Real-Time Co-Simulation of Mechanical Systems

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ABSTRACT

In virtual environment representations or more complex virtual prototyping scenarios subsystem models often need to be coupled through non-iterative co-simulation. In these real-time simulation settings the stability of the simulation is typically a key problem. This is particularly related to how information is exchanged between the subsystems. We investigate models where the main subsystem is a multibody mechanical system model, and it interfaces with other domains such as hydraulic or electrical subsystems.

In such co-simulation models the mechanical system simulation usually needs a larger time step to achieve the real-time requirement. In this multi-rate setup the subsystems from other physical domains run at a faster rate with a smaller time step. Information of the mechanical system behaviour can only be available, i.e. transferred, to the other subsystems at communication time points associated with the large, so-called, macro time step of the mechanical system.

A key element in the co-simulation is the information available about the state of the mechanical system to the other subsystems inside the macro time step. We can consider that time points t_i and t_{i+1} define the macro time step for the mechanical system and these represent the communication points with the other subsystems. As t_i is reached the state of the mechanical system becomes known at that time. However, no additional information will be available until t_{i+1}. Most approaches use some extrapolation technique to approximate the state of the mechanical system inside the $[t_i, t_{i+1})$ time interval. The simplest and most common among these is the zero-order hold where the state determined at t_i is kept during the entire time interval. Other higher-order extrapolation techniques can also use more information from time points before t_i, but none of them can really consider the dynamics of the mechanical system inside the $[t_i, t_{i+1})$ time interval. This can have particularly important effect if the mechanical system has a non-smooth character, i.e., it involves unilateral contact, impact, and friction.

We propose a different approach for the solution of this problem. This relies on the use of a simplified, reduced model of the mechanical system inside the macro time step. This reduced model can run at much higher rate and can approximate the dynamics of the mechanical system inside the time step. Based on this approach the state of the full mechanical system model at t_i is used to update the reduced model, which, in turn, will be used inside the time step to interface the other subsystems, and provide information about the dynamics of the mechanical system. We will illustrate this approach with various examples of simulation of machine systems with both smooth and non-smooth physical phenomena.