A multirate variational approach to simulation and optimal control for flexible spacecraft

Yana Lishkova @ (University of Oxford), Sina Ober-Blöbaum, Mark Cannon, Sigrid Leyendecker

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In this talk we will focus on the advantages of using multirate discrete mechanics for the solution of optimal control problems. Through the example case study of optimal control for flexible satellites we will demonstrate that this methodology can lead to high fidelity solutions at a reduced computational cost.

The methodology, named Multirate Discrete Mechanics and Optimal Control (DMOC), is originally introduced by Gail et al. [1] and tested by means of simple examples whereas its analysis and further development are still open research topics. In this methodology, the description of the mechanical system, as well as the necessary optimality conditions are derived though a multirate discrete version of the Lagrange-d'Alembert principle. The resulting structure-preserving time-stepping multirate equations serve as equality constraints for the optimisation problem and allow for a discrete optimal control problem formulation, which inherits the conservation properties of the continuous-time model. The lower number of time nodes on which some of the generalized coordinates are computed reduces the number of unknowns in the optimisation as well as the dimensionality of the constraints. This results in lower computational cost compared to the single rate method while achieving comparable accuracy in the solution. Further reduction in the computational time and memory usage can be achieved by the exploitation of the resulting sparse structure in the Jacobians of the constraint and cost functions.

As we will demonstrate, this approach also allows for a formulation of the optimal control problem which avoids computation of the momentum during the optimisation process further reducing the number of constraints by half and the unknowns by more than a third depending on the problem. Overall, we will showcase that this approach allows for great customization of the scheme to the time scales of the problem and achieves high computational savings for negligible penalty in the accuracy. These advantages and capabilities of the numerical scheme will be demonstrated through its application for the problem of simultaneous attitude and vibration control of flexible spacecraft.

[1] T. Gail, S. Ober-Blöbaum, and S. Leyendecker, “Variational multirate integration in discrete mechanics and optimal control,” Proceedings of ECCOMAS, 2017, pp. 1–4.