A Toolchain for Solving Dynamic Optimization Problems Using Symbolic and Parallel Computing

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Significant progresses in developing approaches to dynamic optimization have been made. However, its practical implementation poses a difficult task and its real-time application such as in nonlinear model predictive control (NMPC) remains challenging. A toolchain is developed in this work to relieve the implementation burden and, meanwhile, to speed up the computations for solving the dynamic optimization problem after transforming it to a nonlinear programming problem (NLP). To achieve these targets, symbolic computing is utilized for calculating the first and second order sensitivities on the one hand and parallel computing is used for separately accomplishing the computations for the individual time intervals on the other hand.

The toolchain consists of several open-source tools. The Modelica language is used to establish object-oriented models. The Optimica extension serves for the formulation of the optimal control problem. JModelica.org transforms the optimization model to a symbolic optimization model. The automatic differentiation and symbolic manipulations are done by means of CasADi. The interior-point optimizer Ipopt is applied to solve the NLP. The entire approach of the parallelized modified combined multiple-shooting and collocation (MCMSC) method is realized in the Python scripting language using the standard multiprocessing module without any additional software packages.

Two optimal control problems, a satellite control and a combined cycle power plant start-up process, are solved. The efficiency of the developed toolchain, which solves one of the problems with approximately 25,000 variables in a reasonable CPU time, is demonstrated by speed-up factors. A comparison with the collocation approach in JModelica.org is also given.

In general, the larger the NLP and the more CPU cores are available, the greater the advantages of the proposed parallelized MCMSC approach will be.

References

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