NSF-CPS-0930746: Design of Networked Control Systems for Chemical Processes

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Abstract

Traditionally, process control systems rely on centralized control architectures utilizing dedicated, wired links to measurement sensors and control actuators to regulate appropriate process variables at desired values. While this paradigm to process control has been successful, we are currently witnessing an augmentation of the existing, dedicated control systems, with additional networked (wired and/or wireless) actuator/sensor devices which have become cheap and easy-to-install. Such an augmentation in sensor information, actuation capability and network-based availability of data has the potential to dramatically improve the ability of process control systems to optimize closed-loop performance and prevent or deal with abnormal situations more effectively. However, augmenting dedicated control systems with real-time sensor and actuator networks poses a number of new challenges in control system design that cannot be addressed with traditional process control methods, including: a) the handling of additional, potentially asynchronous and/or delayed measurements in the overall networked control system, and b) the substantial increase in the number of process state variables, manipulated inputs and measurements which may complicate the organization and maintenance of centralized control systems as well as impede their ability to carry out real-time calculations within the limits set by process dynamics and operating conditions (particularly when nonlinear constrained optimization-based control systems like model predictive control are used).

To address these key challenges, we have focused on the development of rigorous, yet practical methods for the design of networked and distributed model predictive control systems for chemical processes described by nonlinear dynamic models. Specifically, we have developed a two-tier networked control architecture which naturally augments dedicated control systems with networked control systems. The key idea is the design of a networked controller, via Lyapunov-based and predictive control techniques, which takes advantage of additional, potentially asynchronous and/or delayed measurements, to maintain closed-loop stability and significantly improve closed-loop performance. In addition to networked predictive control, we have developed methods for the design of distributed model predictive control systems for nonlinear processes that utilize a fraction of the time required by the respective centralized control systems to compute optimal manipulated input trajectories and cooperate in an efficient fashion to achieve desired plant-wide performance, stability and fault-handling objectives. We will present applications of the developed networked and distributed predictive control systems to chemical processes and wind/solar energy generation systems using detailed nonlinear models.