Multilevel Iterations for Optimal Feedback Control of Partial Differential Equations

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Abstract: Many spatio-temporal processes in science and engineering are appropriately described by nonlinear, non-stationary PDE models with time-dependent controls. It would be highly desirable to use these control models for a process optimization. However, in the presence of disturbances and modeling errors, the real process will never follow the "off-line" computed optimal solution. Reasons can be e.g. model inaccuracies due to necessary simplifications, uncertain or varying model parameters or unmodelled effects. Remedies for taking these uncertainties into account are improved parameter and state estimates, robust optimization techniques such as worst case optimization, or feedback control techniques. We are interested in computing feedback optimal controls that take these perturbations into account by simultaneous on-line moving horizon estimation (MHE) of the system state and parameters and re-optimization of the optimal control based on the current state and parameter values, as e.g. in nonlinear model predictive control (NMPC). A bottleneck in practical applications is the real time feasible implementation of the algorithm.

One way to substantially reduce the response time are so-called multilevel iterations. For processes modeled by ordinary differential equations (ODE) multilevel iterations reduce the response time by orders of magnitude compared with standard MHE/NMPC methods. However, todays state-of-the-art is to perform MHE and NMPC separately. But for PDE models as well as for large DAE models, neither do the MHE estimates from available data lead to precise information about the complete state and parameter space, nor is this necessary for an efficient, e.g. stabilizing NMPC. Hence, a next logical step is the development of a "simultaneous" MHE and NMPC in one step.

In this talk we present an efficient generalization of existing numerical approaches like multilevel iterations based on coupling of the MHE and NMPC with inexact Newton methods which allows for further acceleration through exploitation of different computational complexities.

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