Hierarchical Coupling Approach Utilizing Multi-Objective Optimization for Non-Iterative Co-Simulation

Franz Rudolf Holzinger[1] Martin Benedikt[1]

[1]Department Electrice/Electronics & Software, VIRTUAL VEHICLE Research Center, Austria,
{franzrudolf.holzinger,martin.benedikt}@v2c2.at

Abstract

A hierarchical scheduling approach for non-iterative co-simulation is presented. With an increasing number of subsystems the number of possible combinations and permutations increases dramatically, resulting in a unsolvable problem to define a proper co-simulation scheduling for application engineers. This paper shows an approach to get an optimal trade-off between simulation duration and simulation accuracy by the usage of a multi-objective optimization approach to find an optimal scheduling for hierarchical co-simulation.

Coupling Mechanism

The most common used coupling approach for co-simulation is to calculate all sub-models at the same time. Each subsystem has not to wait for each other and so this coupling mechanism has the best simulation performance. Nevertheless, this parallel coupling approach causes the most coupling errors, due to the high number of extrapolated inputs. If subsystems are calculated sequentially, i.e. a subsystem starts the calculation when the previous subsystems already finished the calculation step, no inputs have to be extrapolated. With a sequential coupling approach a minimum number of extrapolation can be reached, but the simulation performance will suffer. A hierarchical approach on the other side allows a combination of sequential and parallel scheduling (see table 1). Several subsystems can be nested, where e.g. the subsystems within a group are calculated in sequential order and the several subsets (group) are calculated in parallel.

Table 1. Real-time capability w.r.t. a HEV example.

Coupling Mechanism	*Real-Time Factor*
parallel	0.44
sequential	1.1
hierarchical	0.5 – 0.75

Optimal Hierarchical Approach

A multi-objective optimization problem with minimisation of number of extrapolated inputs and minimisation of the simulation duration can be formulated as follows:

$$\min\{(1-w)J_E + wJ_D\}, \tag{1}$$

where the factor w enables to set the focus of the optimization to the extrapolation error J_E or to the calculation duration J_D. A small factor w weights the optimization in the direction of the minimum extrapolation error and so sequential calculation is preferred. On the other hand the factor $w = 1$ is the focus on the optimization of the simulation duration and so parallel approach is selected.

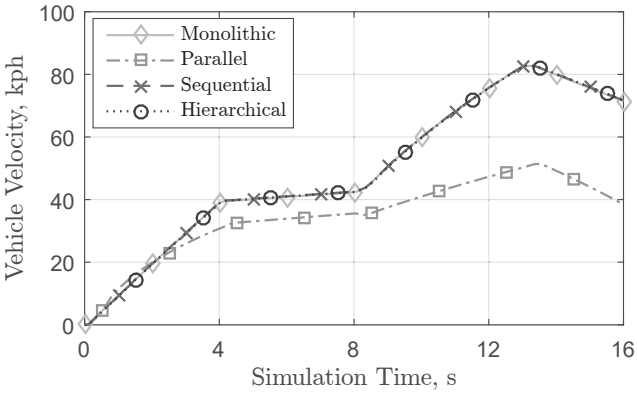

Figure 1. Simulation result (Vehicle Velocity) regarding different coupling mechanisms.

A comparison of sequential and parallel coupling approach (in contrast to the monolithic simulation) is shown in Figure 1. The sequential and hierarchical simulation delivers almost the same results than the monolithic simulation. The results of the parallel coupling approach clearly differ from the reference.

Acknowledgements

This work was accomplished at the VIRTUAL VEHICLE Research Center in Graz, Austria. The authors would like to acknowledge the financial support of the COMET K2 - Competence Centers for Excellent Technologies Programme of the Austrian Federal Ministry for Transport, Innovation and Technology (bmvit), the Austrian Federal Ministry of Science, Research and Economy (bmwfw), the Austrian Research Promotion Agency (FFG), the Province of Styria and the Styrian Business Promotion Agency (SFG).