Bringing System Simulation and 3D Simulations together using FMI and MpCCI

Jan Kleinert, Klaus Wolf
Fraunhofer Institute for Scientific Computing and Algorithms SCAI, Germany

Richard Meyer, Christoph Clauß
Fraunhofer Institute for Integrated Circuits IIS, Germany

Kevin Hofmann, Uwe Grätz
ESI ITI GmbH, Germany

1 Motivation

Even though system simulations and full 3D simulations are both commonly used in industry and science, they remain somewhat seperate disciplines.

3D simulations – e.g. Finite Element Modelling (FEM), Multibody Simulation (MBS) and Computational Fluid Dynamics (CFD) – focus on the behavior of single components and are usually very specialized to depict a small selection of physical phenomena in a very detailed manner. Systems simulations, on the other hand, focus on the overall nonlinear dynamic behavior of complex systems consisting of many components. With today's computational power it is not farfetched to depict the behavior of single components in a complex system via coupling to a full 3D simulation tool.

For instance, the system of electronic control units for the engine, brakes, steering, ventilation, etc. in a modern car can be simulated using a systems simulation tool, while the airflow in the thermal systems is modelled via a full transient CFD simulation. Similarly, critical chassis components can be modelled with finite elements.

2 The Functional Mock–up Interface

The Functional Mock–up Interface (FMI) is a standard for code coupling in systems simulation [1]. A subsystem is implemented within a so–called Functional Mock–up Unit

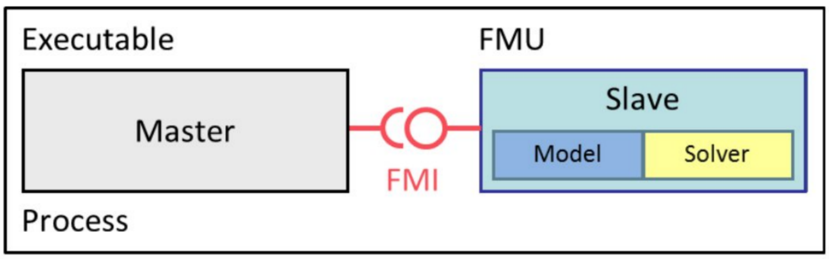


Figure 1: A possible FMI setup running on one computer [1]

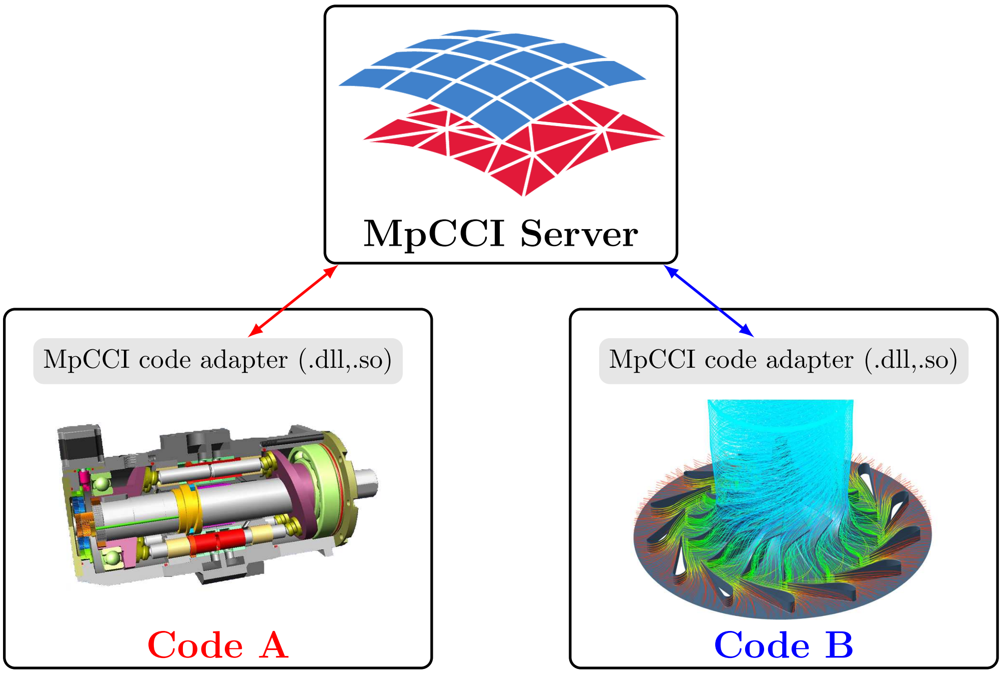


Figure 2: Co–Simulation using the MpCCI CouplingEnvironment

(FMU). A FMU contains a standardized model description and an executable shared library of a solver for the subsystem. The model description contains, among other things, information about inputs and outputs of the subsystems, physical units and parameters. The shared library implements an API that allows external control over writing inputs, reading outputs and advancing the simulation of the subsystem FMU. By October 2016, The FMI website lists 25 simulation tools that support the export to FMUs for FMI version 2.0.

A simulation master is a program that organizes the simulation of several slave FMUs. The implementation of the master is not part of the FMI standard. The master is responsible for physical meaningful robust coupling of the subsystems. Fraunhofer IIS/EAS developed such a co–simulation master for the coupling of FMUs, called the EAS master [2].

3 The MpCCI CouplingEnvironment

The MpCCI CouplingEnvironment is a co–simulation interface for 3D simulations that has been developed by Fraunhofer SCAI [3]. MpCCI includes adapters to many commercial and noncommercial 3D simulation codes[1]. For best coupling results between two codes, it implements several features that go beyond the scope of the current FMI standard. For instance, MpCCI can deal with nonmatching discretizations of geometry features and coupling between codes that use adaptive time step sizes.

In contrast to the EAS Master, MpCCI does not actively advance the simulation of the co-simulated codes. The codes use their own respective space and time discretizations. At certain times during the simulation process, a simulation code uses callback functions to exchange data with the MpCCI CouplingEnvironment. These callbacks are usually

[1]See `www.mpcci.de` for an exhaustive list.

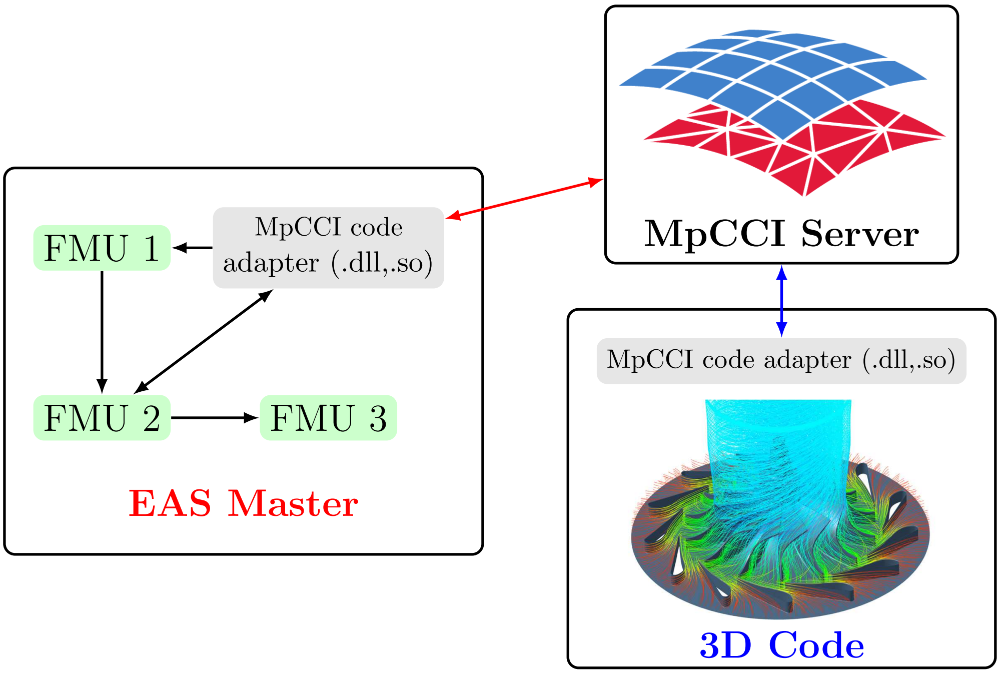


Figure 3: Coupling of the EAS Master and 3D simulation tools using the MpCCI CouplingEnvironment

implemented using the API of the respective code. The so-called MpCCI server handles the correct data association, see Figure 2.

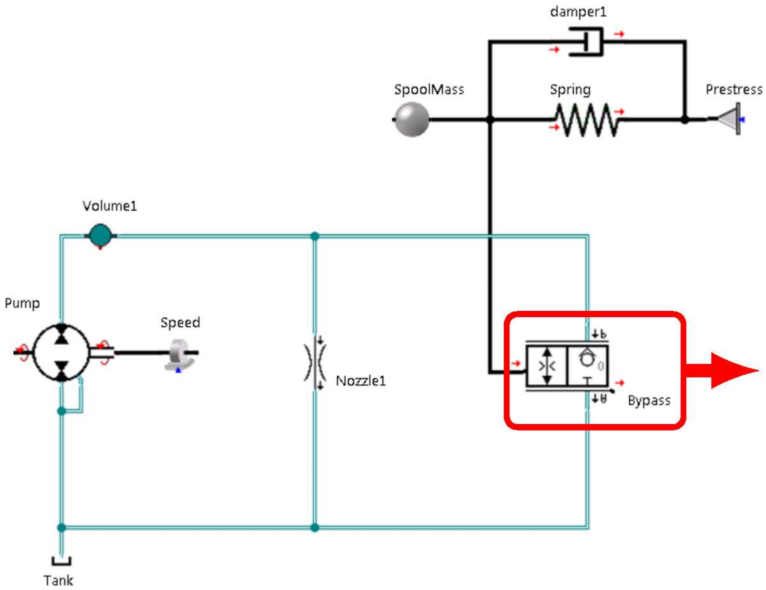
4 Coupling between MpCCI and the EAS Master

To bring the two worlds together, a MpCCI code adapter for the EAS Master has been implemented. With this new feature it becomes easy to couple a system of FMUs, simulated with the EAS Master, to a full 3D simulation (or co–simulation) using any of the CAE tools supported by MpCCI, even if the CAE tool does not offer FMI capabilities.

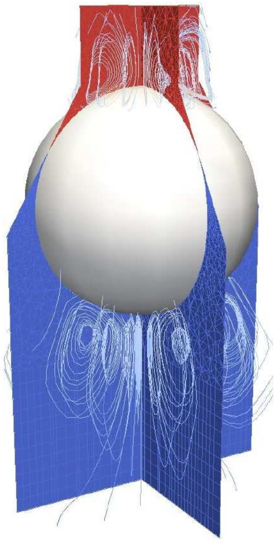
From the perspective of the EAS Master, the MpCCI adapter is another component in a system of FMUs, see Figure 3. After the coupling components have been selected in the MpCCI graphical user interface, the resulting connection graph of FMUs is automatically analysed to detect and treat algebraic loops properly.

5 Application and Outlook

The coupling between FMUs and a full 3D simulation has been demonstrated with the simulation of a hydraulic circuit of oil flow in an engine, see Figure 4(a). A bypass valve controls the maximum pressure behind the oil pump. The hydraulic circuit is modelled using the systems simulation software SimulationX and exported to an FMU, while the bypass valve is modelled in 3D using the CFD software Ansys Fluent. Ansys Fluent receives pressure boundary conditions at the inlet and outlet of the valve from the FMU. In return, the FMU receives the massflow as input from Ansys Fluent. A snapshot of the CFD simulation, shortly after the closing of the valve, is shown in Figure 4(b).



(a) Hydraulic circuit of oil flow



(b) A 3D simulation of a bypass valve

Figure 4: Coupling of a hydraulic circuit and a 3D CFD code: For the co–simulation, the bypass valve is removed from the network before the FMU export

In an initial test, the ball valve including the spring are modelled within Ansys Fluent, while the remaining network is modelled within a single FMU. In the future, the mechanical behavior of the ball displacement within the valve will be modelled using an additional FMU, as depicted in Figure 4(a). The EAS Master has been specifically developed for the co–simulation of a large system of several FMUs.

The results obtained by the standalone SimulationX model are compared to the co-simulated results. The coupled simulation clearly increases the fidelity of the model. An in-depth analysis of the turbulent flow within the bypass valve can hugely levitate the possibilities in early stages of product development.

References

[1] Modelica Association Project FMI. Functional mock–up interface for model exchange and co–simulation version 2.0, July 2014.

[2] T. Schiertz, M. Arnold, and Clauß C. Co–simulation with communication step size control in an fmi compatible master algorithm. In *Proceedings of the 9th International Modelica Conference, Munich, Germany*, 2014.

[3] Fraunhofer SCAI. MpCCI Website www.mpcci.de, 2016 [online].