Chair of Scientific Computing
Department of Informatics
Technical University of Munich

Geometric multi-scale coupling prototypes with preCICE

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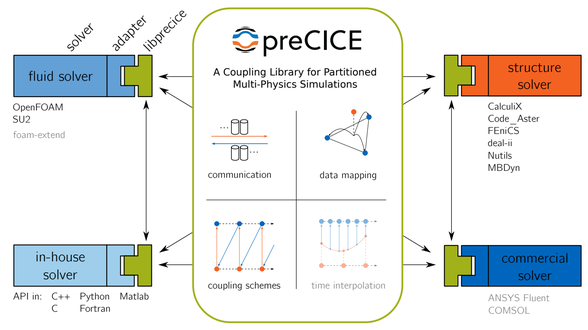
The coupling library preCICE



A coupling library for partitioned, black-box multi-physics simulations [1].

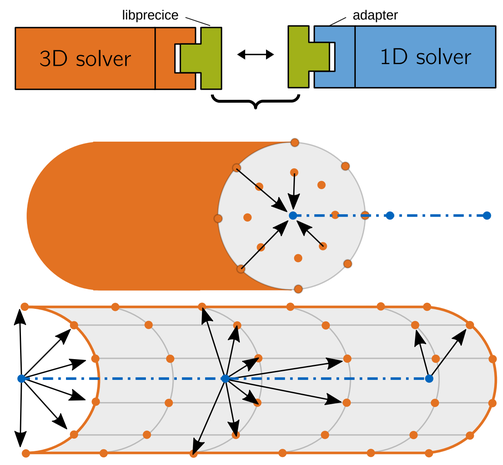
- **Free/open-source:** LGPLv3 license.
- **Typical applications:** Fluid-structure interaction (FSI), conjugate heat transfer (CHT), fluid-fluid coupl. (FF)
- **Minimally invasive:** Couple any code with a few lines of “adapter” code.
- **Mapping methods:** nearest-neighbor, nearest-projection, RBF.

LGPL Free Software – Free as in Freedom · Technical University of Munich · University of Stuttgart Germany

www.precice.org github.com/precice

Geometric multi-scale coupling

- **Current assumption:** Two sides of the interface compatible.
- **Goal:** Couple arbitrary dimensions: 1D-3D, 2D-3D, 5D-6D, ... in a black-box, dimension-agnostic way.
- **Classification:** [2]
  - Axial -vs- radial
  - Collect -vs- spread
  - (already) Consistent -vs- conservative
  - (already) Read -vs- write



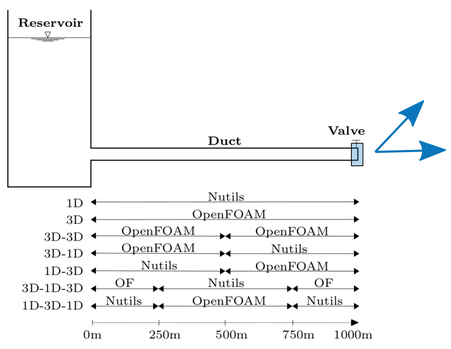
Prototypes

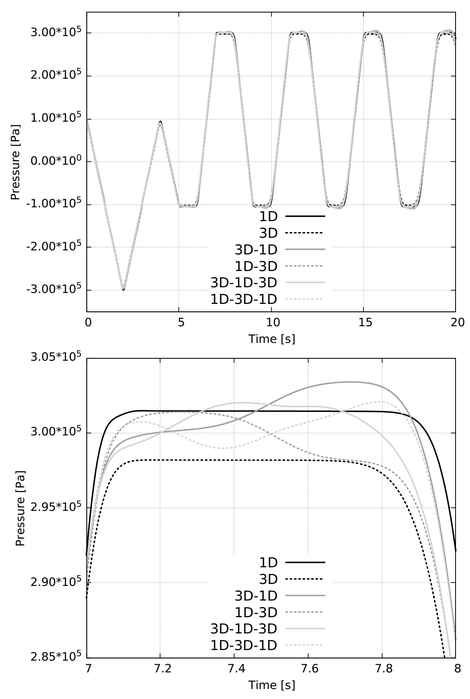
Nuclear reactor pipelines: the ATHLET-preCICE project (1D-3D FF, CHT)

Water hammer

A fluid-fluid coupling case with the 3D OpenFOAM [3] and a 1D Nutils [4] solver.

- **Proof-of-concept:** Geometric multi-scale with preCICE.
- Prototype in preCICE, fluid-fluid module in the OpenFOAM-preCICE adapter [2, 5].
- Comparing the outlet pressure (controlled valve) for axial 1D-3D, 3D-1D-3D, ... [2]

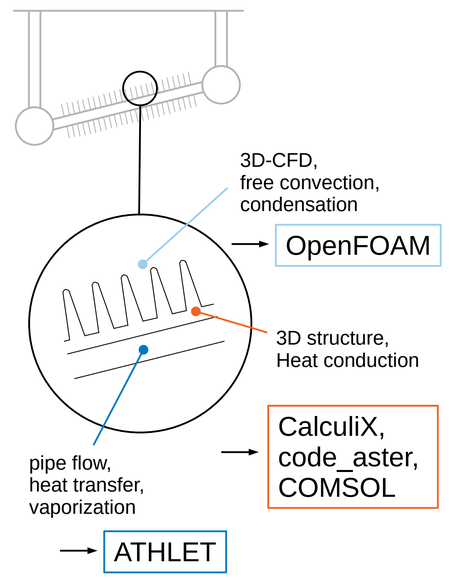




Nuclear reactor cooling

Sustainable coupling of the 1D thermo-hydraulic code ATHLET [6] with external 3D codes: OpenFOAM for axial fluid-fluid coupling and with CalculiX [7] for radial conjugate heat transfer.

- **Application:** cooling system condenser.
- Previous in-house coupling [8].
- Early work on ATHLET-preCICE adapter [9]:
  - Coupled ATHLET-ATHLET.
  - Challenges: time stepping, checkpointing, mapping.
  - Currently using PyAFFE [10], previously followed a plug-in approach [8].

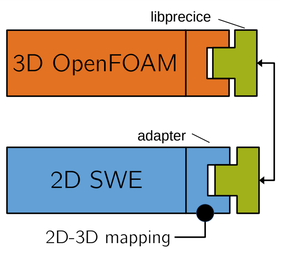


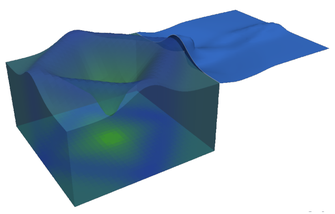
ATHLET

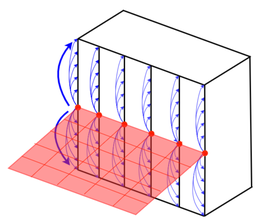
Tsunami near coast (2D-3D FF)

Coupling of 3D OpenFOAM (Navier-Stokes Equations) with an in-house 2D code [11] (Shallow Water Equations).

Axial mapping of U, p to h, hv in the SWE code. Results by Espinosa (2020) [12].



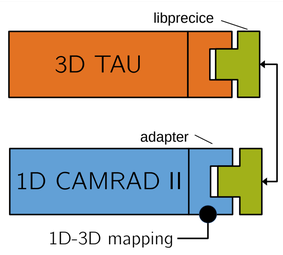


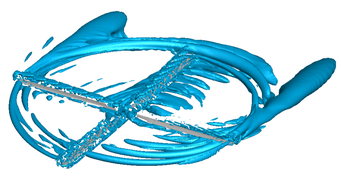


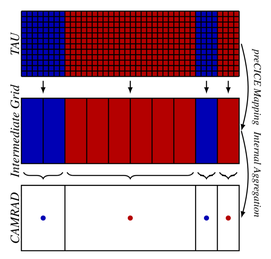
Helicopter blade (1D-3D FSI)

Coupling of 3D TAU [13] (RANS) with 1D CAMRAD II [14] rotorcraft analysis code.

Radial mapping of forces and displacements in the CAMRAD II adapter using intermediate grid. Results by Huang (2019) [15, 16].



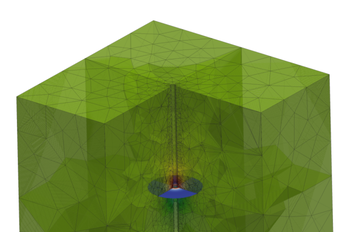




Further applications

In the future, preCICE should be able to handle arbitrary cases, without violating the black-box principle. Similar research using or planning to use preCICE:

- 2D-3D radial mapping in porous media fractures (example picture by Jaust et al. [17]).
- Higher dimensions mapping in magnetic fusion.



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www.precice.org github.com/precice