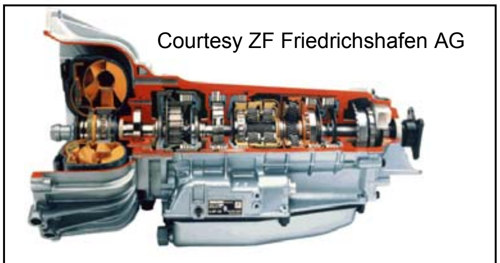
Real Time Simulation with Modelica™

The use of real-time simulation to optimize products and to reduce product development cost and time by hardware-in-the-loop (HIL) simulation for assessment, training and test automation purposes is rapidly increasing. The current need is to simulate increasingly complex physical real-time systems composed of subsystems from multiple physical domains such as mechanic, electric, hydraulic, thermodynamic, and control system components.

Based on the Modelica object-oriented modeling language (http://www.Modelica.org) for multi-domain physical systems it is possible to describe the real-time behavior of large and complex systems by combining re-usable, validated component models from standard libraries in different domains.

One of the primary goals of the EU project RealSim (http://www.ida.liu.se/~pelab/realsim/, Real-time Simulation for Design of Multi-Physics Systems) is to enhance tools for efficient real-time simulation, where Modelica is used as a basis. In order to obtain real-time capability for systems with varying model structure and systems with slow and fast dynamics, special symbolic and numerical model processing and simulation code generation methods have been developed by Dynasim and DLR within RealSim. These methods have been implemented in the modeling and simulation environment Dymola (http://www.Dynasim.se), which supports the Modelica modeling language.


Courtesy ZF Friedrichshafen AG

Varying Model Structure Handling

HIL simulation of automatic gearboxes to optimize gearshift signals of electronic control units (ECU) is a major application dealing with varying model structure depending on whether the clutches in the automatic gearbox are sliding or not. The resulting mathematical model is a mixed system of Boolean equations and differential-algebraic equations with hundreds of unknown variables. There are no general-purpose solvers for such a problem. Dymola incorporates an automatic iterative model translation procedure which generates special code for used combination of configurations. It takes only a few minutes to translate the Modelica model of the gearbox into efficient simulation code. A 500 MHz DEC Alpha processor from dSPACE evaluates one Euler step including a possible mode switch in less than 0.18 ms.

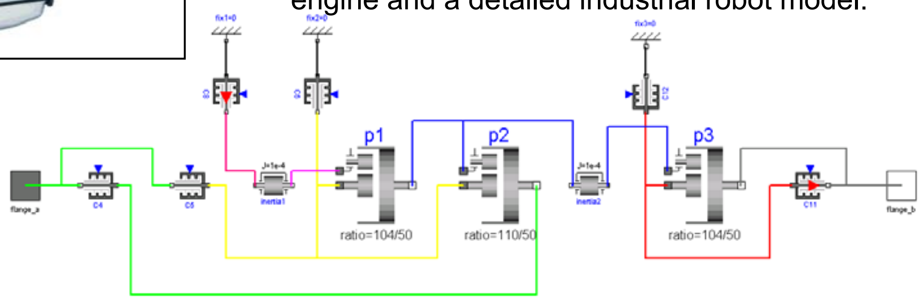
Mixed-mode and Inline-integration

Models have often both fast and slow parts. For example, a model of a hydraulic control system for the automatic gearbox typically introduces fast modes. The problem becomes stiff. Use of explicit methods demand step sizes that are much lower than the given real-time step size. Implicit methods allow larger step-sizes at the cost of solving a non-linear problem at each time step.

A new approach called mixed-mode integration takes a middle course. The system is split up into fast and slow states. Only the fast states are discretized implicitly.

To further increase simulation speed, the concept of inline-integration has been introduced. The discretization formulas are inserted (in-lined) into the problem and the symbolic processing machinery is applied to all the resulting equations.

Speedup factors from about 4-16 have been recorded for applications including a diesel engine and a detailed industrial robot model.



A model of an automatic gearbox is built by composing planetary wheel-sets, shafts, clutches and free-wheels from the Modelica libraries.

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