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Distinguished Lecture

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Nonlinear Programming Frameworks for Real-time Dynamic Optimization

Abstract: Optimization-based operations have long been a goal in process systems engineering. Over the past two decades, effective simultaneous optimization methods have been developed for dynamic optimization models, along with efficient solution strategies. Current practice in real-time optimization (RTO) consists of two layers, with steady state nonlinear programming (NLP) models solved at regular intervals to determine optimal operation. These models provide the setpoints for the faster model predictive control (MPC) layer, whose behavior is determined by linear dynamic models. Implicit in this two-layer structure is a separation of time scales, where disturbance rejection and setpoint tracking can be handled between optimization intervals. On the other hand, the two-layer RTO structure is unsuitable for processes that are never really in steady state, such as batch processes, cyclic processes and continuous processes operate over multiple stages that require frequent transitions. For these processes, a single layer dynamic real-time optimization (D-RTO) approach is needed. Moreover, with the development of efficient strategies for the optimization of differential-algebraic equation (DAE) systems, on-line optimization of dynamic systems can be realized even for large-scale models.

This talk will explore recent results in the development of this single-layer D-RTO framework. To develop this approach, we consider Nonlinear Model Predictive Control (NMPC) as a natural vehicle for Dynamic Real-time Optimization (D-RTO). It can incorporate first principle DAE models and provides compatibility with the controller and dynamic optimization problem, and is readily adapted to handle on-line uncertainties due to noise and process variations. More importantly, stability and robustness properties of NMPC are well understood, and recent work has even extended these properties from setpoint tracking objectives to more general stage costs that are economically based. On the other hand, realization of NMPC requires the application of a fast nonlinear programming (NLP) solver for time-critical, on-line optimization, as well as efficient NLP sensitivity tools that eliminate computational delay and guarantee stability and robustness. Algorithms that meet these demands will be explored and an "advanced step framework" will be outlined for NMPC, state estimation and D-RTO. To demonstrate the dynamic optimization approach, we consider a number of case studies including optimization of chromatographic separation using SMBs, parameter estimation and control in polymerization reactors, and economic-based dynamic optimization for large-scale distillation systems.

Lorenz T. (Larry) Biegler is currently the Bayer University Professor of Chemical Engineering at Carnegie Mellon University, which he joined after receiving his PhD from the University of Wisconsin in 1981. His research interests lie in computer aided process engineering (CAPE) and include flowsheet optimization, optimization of systems of differential and algebraic equations, reactor network synthesis and algorithms for constrained, nonlinear process control. He is an author on over 300 archival publications and two books, and has given numerous invited presentations at national and international conferences. He is the recipient of numerous awards given by AIChE and ASEE, as well as the INFORMS Computing Prize, the Presidential Young Investigator Award from the National Science Foundation, and an honorary doctorate in engineering sciences from the Technical University of Berlin. He is a Fellow of the American Institute of Chemical Engineers and a member of ACS, SIAM, the Mathematical Optimization Society and the National Academy of Engineering.

The scientific community is cordially invited.