“Recent advances in optimization–based state estimation and control of nonlinear systems”

Profitability and safety are central to every decision an engineer makes, from developing a business to operating a single process. Making beneficial process operation corrections based on quantitative measures of these concepts is at the forefront of controller design research. When considering industrial processes this task is further complicated since the presence of state and input constraints, unmeasured states and disturbances is the rule rather than the exception. We responded to these challenges by developing model predictive control (MPC) and its observation dual moving horizon estimation (MHE). The powerful control and estimation methods have been widely applied to chemical, pharmaceutical, and petroleum industries over the past two decades. The control actions in MPC and the state estimates in MHE are computed by repeatedly solving finite-horizon dynamic optimization problems (DOP) on-line as the process evolves. An MHE/MPC structure is thus perfectly suited to tolerate external disturbances, noise and model uncertainty and force the system to follow an optimal path. This resiliency is at the cost of significant computational burden compared to classical controllers (PID) and observers (KFE). Developing an advanced and systematic MPC or MHE synthesis methodology for nonlinear systems thus becomes a daunting task, usually limited to slow evolving or weakly nonlinear processes.

In recent we have attempted to derive MPC and MHE problem formulations that reduce the amount of computation and remove computational delay in solving the DOPs for nonlinear chemical processes. Based on Carleman linearization, we present a method that reformulates the DOPs into nonlinear algebraic ones with analytically derived sensitivity, while preserving the nonlinearity of system dynamics and constraints. This approach markedly speeds up the optimization search since it reduces the errors and computational time that are due to numerical calculation of the sensitivities. The proposed approach is illustrated in the context of MPC and MHE of chemical process examples with significant nonlinearity and disturbances.