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Time stepping review of open-source solvers

Guided research

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1 Introduction

- Introduction to coupling simulations (FSI) and to the preCICE library.
- Some brief motivation of performing a convergence study on the known solvers.
- Talk somehow about higer timestepping schemes, and why/when is good to use them. Should you use a higher order timestepping scheme if it doesn't give good results? (No bc it is slower)
- Say why we chose this two open source solvers.
- Explain difference between preCICEv2 and preCICEv3.

2 OpenFOAM

- Small introduction to OpenFOAM.
- Explain time stepping schemes available in the solver, and their orders. Mainly talk about Euler method, and Crank Nikolson, as they are the two cases we used.
- Talk about the script created to automatize the procedure of running these simulations.

$$\frac{\partial u}{\partial t} = F(u,x,t) \tag{1}$$

$$\frac{u_i^{n+1} - u_i^n}{\Delta t} = (1-\theta){F_i}^n(u,x,t) + \theta {F_i}^{n+1}(u,x,t) \tag{2}$$

$$\frac{f_i^{n+1} - f_i^n}{\Delta t} = (1-\theta)\frac{f_{i+1}^n - 2f_i^n + f_{i-1}^n}{(\Delta x)^2} + \theta\frac{f_{i+1}^{n+1} - 2f_i^{n+1} + f_{i-1}^{n+1}}{(\Delta x)^2} \tag{3}$$

[1]

2.1 Solver parameters

- Talk about the important parameters in the configuration, to obtain accurately enough results, as those where quite time consuming to find. For example, foamToVTK is not accurate enough, and was misleading at the beginning. Also mention the solver used.

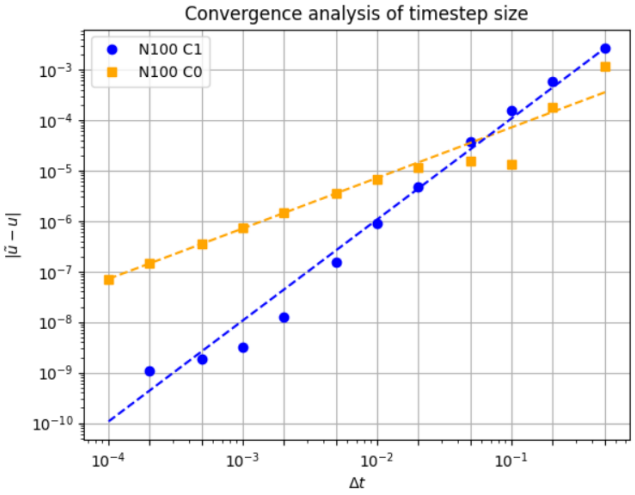

Figure 1 Figure comparing data to the analytical solution of Taylor green vortex.

2.2 Case study: Taylor Green Vortex

- Short introduction to the scenario, present generation formulas of initial conditions and boundary conditions.
- Explain how the error is computed, while commenting Figure 1.
- Talk about the second way of computing the error, while commenting Figure 2. Talk about the appearence of the spatial discretization error, and at which scales happens.

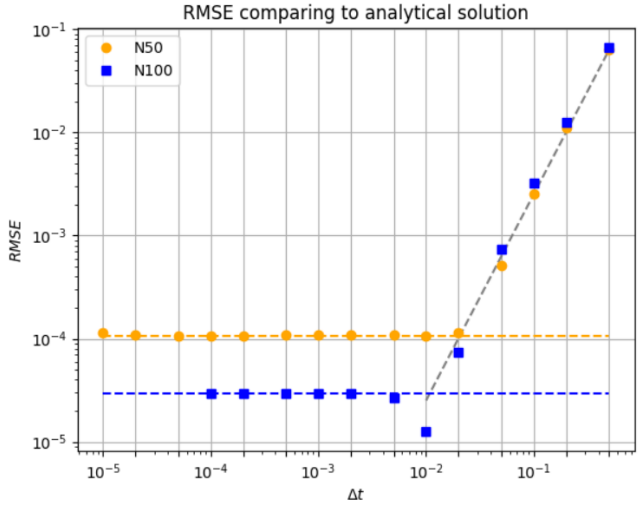

Figure 2 Figure showing spatial error decrease with higher grid definition. TODO: improve this figure, as you computed also with N150.

3 Calculix

- Small introduction to Calculix.

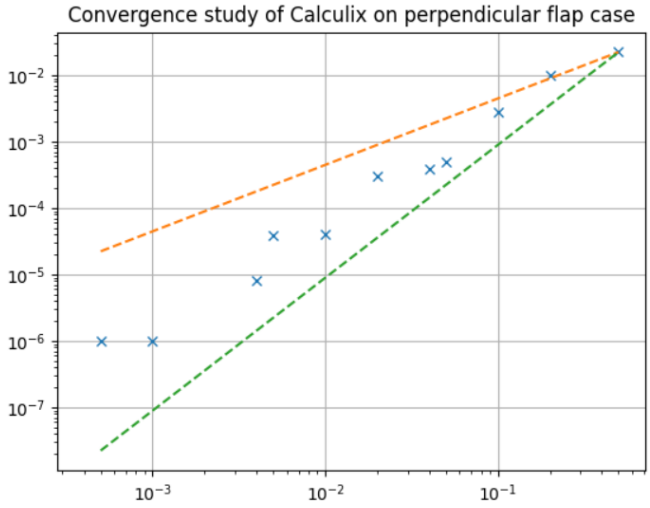

Figure 3 TODO: improve this figure, by adding legend and nicer colors.

3.1 Solver parameters

- Talk about the supported time stepping scheme (only one, but higher order). In this case the parametrization is quite simpler, so I would also summarize it here.

3.2 Case study: perpendicular flap

- Talk about the simulation that we performed, a perpendicular flap versus a constant force.
- Mention the scripts created to automatize this task, and to obtain the tip point value from the results.
- Comment on Figure 3, that shows a higher order (between 1 and 2) of convergence. Mention how we compute the error, and how for values <1e-4 the outputed value is the same, meaning either that for lower timesteps the spatial discretization error governs, or that the solver can't achieve better accuracy bc of how values are stored (max of 6 decimal values, more likely given that the results are the exact same).

4 Coupling the two solvers

- Talk about what a FSI is in general. Talk more specifically about the perpendicular flap case study, based on the preCICE tutorials.
- Talk about the automatization of this, using scripts.
- Supported time stepping schemes, difference between v2 and v3.

4.1 Simulation parameters

- Talk about the parameters of the two solvers (mainly the same as the previous simulations, except change of openFAOM solver).
- Mention the possible preCICE parameters (window-size, ...).

4.2 Case study: FSI - perpendicular flap

- Comment on Figure 4. Show how First order convergence seems to be working, but higher order performs poorly. This is due to an error on the openFAOM adapter, which only supports Euler timestepping.

- Crank Nikolson needs two evaluations per time step, or reuse buffered data of previous timesteps (what is doing openFAOM, most likely, TODO: check this.).
- Give reasoning why this is not working, give some clues what should be done to actually improve it.

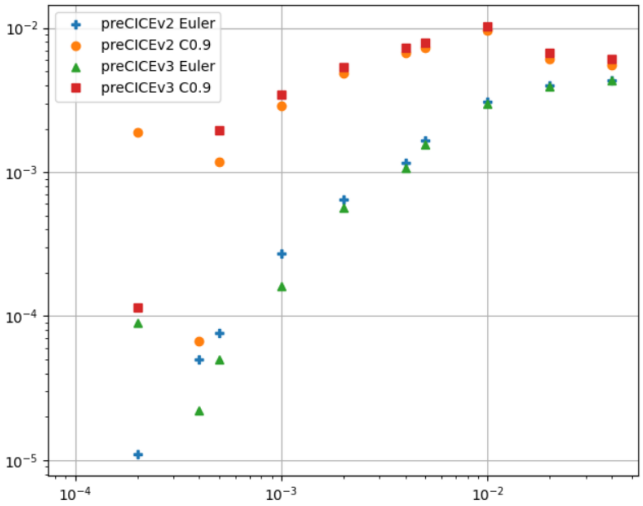

Figure 4 TODO: add title and maybe convergence lines

5 OpenFOAM Adapter

- Maybe explain a bit how it interacts with the solver, quite documented already by Adapter documentation, and by Article of Gerasimos et al..
- Mention what should be fixed, maybe propose a prototype?
- Mention how should be tested, with a fake-fluid setup for example. Then also test with the same setup to see if it is viable.

6 Conclusions and future work

- Talk about the convergence conclusions of each of the solvers. Mention the obtained results with the preCICE couplings.
- Give directions on what to fix of the OpenFOAM adapter, and what to be tested after the fixing implementation.

References

[1] John Crank and Phyllis Nicolson. “A practical method for numerical evaluation of solutions of partial differential equations of the heat-conduction type”. In: *Mathematical proceedings of the Cambridge philosophical society*. Vol. 43. 1. Cambridge University Press. 1947, pp. 50–67.