Tutorial 4 at MODPROD 2015 Workshop
FMI 2.0 Model Exchange, Co-simulation, and TLM Co-Simulation – Theory and Practice

by

Willi Braun (FH Bielefeld), Petter Krus (LIU), Dag Fritzson (SKF),
Adeel Asghar (LIU), Alachew Mengist (LIU),
and Robert Braun (LIU)

Bring your laptop –hands-on exercises with OpenModelica and Hopsan

Part 1: FMI 2.0 Overview Including Model Exchange and Co-Simulation

Willi Braun

FMI (Functional Mockup Interface), www.fmi-standard.org, is a rather recently developed open standard for model interchange and tool interoperability which simplifies whole product modeling and model-based development. It was initially developed in the ITEA2 MODELISAR project (www.modelisar.org) The first version, FMI 1.0, was published in 2010, followed by FMI 2.0 in July 2014. As of today, development of the standard continues through the participation of 16 companies and research institutes. FMI is supported by over 35 tools and is used by automotive and non-automotive organizations throughout Europe, Asia and North America.

The intention of FMI is that a modeling environment can generate C-Code from a dynamic system model that can be exported to other modeling and simulation environments either in source or binary form.

Models are described by differential, algebraic and discrete equations with time-, state- and step-events. In particular, all Modelica 3.2.2 models are supported and all Modelica variable attributes (like units and display units) as well as description texts can be exchanged. The models to be treated by this interface can be large for usage in offline or online simulation or can be used in embedded control systems on micro-processors. It is possible to utilize several instances of a model and to connect models hierarchically.

A model is independent of the target simulator since it does not use a simulator specific header file as in other approaches. A model is distributed in one zip-file with the extension ".fmu" (Functional Mockup Unit) that contains several files:

- An xml-file contains the definition of all variables in the model and other model information. It is then possible to run the model on a target system without this information, i.e., with no unnecessary overhead.
- All needed model equations are provided with a small set of easy to use C-functions..
- Additional data can be included in the zip-file, especially maps and tables needed by the model.

This first part of the tutorial will give a theoretical overview and introduction to FMI.

Part 2: TLM-Based Solvers, Co-simulation, Theory and Practice

Petter Krus and Dag Fritzson

A single centralized solver is the normal approach to simulation in most of today's simulation tools. Although great advances have been made in the development of algorithms and software, this approach suffers from inherent poor scaling. That is, execution time grows more than linearly with system size. By contrast, distributed modeling, where solvers can be associated with or embedded in subsystems, and even component models, has almost linear scaling properties. Special considerations are needed, however, to connect the subsystems to each other in a way that maintains stability properties without introducing unwanted numerical effects.

Technologies based on bilateral delay lines [3], also called transmission line modeling, TLM, have been developed for a long time at Linköping University. It has been successfully implemented in the HOPSAN simulation package, which is currently almost the only simulation package that utilizes the technology, within mechanical engineering and fluid power.

Petter Krus will first present principles and methods of TLM-based solvers.

Dag Fritzson will present experience of implementing and using TLM for co-simulation at SKF.

Part 3: Hands-on FMI and TLM Exercises with OpenModelica and Hopsan

Adeel Asghar, Alachew Mengist, and Robert Braun

Here you will be able to do hands-on exercises regarding model FMI export, import, and co-simulation, involving the OpenModelica and Hopsan environments.

Short Biographies

Petter Krus is professor in Fluid and Mechatronic Systems and has also held a professorship in Machine Design, both at Linköping University, Sweden. His research interests are in system modelling, and methods that utilises modelling for system analysis and optimization. The applications are in fluid power, aeronautics, automotives and construction machines.

Dag Fritzson is senior Bearing Analyst at SKF and adjunct professor at Linköping University, Sweden. His main interests are in mechanical system modeling and simulation, especially detailed contact analysis. Another strong interest is in practical applications of parallel programming and multi-core technology for heavy simulations. He is one of the main people behind the development of SKF BEAST (BEAring Simulation Tool).

Willi Braun is PhD student at Fachhochschule Bielefeld, Bielefeld, German. He implemented a substantial part of the FMI support in OpenModelica, especially those parts which are integrated with event handling and numerical equation solution.

Adeel Asghar is developer for the Open Source Modelica Consortium, employed at SICEast, Linköping. He implemented most of the FMI 2.0 support in OpenModelica.

Alachew Mengist and Robert Braun are PhD students at Linköping University. Robert implemented the Hopsan FMI support and large parts of the Hopsan TLM support. Alachew participates in the ongoing OpenModelica TLM implementation effort.