1 Background

Partitioned Black-Box Coupling In our group, Scientific Computing in Computer Science (SCCS) at the TU München, we aim to develop partitioned multi-physics approaches. In such approaches, the coupling between different physics should take place at the highest possible level. In fluid-structure interaction (FSI), this is done by boundary descriptions including Dirichlet-Neumann coupling, the most common technique. In contrast, monolithic schemes couple at a very low level. This means, they assemble one large system of equations and use separate fluid and structure solvers only on a preconditioner level. The disadvantages of partitioned coupling are possible stability issues, but this effort is worth taking. By separating the physical regimes, we can reuse existing solver codes and, thus, benefit from the experiences that have been made in each field.

Our second development principle is the use of black-box solvers, where a black-box solver is a solver that has the same technical interface-depth as standard commercial solvers usually offer. This means, in particular, that the coupling must be formulated independently of the spatial and time discretization of each solver. Furthermore, Jacobian information is in general not available. With this approach, solver codes can easily be exchanged permitting the integration of existing codes in a plug-and-play manner.

Figure 1: Main functionality and coupling principles of preCICE. In the middle, the four main groups of functions are shown, namely equation coupling schemes, data mapping methods, communication between distributed solvers, and surface geometry query functionality. preCICE can be used for parallel solvers (such as solver A on the left) or sequential solvers (such as solver B on the right). This drawing is taken from [1]

Our group developed the coupling environment preCICE\textsuperscript{1}, which implements partitioned black-box coupling, data mapping functionality for non-matching grids, and communication routines. It allows a very flexible and easy exchange of solver codes.

\textsuperscript{1}http://www5.in.tum.de/wiki/index.php/PreCICE\_Webpage
Coupling Algorithms  To overcome the above mentioned stability issues, under which the partitioned approach suffers, in particular, for light-weighted or very elastic structures, sophisticated coupling algorithms have to be applied. The simplest case can be an underrelaxation, but various more efficient variants exist. The state of the art techniques are based on a interface least-square (ILS) system that is solved in every iteration. We implemented the IQN-ILS approach (cf. [2]) and a recently developed generalization (cf. [3]) in preCICE. For the latter we observed that a scaling of the sub-equations that constitute the ILS system influences the convergence rate drastically. We suppose that a rigorous weighting of ILS system might be even more beneficial to the overall efficiency of the algorithms.

2 Thesis Topic

The master thesis should, first, analyse the ILS system including a more general literature review of weighted least-square system. Then, the student should develop and test a dynamic scaling approach of the ILS system. We suggest the following agenda:

1. Familiarization with FSI, coupling algorithms and weighted LS theory
2. Development of scaling approaches for the ILS system
3. Testing of these approaches by means of an 1D MATLAB implementation
4. Implementation of the best approach in preCICE
5. Running several test cases to validate the algorithm and compare the performance to classical methods

3 Prerequisites

• Strong background in numerical methods, especially for PDE’s.
• Working knowledge in MATLAB
• At least basic knowledge of computational fluid dynamics (CFD) and/or computational structural mechanics (CSM)
• At least basic knowledge of C++

For more information and your application please contact Benjamin Uekermann (uekermann@in.tum.de).
References

