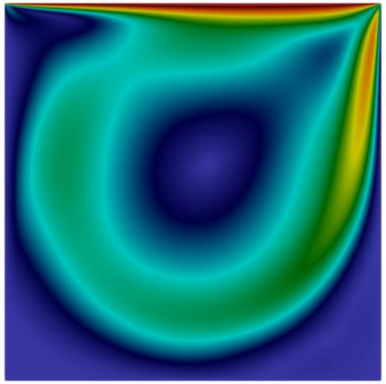
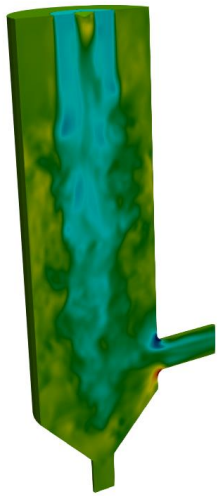
2021, Stockholm, Sweden

KTH ROYAL
INSTITUTE
OF TECHNOLOGY



Starting with *OpenFOAM*

Marco Atzori and Fermin Mallor



General information

- **Main reference**:
  A tensorial approach to computational continuum mechanics using object-oriented techniques, Weller *et al.* (1998), Comput. Physics, **12**, 620

OpenFOAM uses the Finite-Volume approach.

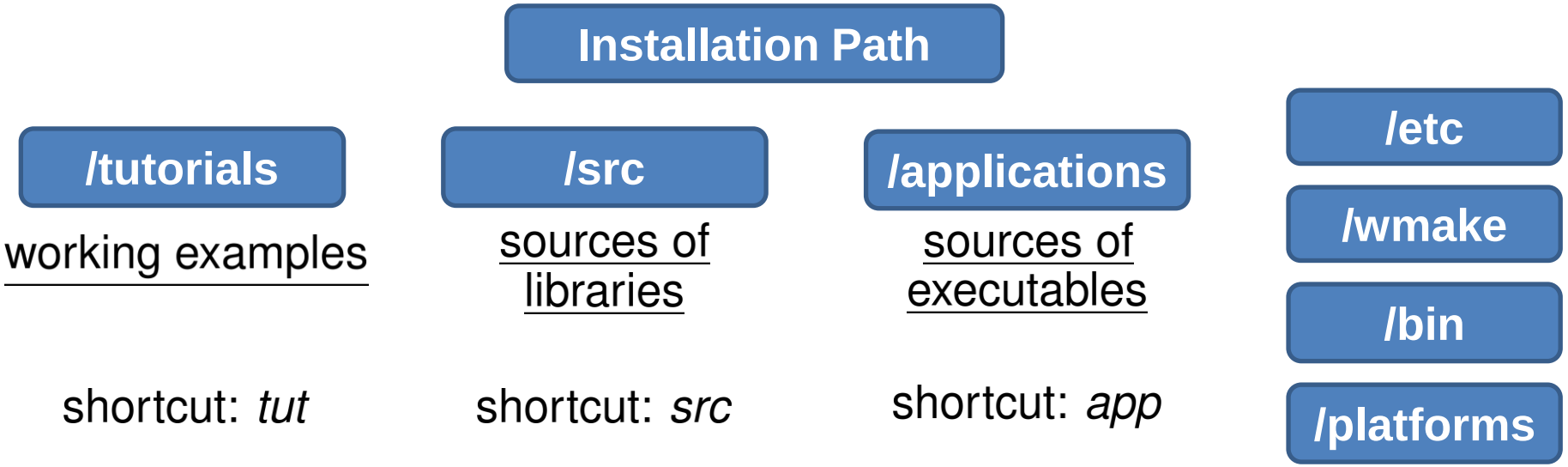
- **Different distributions**:
  1. OpenFOAM Foundation: `https://openfoam.org/`
  2. ESI Group: `https://openfoam.com/`

How to start:

Read the documentation!

Git repository with instructions: https://github.com/KTH-Nek5000/tutorialOF

Mac and Windows → use a virtual machine with Ubuntu 20



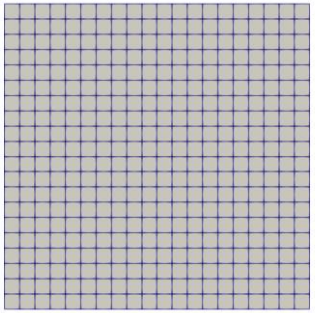
Run the first case: **Cavity**

1. Copy a tutorial from the *tutorial* folder, for instance:

   /tutorials/incompressible/icoFoam/cavity/cavity

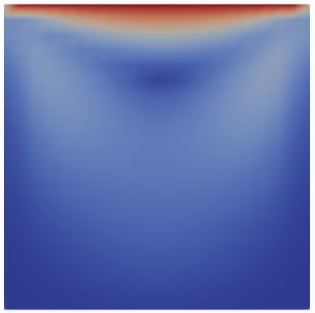
2. Create the mesh:

   blockMesh



3. Run the solver:

   icoFoam



4. Visualize with *paraView*:

   paraFoam

Figures: (top) grid and (bottom) velocity magnitude.

Structure of the case (for *cavity*)

- Folder *system*:
  - **blockMeshDict**: utility to create structured grid.
  - **controlDict**: Δt, run time, outpost...
  - **fvSolution**: numerical solvers, algorithm settings...
  - **fvSchemes**: discretization of the derivatives...
- Folder *constant*:
  - **transportProperties**: physical constants, *i.e.:* ν
  - Folder *polyMesh*: the grid (*points*, *boundary*, *faces*, ...)
- Folder *0*:
  - **p**: boundary and initial conditions for p.
  - **U**: boundary and initial conditions for U.

Create structural grid: *BlockMesh*

- Set the scale.
- Define *vertices* (**the order matters!**).
- Define *blocks*, and set the discretization (either uniform or not).
- Define *boundary*

The boundaries:

- have a *name* (which is arbitrary).
- have a *type* (**the type matters!**)
- are defined as list of quadrilateral faces.

The simulation: *controlDict*

- *application*: used for builtin functions.
- *startFrom* & *startTime*: starting time (*e.g.*: first time or latest saved time).
- *stopAt*: *e.g.:* **endTime**, **nextWrite**, **writeNow**, ...
- *endTime* & *deltaT*: last time and Δt between each time step.
- *writeControl*: it is the *writeInterval* "unit", *e.g.:* **timeStep** (number of time steps), **runTime** (physical time), **clockTime** (elpased time from start), ...
- *writeInterval*: "writeControl" times between fields outpost.
- *purgeWrite*: number of outpost fields not overwritten.
- *writeFormat*, *writePrecision*, *writeCompression*, *timeFormat* & *timePrecision*: outpost formats.
- *runTimeModifiable*: if *true*, the dictionaries are read every iteration.

The simulation: *fvSchemes*

- Time derivative: (explicit) Euler.
- Pressure gradient: Gauss linear (second order).
- Divergence of ϕ, U: Gauss linear (second order).
- Laplacian: Gauss linear orthogonal (second order)
- Interpolation: linear
- (?)

The simulation: *fvSolution*

- Solver for the pressure, *e.g.* in *cavity*:
  - Preconditioned Conjugate Gradient (PCG), with simplified Diagonal-based Incomplete Cholesky (DIC) preconditioner;
  - absolute and relative tolerance.
- Solver for the velocity, *e.g.* in *cavity*:
  - symmetric Gauss Seidel smoother;
  - absolute and relative tolerance.
- Settings for the algorithm, *e.g. PISO* in *cavity*:
  - number of corrector steps;
  - number of non-orthogonal corrector steps;
  - reference pressure.

The algorithm: *icoFoam* (*PISO*)

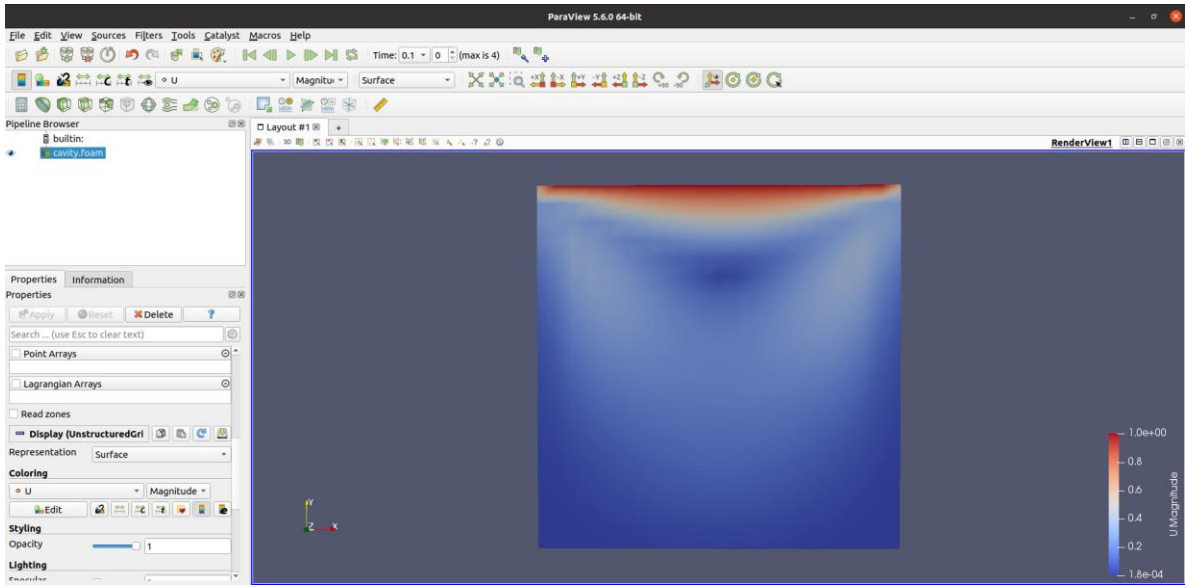
PISO (Pressure-Implicit with Splitting of Operators):

- Extension of SIMPLE algorithm
- Used mainly for unsteady flow (it is now also adapted for steady-state problems)
- 1 predictor step and 2 (or more) corrector steps to satisfy mass conservation (continuity)

(1): R.I. Issa. "Solution of the implicit discretized fluid flow equations by operator-splitting*". J. Comp. Physics*, 62(1):40-65, 1986.

Visualization of results: *Paraview*

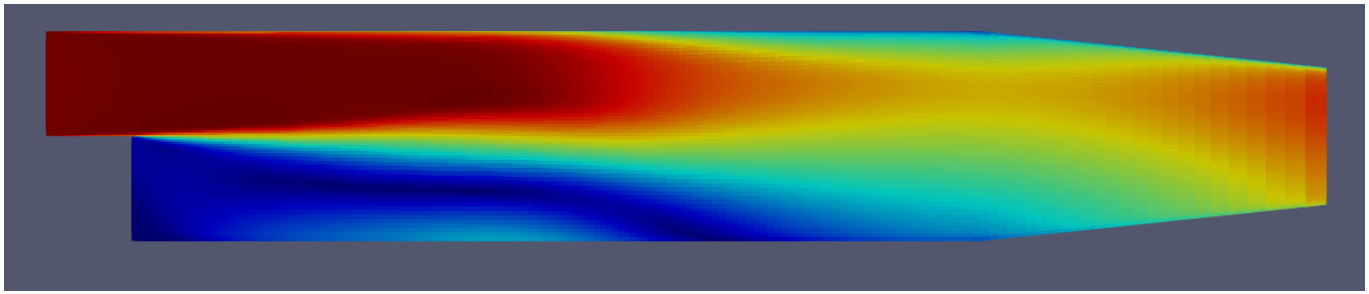
- Use *paraFoam –builtin*
- Visualization (contours, slices, line plots...) of all fields stored (U, flux, p...) at the output time-steps (or iterations)



Second case: Pitz & Daily (1983)

- Backward-facing step
- RANS equations (incompressible, steady-state)
- SIMPLE algorithm (predictor + corrector steps)
- Turbulence model for closure

  constant/turbulenceProperties



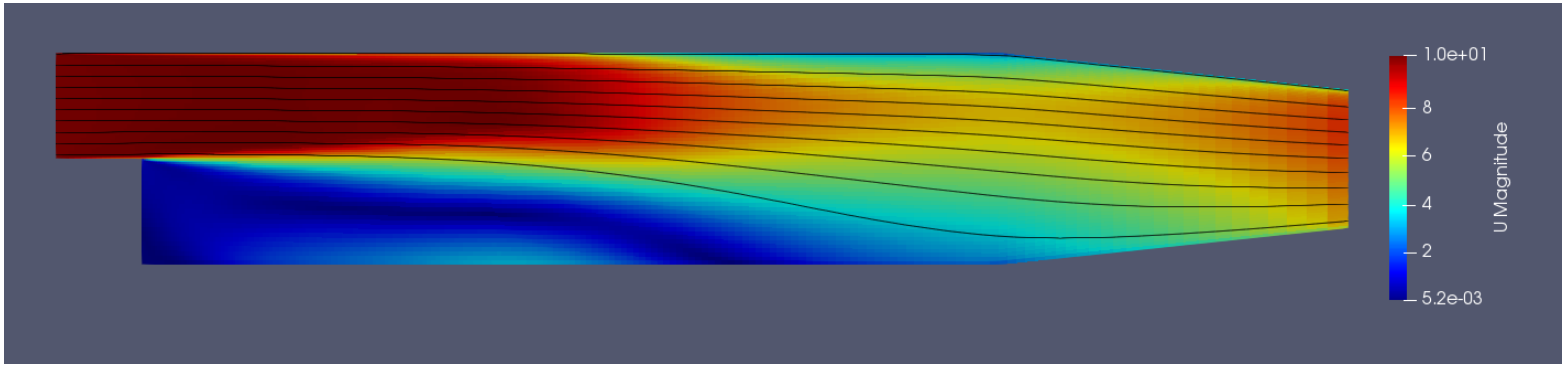
Visualization of results: *Paraview*

- *Create VTK fields using post-processing functions:*

  simpleFoam -postProcess -func wallShearStress

  simpleFoam -postProcess -func streamlines

- *paraFoam -builtin*



More information

- *Check the User guide (really useful!)*

https://www.openfoam.com/documentation/user-guide/