Fast Nonlinear Model Predictive Control of Automotive Systems using Multi-Level Iteration Schemes for Multicore Architectures

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Abstract: Recent advances in the area of nonlinear model predictive control have lead to major improvements towards real-time control of nonlinear systems with fast dynamics. The ideas of real-time iterations as presented in [3] for a direct multiple shooting framework were extended to hierarchical multi-level iteration schemes in [2]. The four-level scheme gives ultra-fast feedback on the lowest level by solving small QPs quickly using an online active set strategy. On the second level nonlinear constraints are evaluated to improve feasibility, on the third level the Lagrange gradient is evaluated by adjoint sensitivities to improve nonlinear optimality and on the topmost level the complete derivative information is generated. This approach was successfully used to treat several applications from chemical and automotive engineering. In particular, the disturbance rejection for a fast traveling vehicle using a highly nonlinear Pacejka type tire model was realized in [1].

In this contribution we extend the multi-level iteration approach with respect to efficient application on computers with parallel processing units, as they have become standard in modern computers. In particular, automated strategies for the coordination and distribution of the different update levels to the available CPU cores will be presented. The efficiency and computational performance of this new parallel multi-level iteration scheme is investigated at the example of a simulated race car whose dynamic behavior is not explicitly known. Feedback is generated using a simplified nonlinear model covering the most important dynamic effects.

References

[1] J. Albersmeyer, D. Beigel, C. Kirches, L. Wirsching, H.G. Bock and J.P. Schlöder. Fast Nonlinear Model Predictive Control with an Application in Automotive Engineering. In L. Magni, D.M. Raimondo and F. Allgöwer, editors, *Nonlinear Model Predictive Control, Lecture Notes in Control and Information Sciences 384*, p. 471–480. Springer, 2009.

[2] H.G. Bock, M. Diehl, E.A. Kostina, and J.P. Schlöder. Constrained Optimal Feedback Control for DAE. In L. Biegler, O. Ghattas, M. Heinkenschloss, D. Keyes, and B. van Bloemen Waanders, eds., *Real-Time PDE-Constrained Optimization*, p. 3–24. SIAM, 2007.

[3] M. Diehl, H.G. Bock, J.P. Schlöder, R. Findeisen, Z. Nagy, and F. Allgöwer. Real-time optimization and nonlinear model predictive control of processes governed by differential-algebraic equations. *J. Proc. Contr.*, 12(4):577–585, 2002.

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