

## Interfacing SIMPACK to Modelica/Dymola for multi-domain vehicle system simulations

The demands on vehicle systems increase and their design tends to higher complexity using mechatronic and multi-domain components, that significantly influence the over-all behaviour of the vehicle. In order to represent such a complex vehicle system for simulation purposes the interfacing of SIMPACK with the tool Modelica/Dymola is assumed to be an interesting concept.

This is why a diploma thesis on the feasibility of such an interface, on various implementation strategies and their features has been conducted at Halle University in cooperation with DLR, Daimler AG and INTEC GmbH.

Due to its native capability, a multi-body tool such as SIMPACK is perfectly suited to depict vehicle mechanics, but is not tailored to set up highly accurate physical models of non-mechanical or multi-domain components such as servo-hydraulic steering mechanisms.

That is the background that motivates the implementation of interfaces to tools and methods of other engineering disciplines and in particular to Modelica [2], which is an open, object- and component-oriented language specifically designed to model heterogeneous physical systems. Modelica and its commercial simulation environment Dymola support the implementation of physical equations by graphical user

- » CUSTOMER APPLICATION ..... 01  
*Martin Busch, Martin Arnold, Universität Halle-Wittenberg*  
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Interfacing SIMPACK to Modelica/Dymola for multi-domain vehicle system simulations
- » CUSTOMER APPLICATION ..... 04  
*Francisco Oyague, NREL*  
  
SIMPACK in the NREL Gearbox Reliability Collaborative
- » APPLICATION ..... 06  
*Andrea Paul, VISENSO*  
  
COVISE/SIMPACK interface allows optimized development of multi-body systems
- » SOFTWARE ..... 07  
*Steven Mulski, INTEC GmbH*  
  
Rotor Blade Generator
- » SIMPACK RAIL..... 08  
*Anneli Orvnäs, KTH Stockholm*  
  
Development of Track-Friendly Bogies for High Speeds
- » NEW STAFF..... 10
- » SIMPACK EVENTS ..... 11

interface as well as by ASCII input and offers predefined model libraries from many engineering fields.

Once a model is defined, its system equations are symbolically processed by Dymola in order to generate fully parameterised C-source code.

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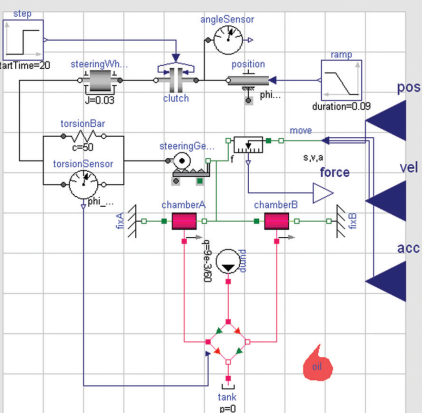


Fig. 2: Model of the servo-hydraulic steering system in Modelica

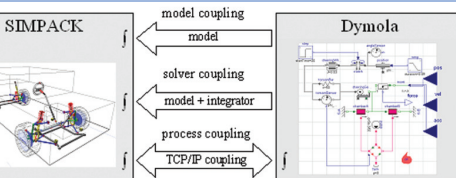


Fig. 3: Different interface approaches of the diploma thesis

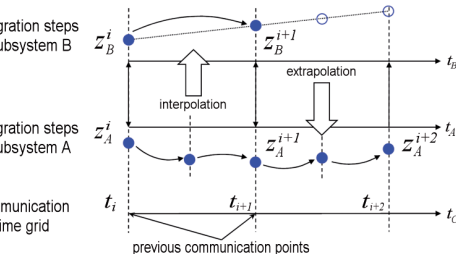


Fig. 4: Interchange of coupling data between subsystems

This C-code may be compiled and executed in Dymola or may be used to define user-elements for other simulation environments such as SIMPACK or Matlab-Simulink.

This was the starting point of a diploma thesis at the Halle University [1] that has been conducted in close cooperation with Daimler AG, Intec GmbH and the DLR Institute of Robotics and Mechatronics that essentially has been contributed to the development of Modelica since 1992.

An exemplary use case, namely a car with servo-hydraulic steering system performing a specific driving manoeuvre, was defined in order to examine and implement three different approaches to couple SIMPACK with Modelica/Dymola. Therefore, a generic SIMPACK vehicle model was provided by Intec (fig. 1), the servo-hydraulic steering system has been modelled in Modelica/Dymola by Daimler AG (fig. 2).

The first interface approach of the diploma thesis is called model coupling (fig. 3). It utilises the physical model equations of the steering system, that have been processed by Modelica/Dymola and are submitted as C-code.

This C-code is then embedded in a SIMPACK user routine that plays the role of a force element. Consequently, the time integration of the coupled system equations is completely performed by SIMPACK and its solver.

For the second approach, the solver coupling (fig. 3), not only the physical model equations are exported from Modelica/Dymola, but the C-code to be embedded in SIMPACK also contains its own time integration routine, which is to be selected out of various fixed-step-solver routines offered in Modelica/Dymola. During time integration the SIMPACK solver calls the user routine with the steering system model in each time step.

The user routine internally performs sub steps according to the set-up of the embedded so called inline-integration solver [3] of Modelica/Dymola.

Since SIMPACK and its variable step-size solver is the master, the communication points, at which the user routine is called and both subsystems interchange information, form a time grid with variable macro steps.

The third approach, the process coupling (fig. 3), is an adaptation of the SIMPACK's SIMAT interface. The time integration is organised in two processes that work in parallel. The SIMPACK solver integrates the model equations of the car, Modelica/Dymola integrates the equations of the steering system. Both processes interchange their integration results via TCP/IP-interprocess communication at communication points that form an equally spaced time grid. Due to implementation restrictions this is the only approach that is capable to consider discrete time events of a Modelica/Dymola model, i.e. of the steering system.

Both co-simulation approaches, the process and the solver coupling, have in common that one subsystem A only has those information on the foreign subsystem B that has been interchanged at previous communication points. However, A may exploit this given information, i.e. the given results of B may be used to approximate the behaviour of B between two communication points (fig. 4).

Therefore it was one issue of the diploma thesis to examine different interpolation or extrapolation methods and their influence on the overall accuracy and performance of the simulation of the complete vehicle system.

The simulation scenario to be presented here starts with an excitation of the steering wheel angle of 180° within "0.5 s".

After "10s", when the car, that moves with constant velocity of 70 km/h, has reached a circular trajectory, the steering wheel is released which corresponds to a vanishing torque at the steering wheel.

This is a challenging scenario with high demands on the robustness of the simulation scheme and is associated with high dynamical loads on the vehicle system.

In Figure 5 the interface variables between the models are shown, that are the displacement and the force of the rack-and-pinion steering. The results of the simulations of the model coupling, the solver and the process coupling are compared. If we consider the result of the model coupling as reference solution, then all coupling approaches calculate the correct solution with only small differences.

As a result of the steering wheel excitation the force signal reflects the feedback of the roll movement of the car body to the steering system.

After releasing the steering wheel the movement of the car is stabilized again to the straightforward driving.

The results of the diploma thesis may be concluded as follows: For subsystems that have similar numerical stiffness properties the model coupling is an easy and robust alternative to co-simulation approaches.

Due to its variable communication step size the solver coupling turns out to be the most efficient one, in particular if it is combined with a first order approximation of the foreign subsystem between two communication points.

This result may motivate an improved implementation of the SIMPACK's SIMAT interface in order to allow for variable communication step sizes in the future.

Anyway, the diploma thesis showed that the coupling of SIMPACK to Modelica/Dymola is a feasible and promising approach in order to perform multi-domain system simulations.

The author of the thesis will continue to work in this field with the Multi-body Dynamics Group of Prof. Dr.-Ing. Schweizer at the University of Kassel.

#### References:

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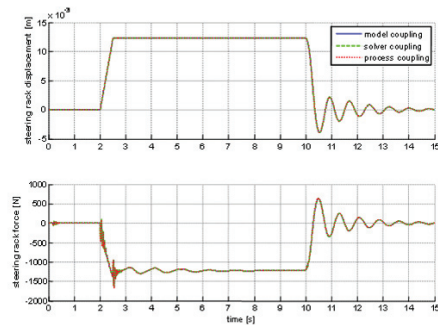


Fig. 5: Simulation results of the methods "model, solver and process coupling"