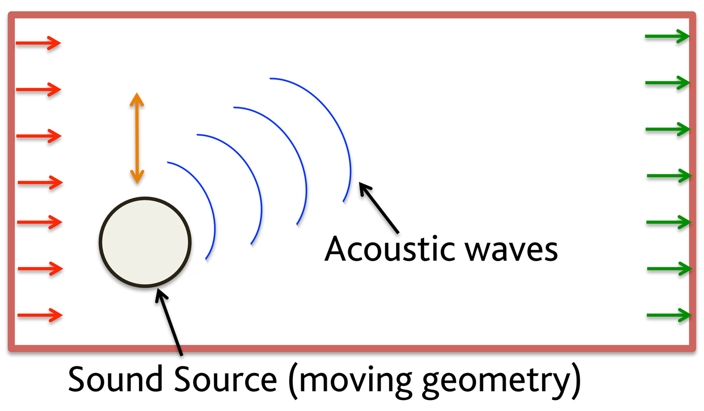
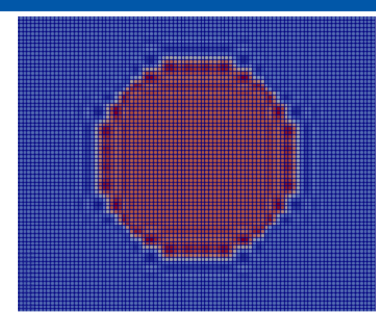
Numerical simulation of flow around complex geometries using immersed boundaries and DG

Motivation

- Numerical simulation of flow around geometries
  - Complex geometries
  - Moving geometries
  - Multi-scale, multi- physics
- Improvements in engineering field
  - Noise reduction e.g. fans, wind turbines etc.



Method



- Immersed boundary method
  - Cartesian mesh
- Discretization: Discontinuous Galerkin method
- Brinkman Penalization: Geometry = porous material
  - Penalize mass (1), momentum (2) and energy (3) equation

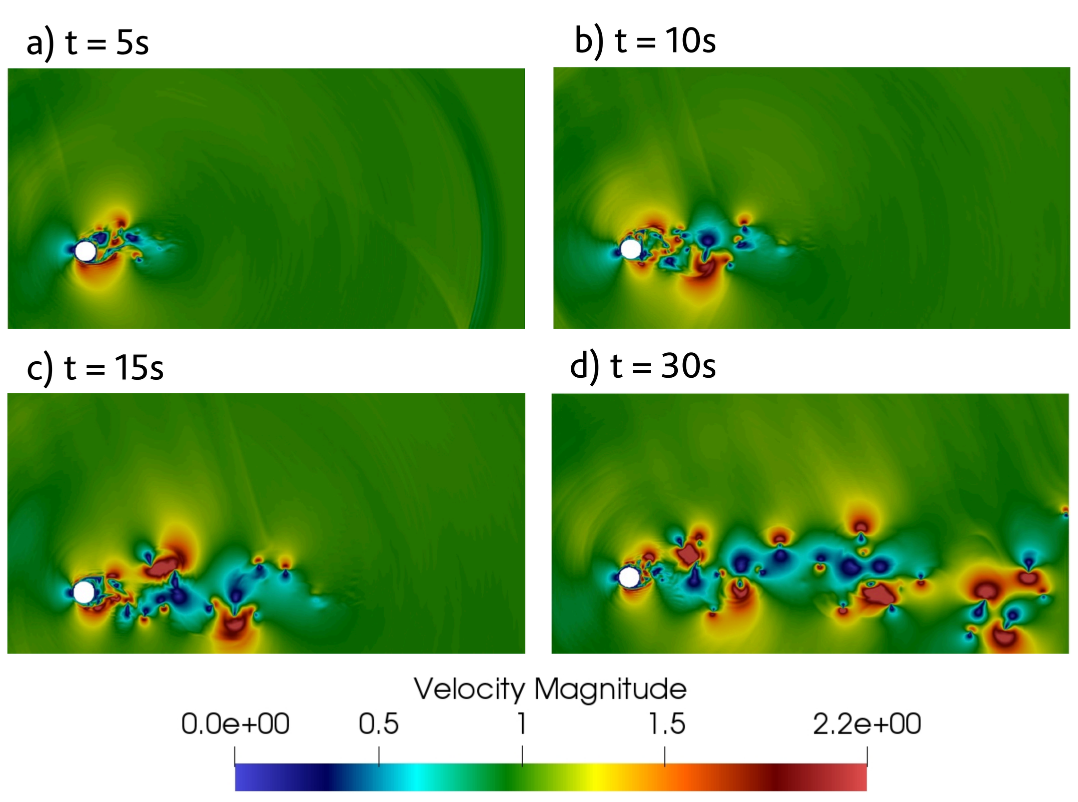
$$\frac{\partial \rho}{\partial t} = -\frac{\partial m_j}{\partial x_j} - \left(\frac{1}{\phi} - 1\right)\chi \frac{\partial (u_j - U_{oj})\rho}{\partial x_j} \quad (1)$$

$$\frac{\partial m_i}{\partial t} = -\frac{\partial}{\partial x_j}(m_i u_j) - \frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} - \frac{\chi}{\eta}(u_i - U_{oi}) \quad (2)$$

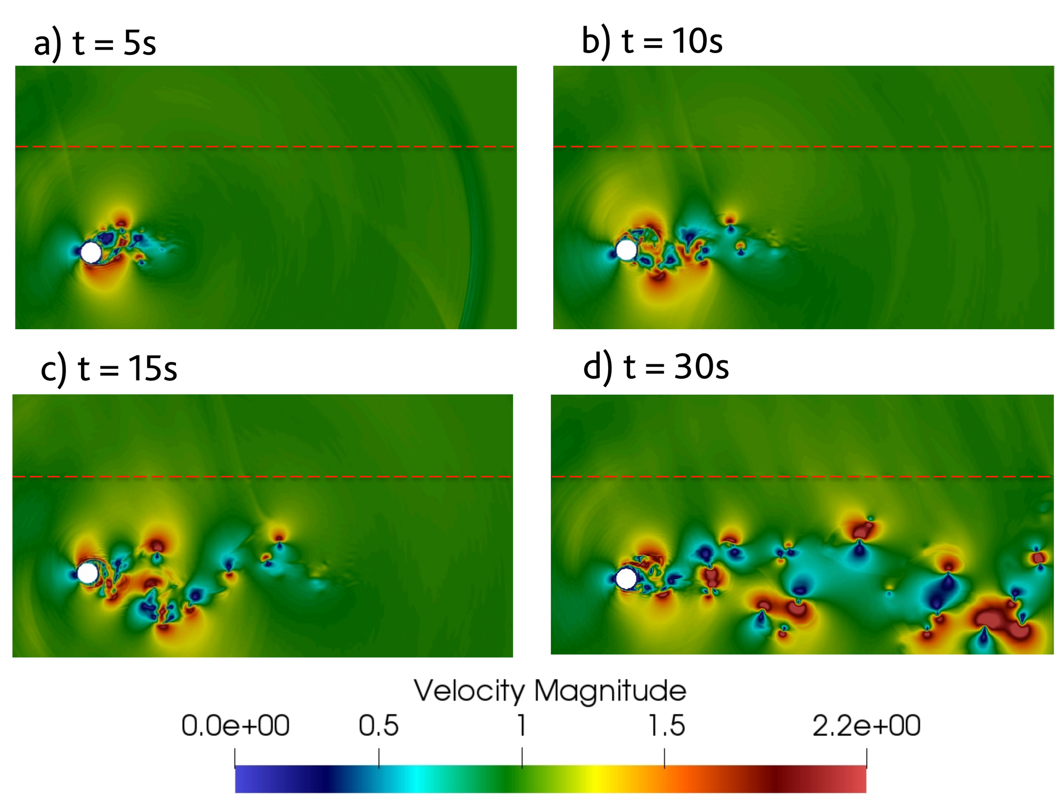
$$\frac{\partial e}{\partial t} = -\frac{\partial}{\partial x_j}\left[(e+p)u_j\right] + \frac{\partial}{\partial x_i}(u_i \tau_{ij}) + \frac{\partial}{\partial x_j}\left(k\frac{\partial T}{\partial x_j}\right) - \frac{\chi}{\eta_T}(T - T_o) \quad (3)$$

Results

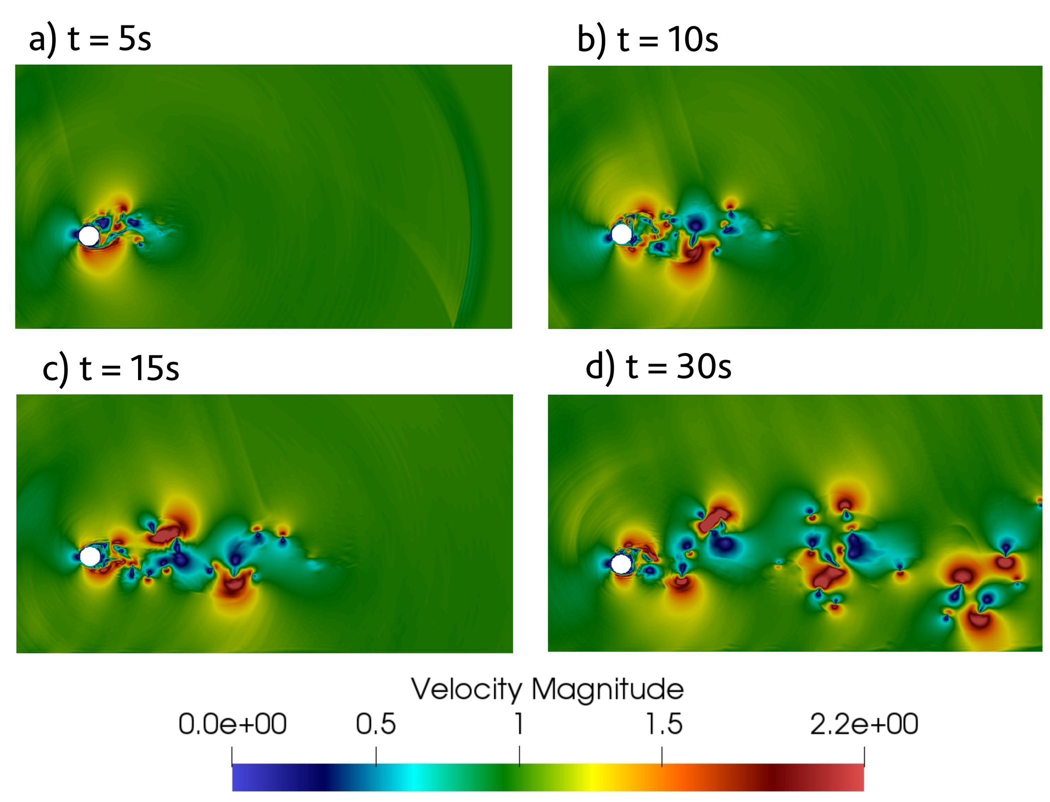
Monolithic: Solving the domain everywhere with the inviscid Euler equations.



Partitioned coupling: Decomposition of the domain in lower and upper, using the Euler and linearized Euler equations respectively.

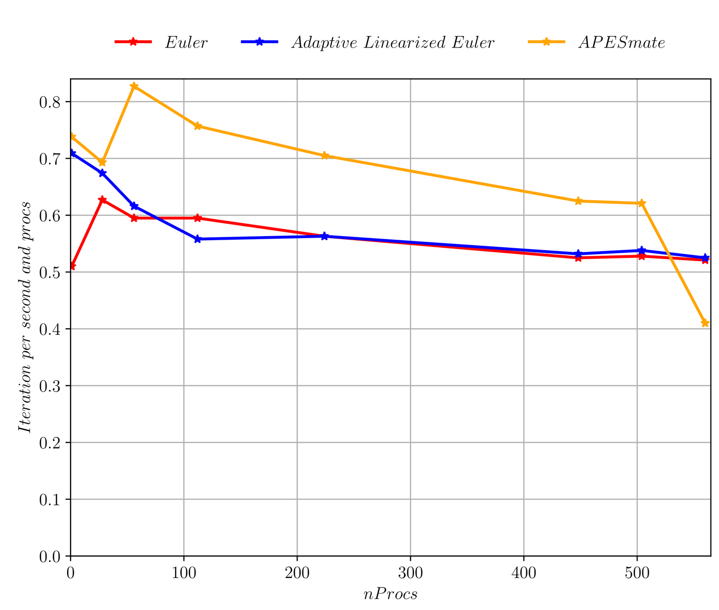


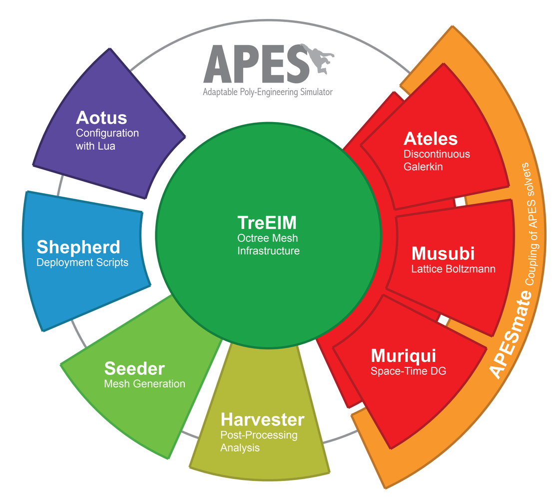
Adaptive linearized Euler: Switching between Euler and linearized Euler equations element-wise using energy as indicator.



Performance

- Compute cost for the methods:
  - Monolithic:
    - Expensive computation
    - Accurate solution
  - Partitioned coupling:
    - Decreased computational cost in linearized domain
    - Costly computation of coupling elements
    - Heuristic decomposition of the domain
  - Adaptive linearized Euler:
    - Switching equations adaptively during computation
    - Decreased computational cost due to element local linearization
    - Challenging to balance computational load





APES is a massively parallel CFD framework, which provides pre- and post-processing tools. It includes different solvers and allows the coupling of them using the integrated coupling approach APESmate.

DFG Deutsche Forschungsgemeinschaft
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