MISSILES: an Efficient Resolution of the Co-simulation Coupling Constraint on Nearly Linear Differential Systems through a Global Linear Formulation

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In a co-simulation context, interconnected systems of differential equations are solved separately but they regularly communicate data to one another during these resolutions. Iterative co-simulation methods have been developped in order to enhance both stability and accuracy. Such methods imply that the systems must integrate one or more times per co-simulation step (the interval between two consecutive communications) in order to find the best satisfying interface values for exchanged data (according to a given coupling constraint).
MISSILES is a non-iterative method that leads to the same solution than an iterative co-simulation method (IFOSMONDI-JFM [1]), given a few hypothesis.
Through a transformation of the problem, an equivalent linear formulation of the global coupling constraints can be achieved. Hence, a single resolution leads directly to smooth (C1) and non-delayed interface signals satisfying the global coupling constraint of the co-simulation problem.
This method can be used with systems that are not rollback-capable. In other words, systems that cannot integrate more than once a co-simulation step are not a limitation for the MISSILES algorithm. The main underlying hypothesis for this method is that the outputs of the differential systems can be written as a linear expression of the internal states variables and the coefficients of the polynomial of every input. Such a formulation can be achieved with a method based on the transfer function (in the Laplace domain): the COSTARICA[1] process. The later is very reliable on linear systems, and can be corrected regularly according to regular successive linearizations for non-linear systems. As a consequence, applications to multibody mechanical systems are feasible and promising. Regarding non-linear systems, a similar process can at least be used as a convenient predictor for non-iterative co-simulation algorithms as it does not imply integrations of the systems.

[1]Cautiously Obtrusive Solution To Avoid Rollback in Iterative Co-simulation Algorithms

References

[1] Y. Éguillon, B. Lacabanne, D. Tromeur-Dervout, IFOSMONDI Co-simulation Algorithm with Jacobian-Free Methods in PETSc, arXiv, math.NA, 2101.04485, 2021.