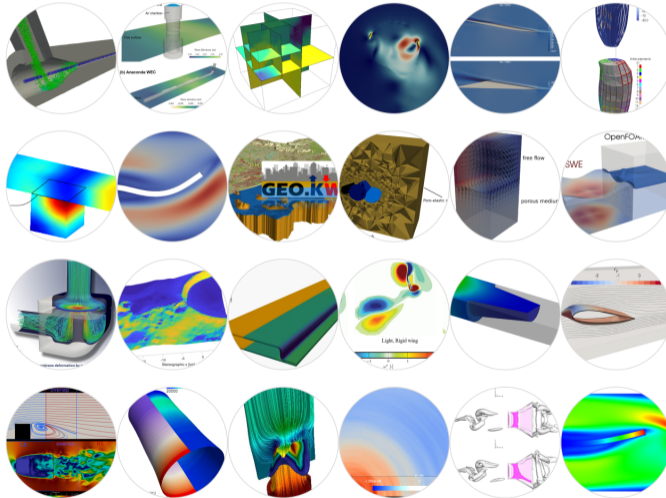


Verification and debugging of partitioned multiphysics simulation with preCICE and open-source solvers

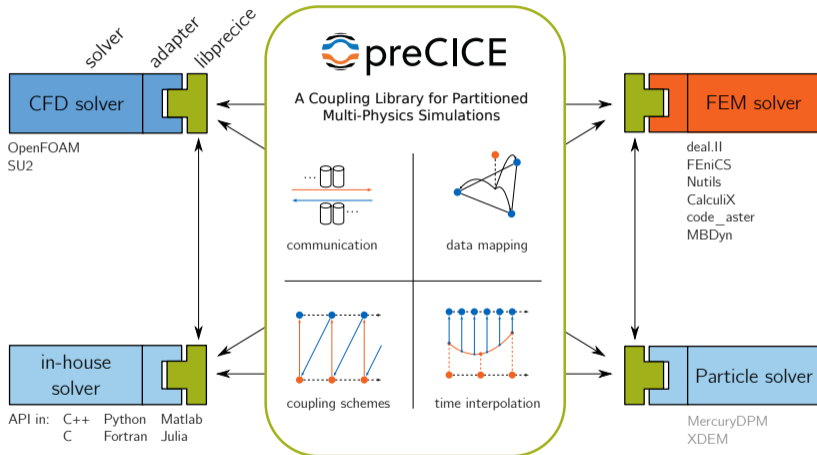
ICCE 2024, Darmstadt

Benjamin Rodenberg, Benjamin Uekermann, Hans-Joachim Bungartz

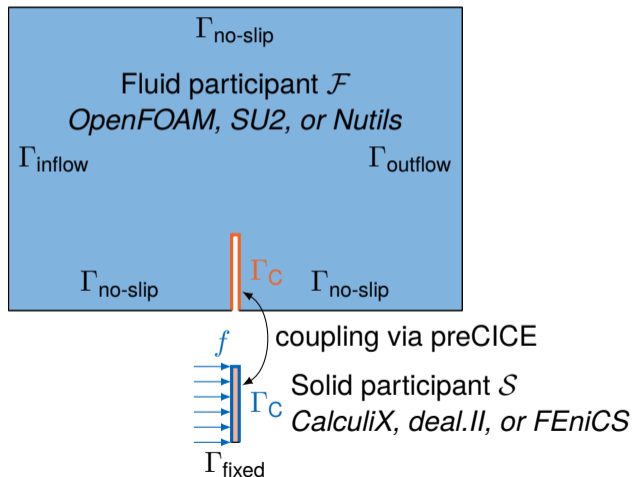
September 30, 2024



preCICE overview



DEMO TIME



Divide

Conquer

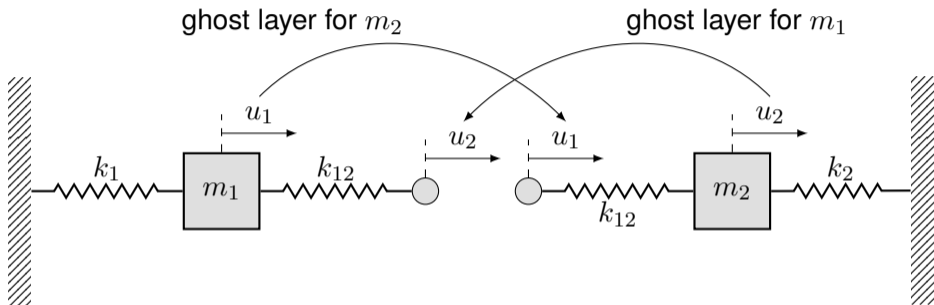
Combine

DEMO TIME

Verification and debugging with preCICE

- 1 Motivation: Higher-order time stepping
- 2 End-to-end testing
- 3 Fake input

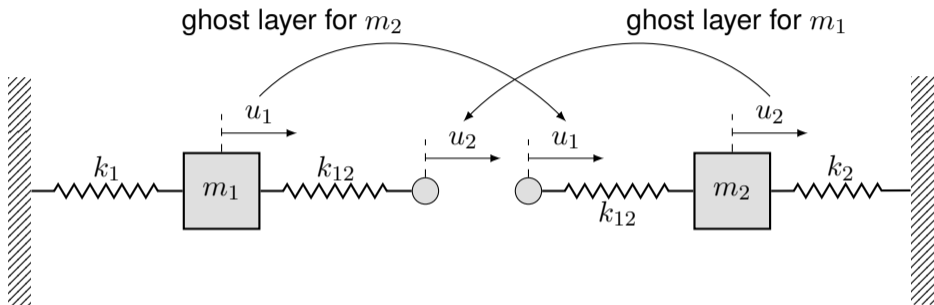
Motivation: Higher-order time stepping



Approach:

- Use manufactured/analytical solution
- Concentrate on a simple (symmetric) case

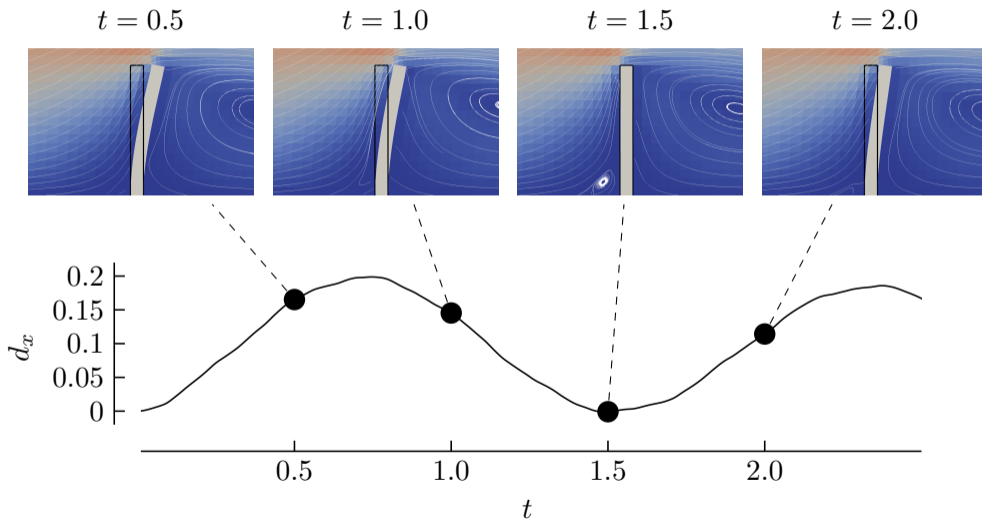
Motivation: Higher-order time stepping

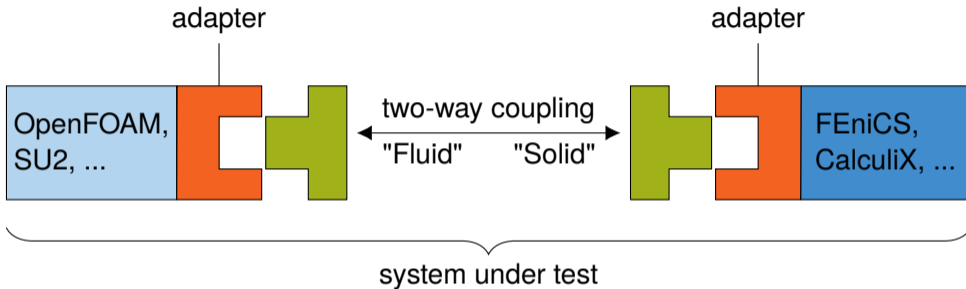


Problems:

- Reality is very different
- Multiphysics is much more complex (algorithms, software)

Real life \neq analytical solutions

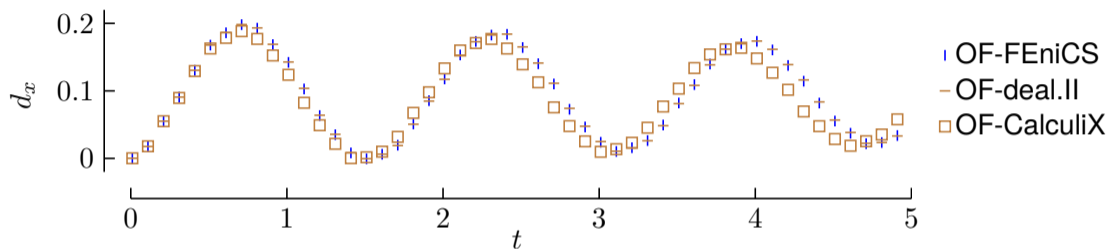




Approach:

Swap solvers and compare measurements (cross-validation)
Check OpenFOAM/SU2 + FEniCS/CalculiX/Deal.II

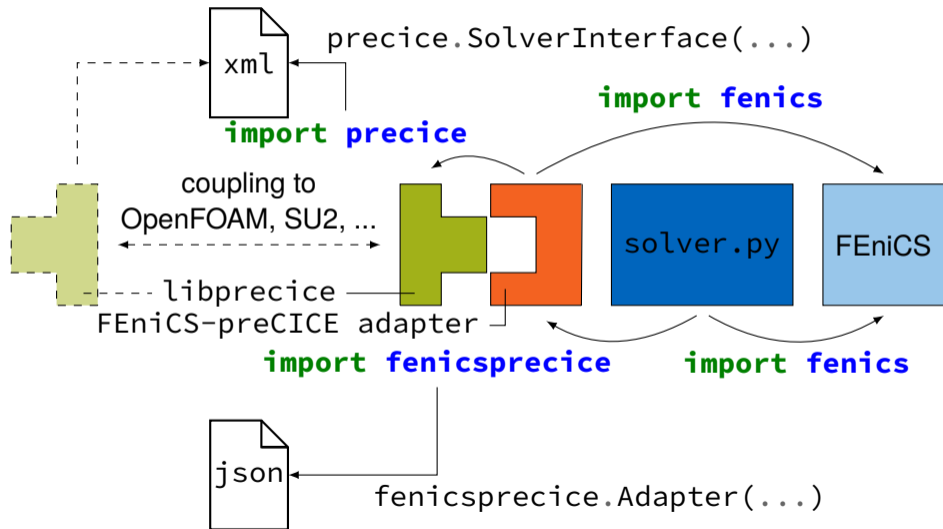
End-to-end testing



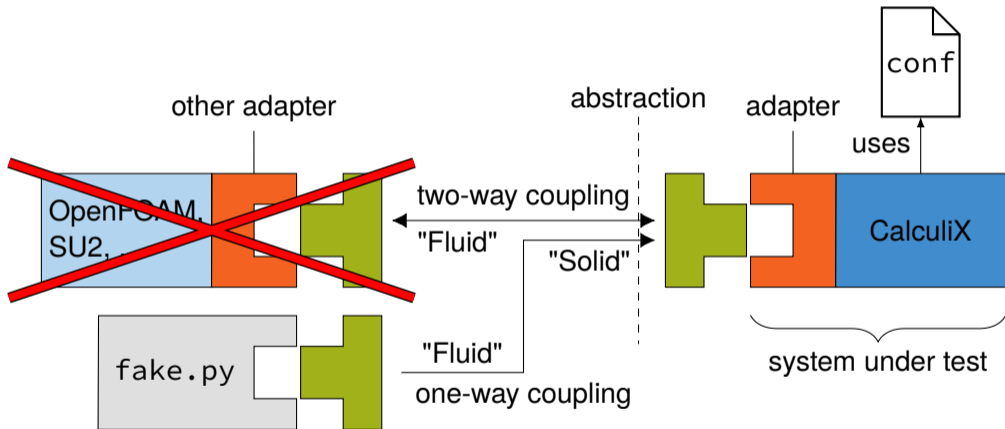
Problems:

- Setup is complicated
- Runtime is high
- Hard to identify origin of error

Example: FEniCS-preCICE



Fake input



Act 1: Dear internet, please help!

precice / tutorials Public Sponsor Notifications Fork 106 Star 102

<> Code Issues 61 Pull requests 21 Actions Projects Security Insights

perpendicular-flap: Results for CalculiX differ from FEniCS and Deal.II #176

New issue

Closed BenjaminRodenberg opened this issue on Mar 27, 2021 · 5 comments · Fixed by #250



BenjaminRodenberg commented on Mar 27, 2021

Member ...

Problem & some Background

We observed a mismatch between results of the perpendicular flap case when preparing [this publication](#). In the end we used the Deal.II - SU2 and FEniCS - SU2 cases in the publication. They show good agreement. CalculiX - SU2 disagrees with these cases. Our current explanation for this behavior is that the CalculiX case uses C3D8 elements, which should not be used according to the CalculiX documentation (see ["...the locking phenomena observed in the C3D8 element..."](#)).

Assignees

No one assigned

Labels

bug student

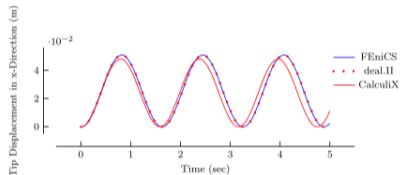
Projects

No open projects

Act 1: Dear internet, please help!

Additional Material

For debugging this case we developed a `fluid-fake` solver that I would like to share in this issue (see [fluid-fake.zip](#)). This allows to replace the fluid solver with a simple constant force for quicker debugging. I'm plotting the tip displacement over time. Already this simple setup can be used to show the mismatch of CalculiX and the other two solvers:



Code Versions

- `tutorials` : `a166efadfe7dbd3231e14897dcbeecebb90ea97e`
- `fenicsprecice` : `v1.0.1`
- `precice` : `v2.2.0`
- `mvnprecice` : `v2.2.0.1`

Successfully merging a pull request may close this issue.

🔗 [Change C3D8 elements to C3D8I elements in...](#)
AndresPedemonteFIUBA/tutorials

4 participants



Act 2: It actually worked



Closed

perpendicular-flap: Results for CalculiX differ from FEniCS and Deal.II #176

BenjaminRodenberg opened this issue on Mar 27, 2021 · 5 comments · Fixed by #250

**AndresPedemonteFIUBA** commented on Jan 22, 2022 · edited ▾

Contributor ...

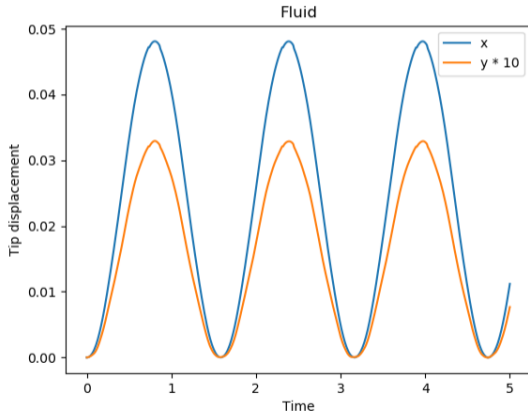
Since the issue is still open, I'll chime in. It might be worth trying with incompatible mode eight-node brick elements (C3D8I), which are implemented in CalculiX (https://petegustafson.com/CalculiX/ccx_2.15/doc/ccx/node29.html). Quoting: *the incompatible mode eight-node brick element is an improved version of the C3D8-element. In particular, shear locking is removed and volumetric locking is much reduced. (...) The C3D8I element should be used in all instances in which linear elements are subject to bending.*

EDIT: I decided to try it out, using the `fluid-flake` solver and its plotter. Check this out:

-CalculiX 2.16 with C3D8 elements (this is the figure provided in Benjamin's `fluid-flake.zip` file; I ran the case again to check and got the same):

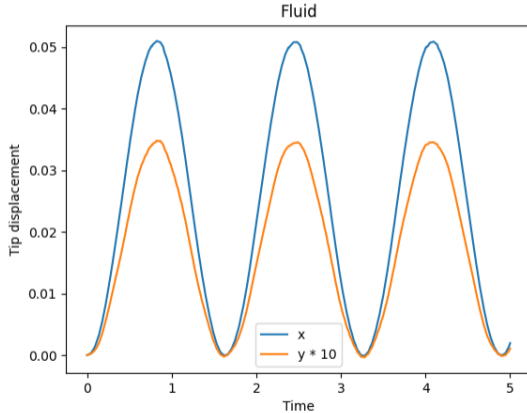
Act 2: It actually worked

-CalculiX 2.16 with C3D8 elements (this is the figure provided in Benjamin's `fluid-flake.zip` file; I ran the case again to check and got the same):



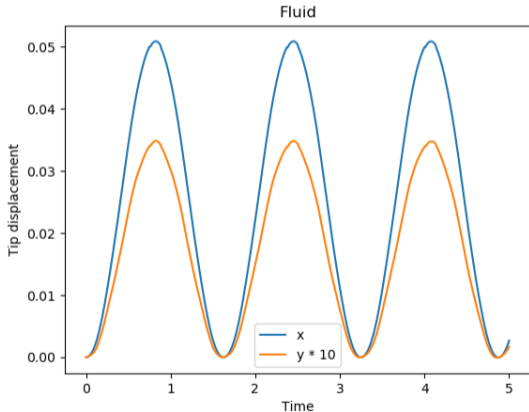
Act 2: It actually worked

- CalculiX 2.16 with C3D8I elements (my run):



Act 2: It actually worked

- FEniCS (this is the figure provided in Benjamin's `fluid-flake.zip` file):



Act 3: Results for paper fixed

Closed

perpendicular-flap: Results for CalculiX differ from FEniCS and Deal.II #176

BenjaminRodenberg opened this issue on Mar 27, 2021 · 5 comments · Fixed by #250

AndresPedemonteFIUBA mentioned this issue on Jan 24, 2022

Change C3D8 elements to C3D8I elements in perpendicular-flap solid-calculix

Merged

#250



AndresPedemonteFIUBA commented on Jan 24, 2022

Contributor ...

@BenjaminRodenberg: I just opened the pull request, [#250](#), with a minor explanation of the changes. It works out-of-the-box, no modification of the CCX adapter is required.

Apart from the test with `fluid-flake`, I also tested the full case (OpenFOAM-Calculix) and it ran successfully.

I don't have any of the other structural solvers built, so perhaps someone who has could go ahead and compare the new CCX results with them.

Andrés



BenjaminRodenberg linked a pull request on Jan 29, 2022 that will close this issue

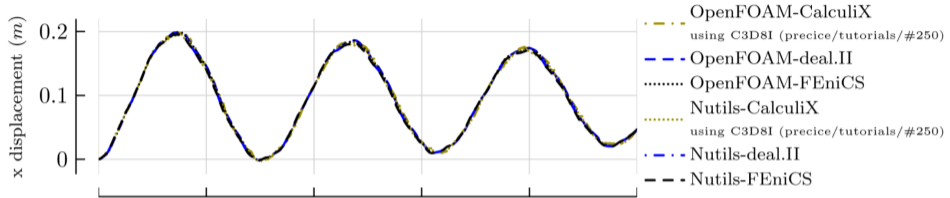
Change C3D8 elements to C3D8I elements in perpendicular-flap solid-calculix

Merged

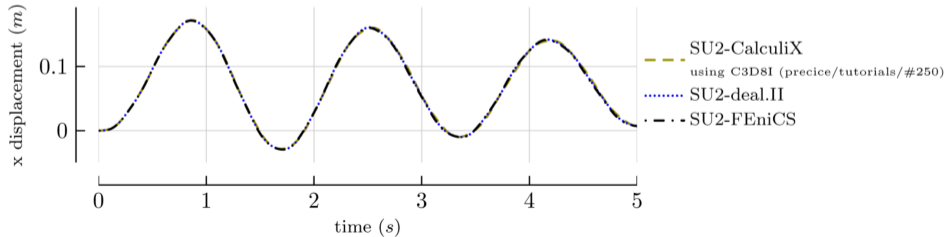
#250

Act 3: Results for paper fixed

Fluid-structure interaction with incompressible flow solvers OpenFOAM or Nutils



Fluid-structure interaction with compressible flow solver SU2



Summary

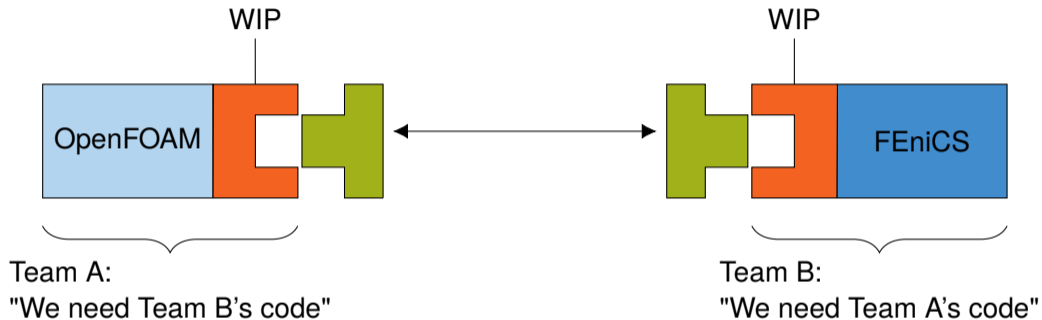
Take home

- If you can: Use simple scenarios and analytical solutions
- If not: Study data at watchpoints
- Swap implementations to find errors
- Reduce complexity through fake input
- Open source SW development helps improving the quality of your results

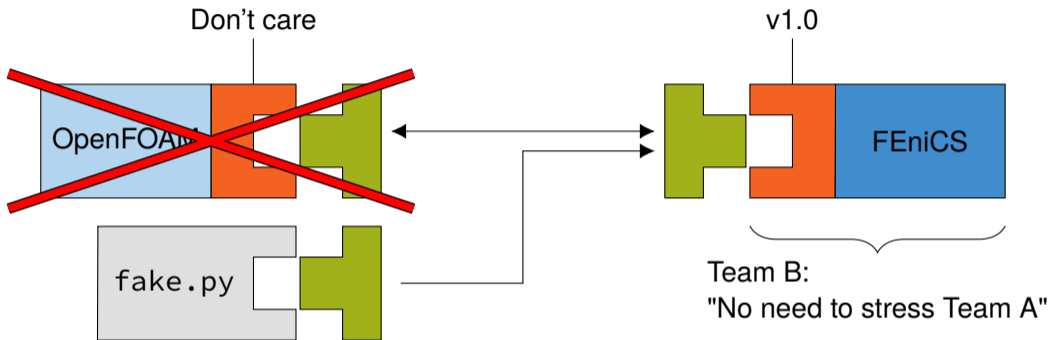
Recommendations

- If you develop a coupling framework: Standardized recording of watchpoints
- If you are dealing with multiple components: Testing using mocking/faking

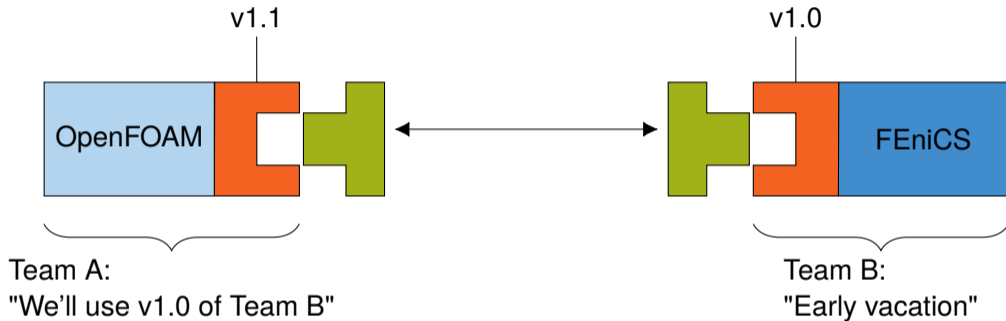
How to (not) miss a deadline:



How to (not) miss a deadline:



How to (not) miss a deadline:





preCICE Workshop 2024@Stuttgart

Stay in touch?

precice.org/community
precice.discourse.group

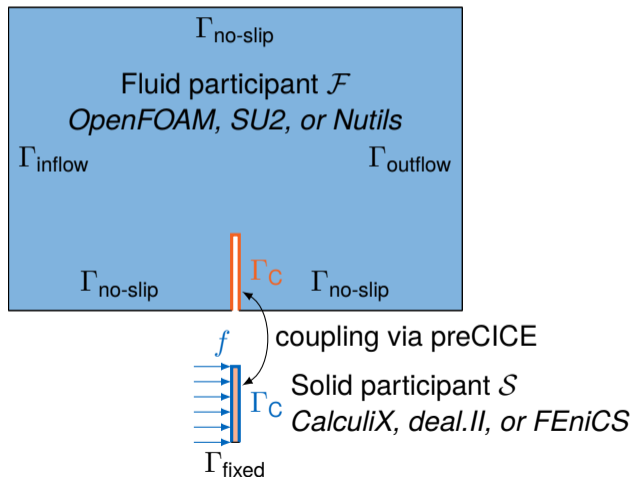
Conferences

Coupled Problems

26-29 May 2025@Sardinia

preCICE Workshop

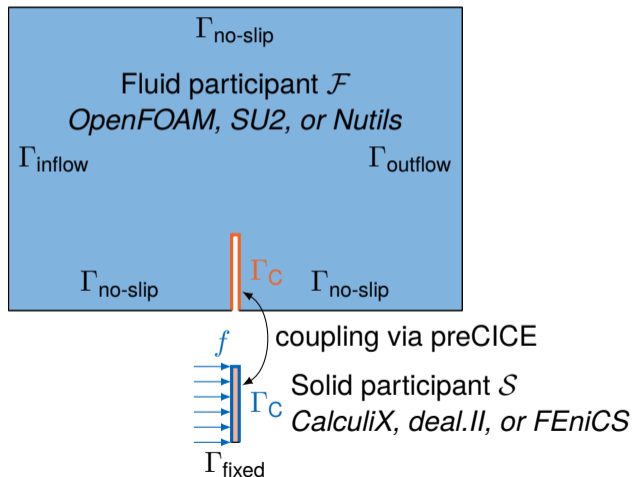
9-12 Sept 2025@Hamburg



Divide

Conquer

Combine

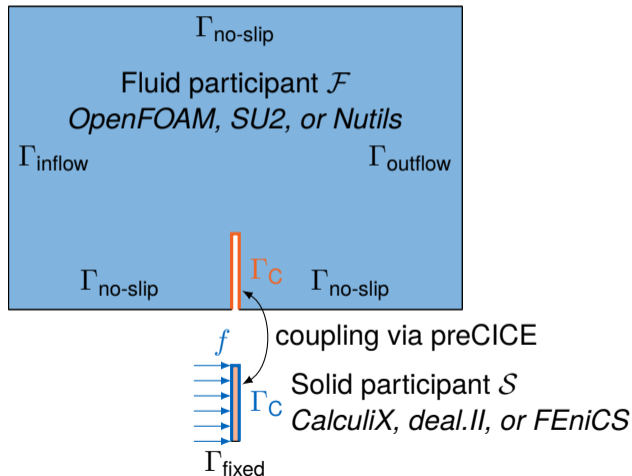


Divide

- OpenFOAM \neq FEniCS
- Dirichlet-Neumann
(= black box)

Conquer

Combine



Divide

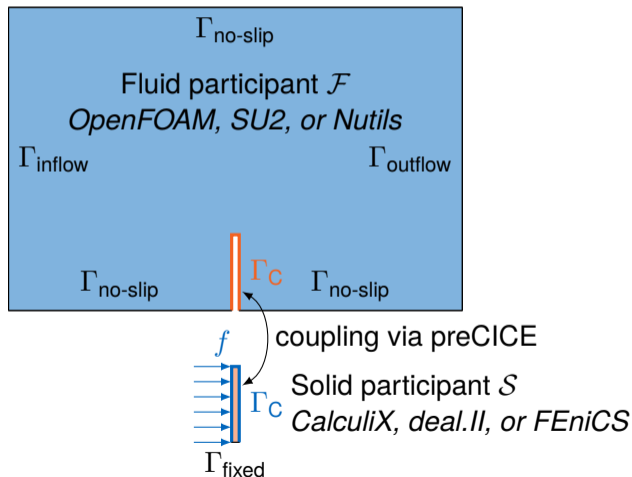
Conquer

- Fluid: $\mathcal{F}(d) = f$
- Solid: $\mathcal{S}(f) = d$

Boundary response maps

(= Poincaré-Steklov operator)

Combine



Divide

Conquer

Combine

- $\mathcal{F}(\mathcal{S}(f^k)) = \tilde{f}^k$
- $\tilde{f}^k \xrightarrow{\mathcal{A}} f^{k+1}$

Picard iteration + acceleration