A Framework for Massively Parallel Simulation of FSI Problems

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Introduction

We present a massively parallel framework for simulation of large scale Fluid-Solid Interaction (FSI) problems. We follow a partitioned approach in which fluid and solid are treated independently by using well-adapted solvers for each domain. In this approach, a coupling tool is needed to connect two solvers. The partitioned approach provides great flexibility and robustness. In addition, the possibility of using well-validated numerical methods further improves the reliability of the framework. However, it introduces new challenges that must be addressed:

Main challenges

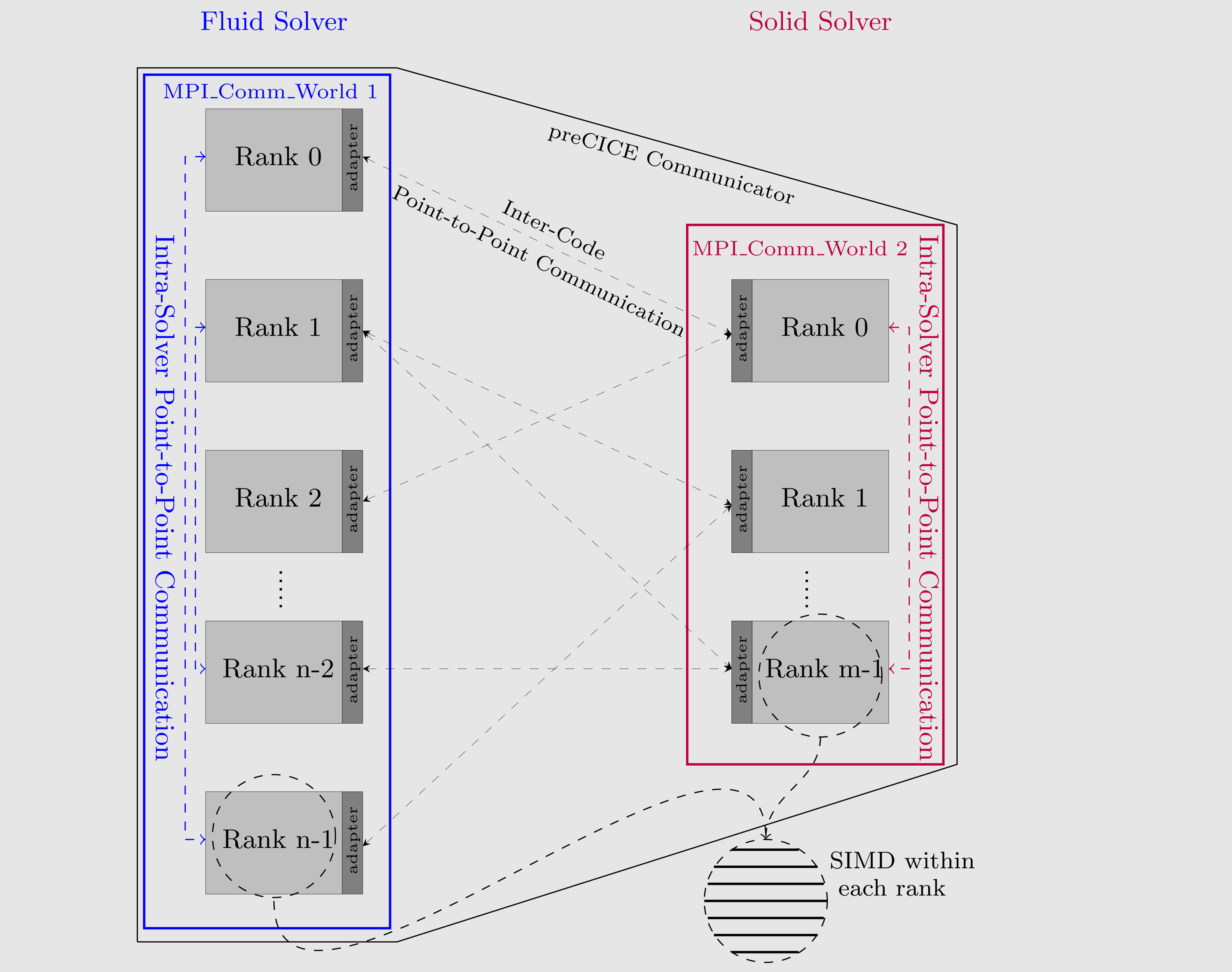
- Inter-code data communication
- Equation coupling
- Boundary data mapping
- Inter-code load balancing

Multi-Level Parallelization

To maximize the scalability of the framework, we have exploited multi-level parallel processing ranging from inter-solver data communication to node level computation.

Exploited parallelism within the framework

- Fully point-to-point communication (inter-solvers and intra-solver)
- A parallel Quasi-Newton coupling scheme
- SIMD instructions in the node level
- Parallel communication initialization



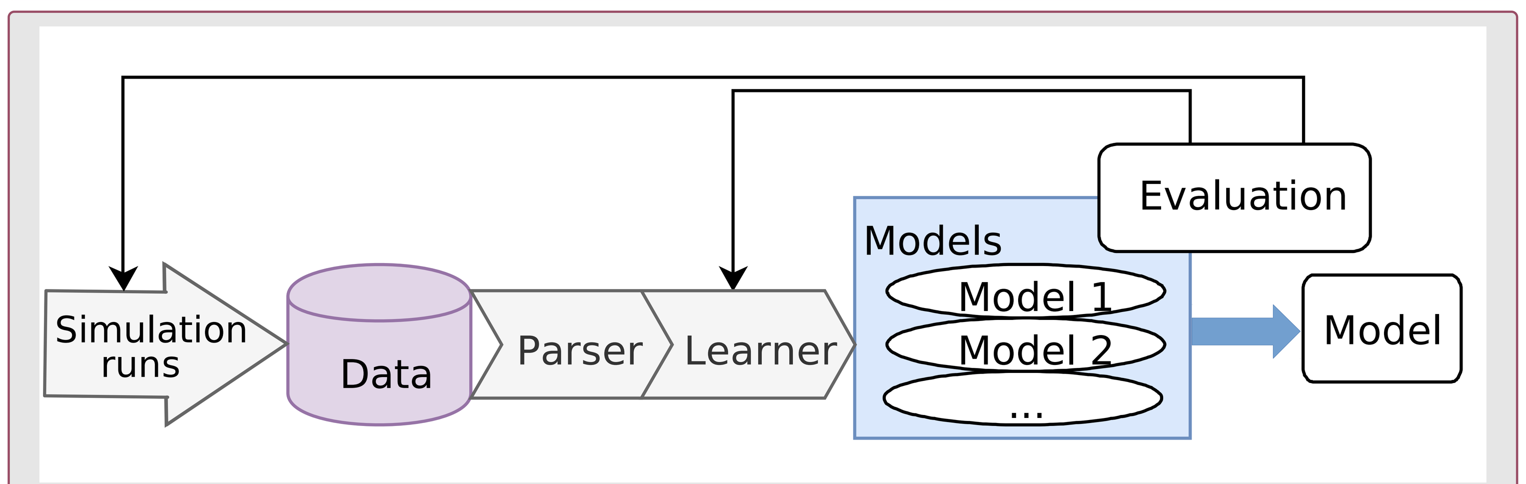
Parallel point-to-point inter-solver and intra-solver communication [1].

Machine Learning for Inter-Solver Load Balancing

Inter-solver load balancing can significantly increase the performance of the framework. We use a two steps approach for load balancing: 1- Machine learning is used for performance modeling of solvers, 2- An integer optimization is exploited to efficiently distribute computation resources among solvers and minimize the solvers waiting time [2].

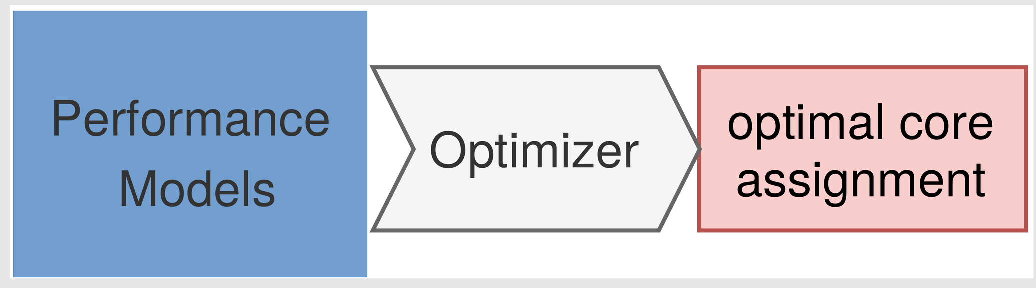
Step 1: Modeling

- We run a small number of simulations to generate performance data.
- The data used to train the performance model. This model can be a regression or a neural network.



Step 2: Optimization

- The trained performance models are used for core distribution optimization.
- The optimization problem depends on the coupling scheme (parallel or serial).

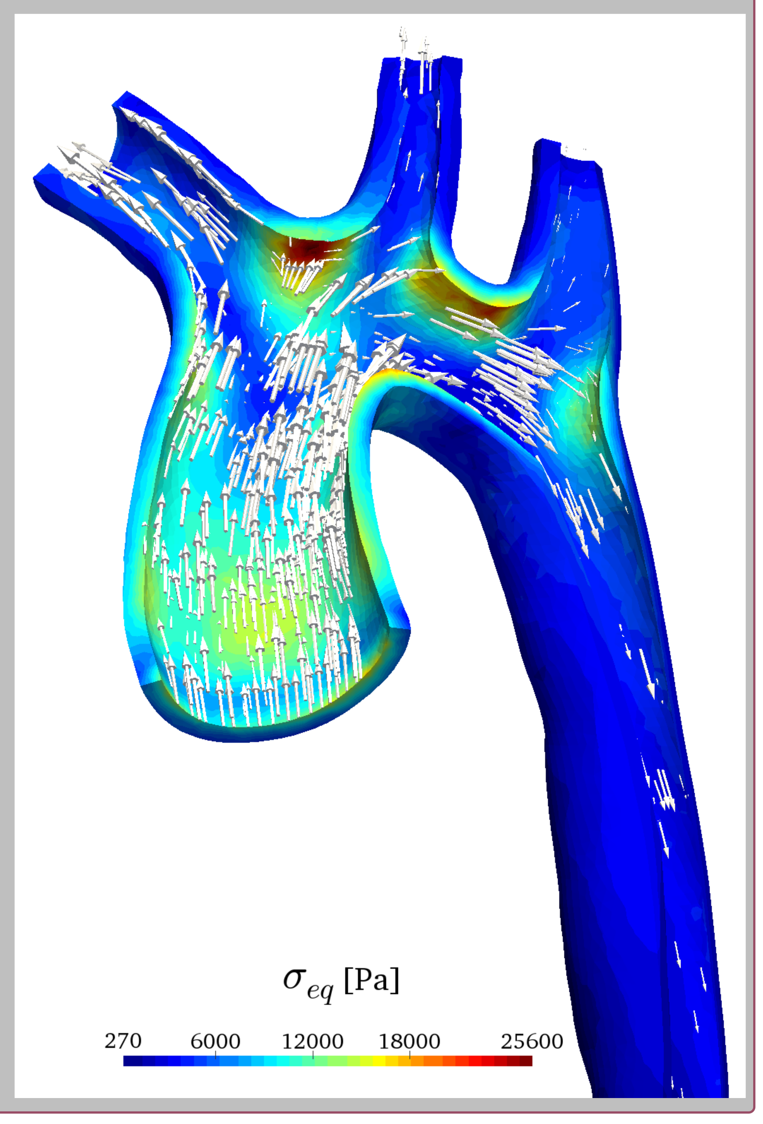


Numerical Results

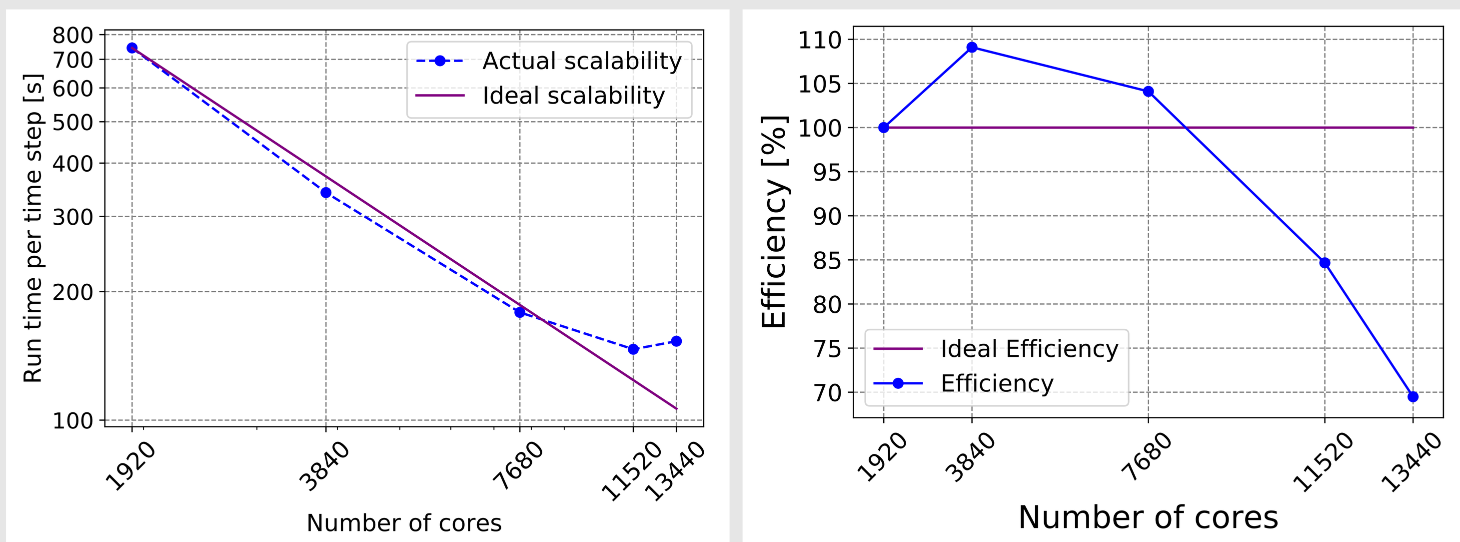
We present strong scalability measurements for a patient specific aorta which is a very complex problem in the filed of hemodynamic simulation.

Test case description

- Two instances of TermoFluids[3] are used for solid and fluid simulation.
- For code coupling, preCICE coupling library [4] is used.
- Fluid mesh: unstructured tetrahedral mesh with 116 million cells
- Solid mesh: unstructured tetrahedral mesh with 60 million cells
- A semi-implicit coupling strategy is followed.
- The scalability tests are carried out on the SuperMUC-NG supercomputer at LRZ Supercomputing Center in Garching, Germany.



Strong scalability measurements



Summary and Conclusion

- A framework for massively parallel simulation of FSI problems is presented.
- Different levels of exploited parallelism are illustrated.
- A machine learning based load balancing approach is introduced for inter-solver load balancing.
- An excellent scalability up to **11520** cores is shown (with 85% parallel efficiency).

References

[1] Naseri, Alireza, Totounferoush, Amin , González, Ignacio, Mehl, Miriam , Pérez-Segarra, Carlos David. "A Scalable Framework for the Partitioned Solution of Fluid-Structure Interaction Problems". Submitted to Computational Mechanics, 2020.
[2] Totounferoush, Amin, Ebrahimi Pour, Neda, Schröder, Juri, Roller, Sabine, Mehl, Miriam. "A new load balancing approach for coupled multi-physics simulations." 2019 IEEE International Parallel and Distributed Processing Symposium Workshops (IPDPSW). IEEE, 2019.
[3] O. Lehmkuhl, C. Perez-Segarra, R. Borrell, M. Soria, A. Oliva, TermoFluids. "A new parallel unstructured CFD code for the simulation of turbulent industrial problems on low cost PC cluster", in: Parallel Computational Fluid Dynamics 2007, Springer, 2009, pp. 275–282 (2009).
[4] Bungartz, Hans-Joachim, Florian Lindner, Bernhard Gatzhammer, Miriam Mehl, Klaudius Scheufele, Alexander Shukaev, and Benjamin Uekermann. "preCICE a fully parallel library for multi-physics surface coupling." Computers and Fluids 141 (2016).

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