A general co-simulation approach based on a novel weak formulation at the interface

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Abstract. Co-simulation methods are widely used to enable global simulation of a coupled system via composition of simulators. In this work, the focus is initially placed on a new scheme for the numerical integration of each subsystem, since the corresponding accuracy constitutes a keystone for the correct solution of a decomposed model. Subsequently, the new co-simulation techniques are presented. Specifically, a novel coupling strategy for satisfying the coupling conditions in their integral (weak) form, in the time domain, is proposed. This formulation constitutes a general framework for the generation of coupling condition schemes with varying accuracy and stability properties, based on the choice of basis and order of polynomials for the quantities involved. Finally, the methods presented are applied to a linear oscillator model and a couple of nonlinear pendulum models. Even though the models examined are relatively simple, the methods developed have general validity and can be applied for coupling arbitrary multibody or structural solvers.

Introduction

Co-simulation or solver coupling has already been utilized extensively in numerous engineering fields [1]. The core idea consists in a decomposition of the global mechanical model into two (or more) submodels. The different subsystems are connected by coupling variables, which are exchanged only at the macro-time (or communication) points. Among these points, the subsystems integrate their dynamics independently, using their own solver. Generally, the subsystems are coupled by physical force/torque laws (applied forces/torques) or by algebraic constraint equations (reaction forces/torques) [2]. Furthermore, co-simulation approaches are subdivided into explicit, implicit and semi-implicit methods. Finally, concerning the decomposition of the overall system into subsystems, three different possibilities are distinguished. Namely, force/force, force/displacement and displacement/displacement decomposition [2, 3].

Results and discussion

The new methods were initially applied to a linear oscillator model with two masses, constrained with a fixed joint, as depicted in Figure 1 (a). Then, nonlinear models of a single and a double pendulum were investigated with respect to the new numerical integration and co-simulation techniques, respectively. Within this study, the main emphasis is placed on verifying the accuracy of the schemes proposed. More specifically, a detailed analysis of the convergence and numerical error behavior is carried out in the aforementioned models. Typical results are presented in Figure 1 (b). Even though the models examined are relatively simple, the results obtained demonstrate the validity and accuracy of the new numerical integration and co-simulation techniques. Based on this, the new methods are currently extended and applied to complex structural and multibody dynamic systems.

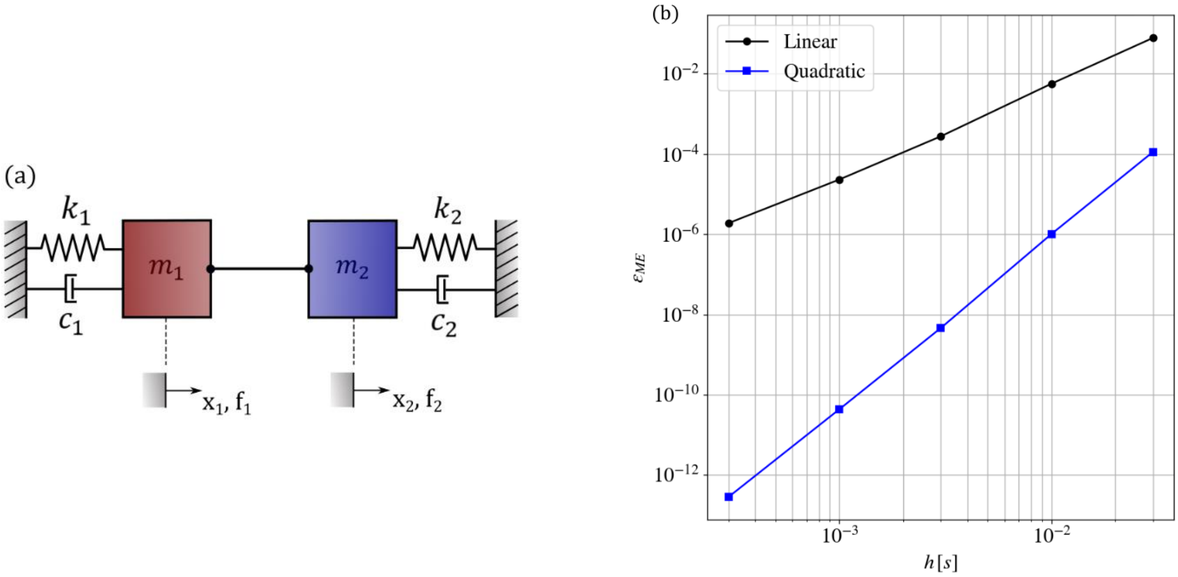

Figure 1: (a) A linear oscillator model and (b) typical numerical results for a nonlinear pendulum model

References

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