ECCOMAS Thematic Conference on Multibody Dynamics
June 29 - July 2, 2015, Barcelona, Catalonia, Spain

On the Stability of Explicit and Implicit Co-Simulation Approaches

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Abstract
Applying a co-simulation approach [2], the numerical stability of the coupling method is a crucial point. In the framework of this paper, we consider explicit and implicit co-simulation approaches. The two subsystems are assumed to be coupled by constitutive equations, i.e. we consider the case that the subsystems are connected by applied forces/torques [1, 3]. Coupling approaches based on algebraic constraint equations are not considered here.

The numerical stability of time-integration schemes is defined by Dahlquist´s test equation. From the mechanical point of view, this equation can be interpreted as the complex representation of the equations of motion of the autonomous linear mass-spring-damper oscillator. For analyzing the stability of co-simulation methods, an appropriate test model has to be defined. Considering coupling methods based on constitutive equations, the most usefull choice is the two-mass oscillator shown in Figure 1. This 2-DOF oscillator can be regarded as two single-mass oscillators (masses m_1/m_2, spring constants c_1/c_2, damping coefficients d_1/d_2), which are coupled by the coupling spring c_c and the coupling damper d_c. Therefore, the two-mass oscillator can be considered as two Dahlquist equations, which are coupled by a linear spring/damper system.

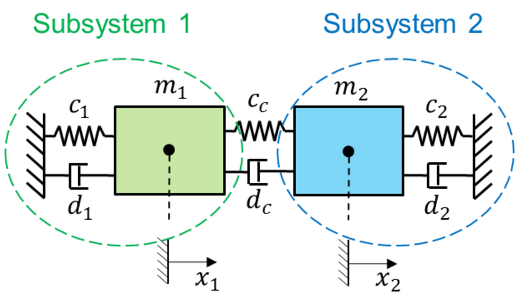

Figure 1: Test model for analyzing the stability of co-simulation methods:
Linear two-mass oscillator.

Introducing dimensionless variables, it can be shown that the co-simulation test model is described by seven independent parameters. By discretizing the co-simulation test model with a linear co-simulation approach, a linear recurrence equation system can be derived, which describes the time discrete solution of the co-simulation approach [4]. The stability of the co-simulation method can easily be determined by calculating the spectral radius of the recurrence equation system. In the paper, stability plots are presented as a function of the seven test-model parameters. Different co-simulation techniques are compared with respect to their numerical stability.

References

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