A Tale of Two Solvers: Vortices in MFEM and OpenFOAM Fluid Flow Simulations

Justin Crum and Craig Gross
Computing/DSSI
Vic Castillo, Andrew Gillette, Josh Levine, Yamen Mubarka, Brian Yoxall

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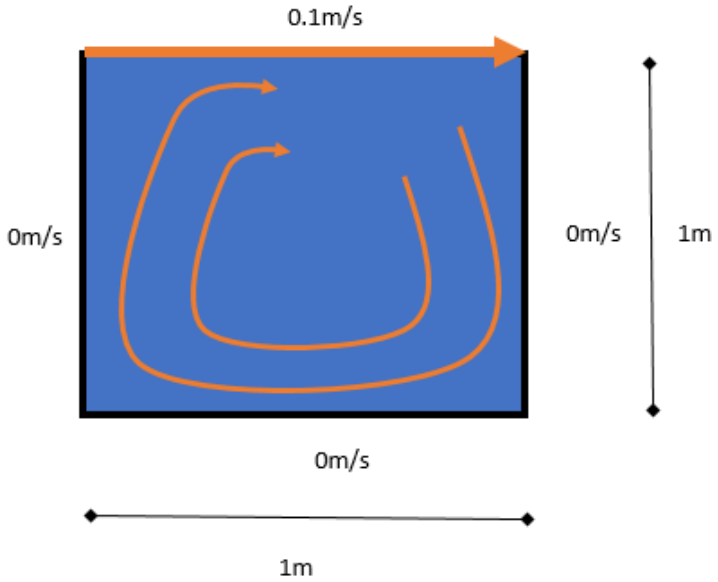
Lid driven cavity



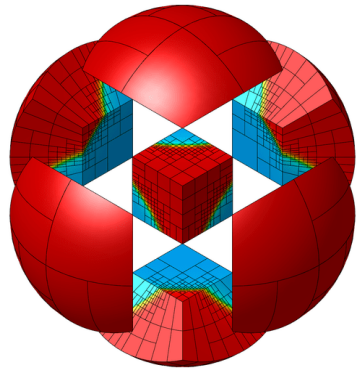
$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} = -\nabla p + \nabla^2 \mathbf{u}$$ inside the cavity,

$$\nabla \cdot \mathbf{u} = 0$$

$$\mathbf{u} = \begin{cases} (\mathrm{Re}, 0) & \text{on the lid} \\ 0 & \text{on the other walls} \end{cases}$$

OpenFOAM and MFEM

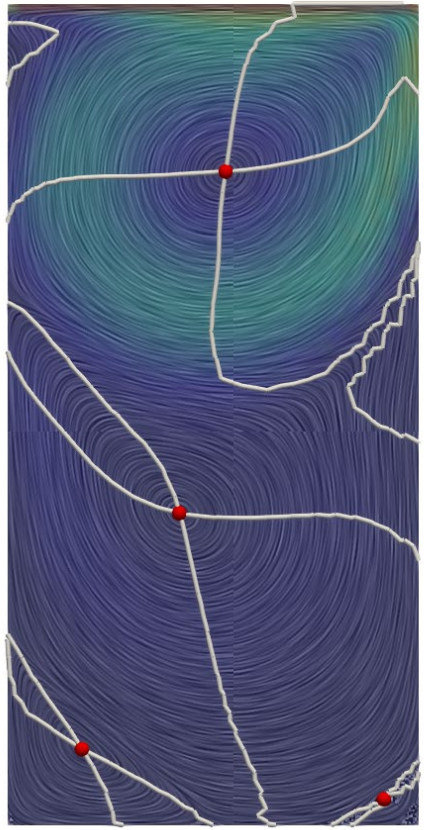
- OpenFOAM
  - Open source CFD library
  - Meshing capabilities
  - `simpleFoam` solver
  - openfoam.org
- MFEM
  - Finite element method
  - Higher order solutions
  - Navier-Stokes miniapp
  - MFEM.org



Vortices

Streamlines in a typical steady-state flow

- Vortices are regions of rotational motion
- White lines trace locations of no velocity in horizontal or vertical directions
- Red dots represent vortices

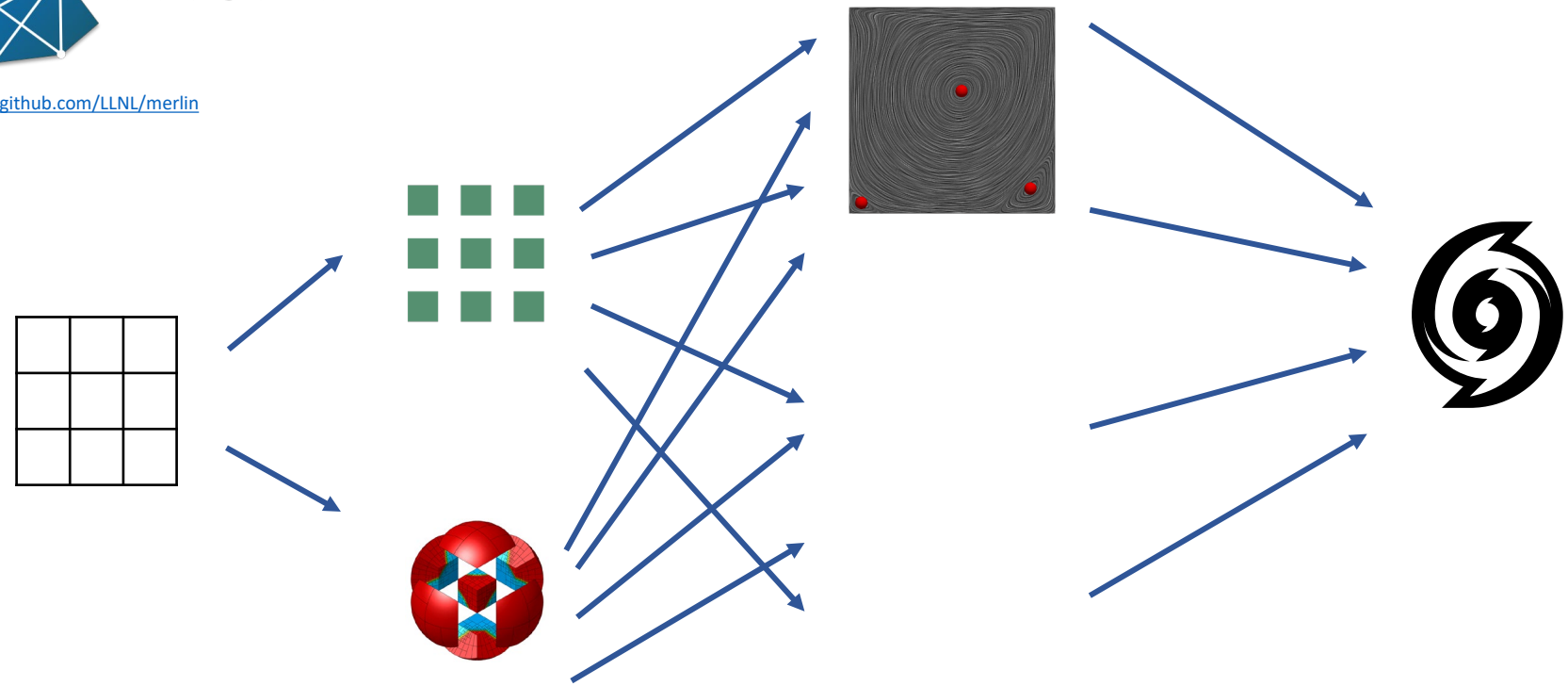


Visualization of vortex detection algorithm

Experiment design with Merlin

Merlin

https://github.com/LLNL/merlin



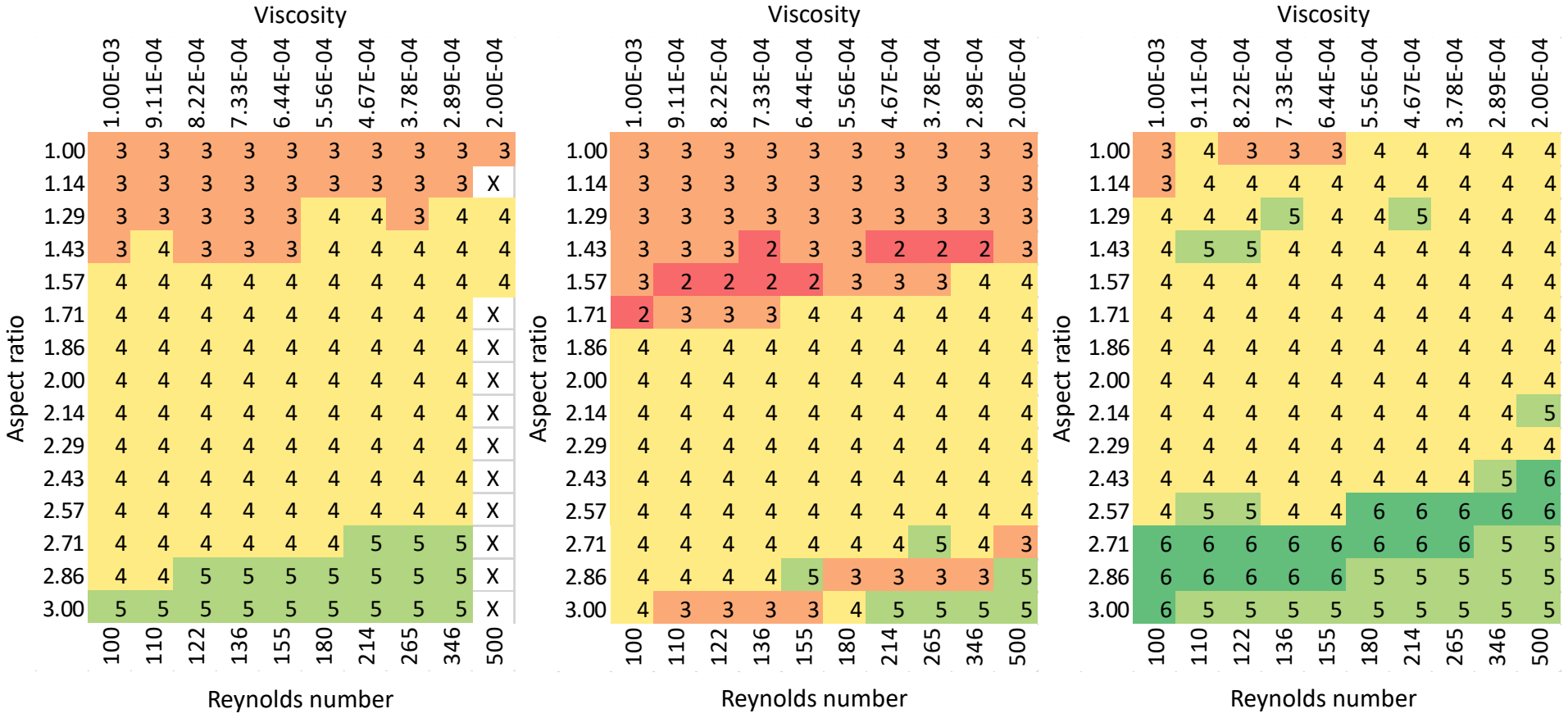
Mesh

Solve

(Some solutions for various geometries)

Vortex detection

Results



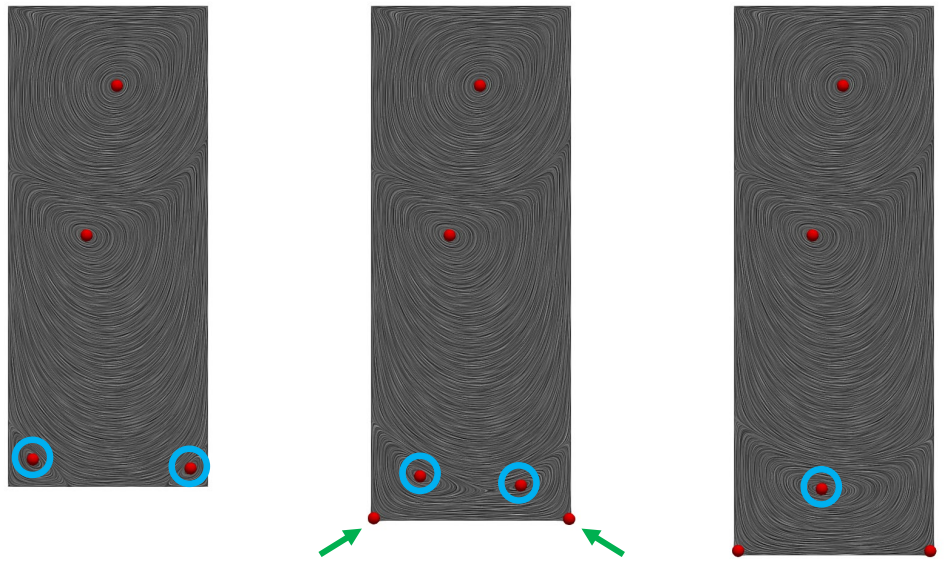
MFEM (low resolution)

OpenFOAM (low resolution)

OpenFOAM (high resolution)

Conclusion and Future Work

- Conclusions
  - Vortices
  - Challenges
    - MFEM
    - OpenFOAM
- Future work
  - Machine Learning
    - Vortices
    - Big Navier-Stokes data set
  - Complex Geometries
  - Improved Merlin Workflows



4 vortices

6 vortices

5 vortices