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An ongoing journey toward model-based control and optimization in the presence of uncertainties

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Abstract: This plenary talk addresses the general objective of how to control and optimize a process system based on an available model which, in general, describes the actual process behavior in an approximate way. The presence of systematic uncertainties, such as gain errors, poses challenges to model-based control and optimization systems so that without adequate compensation strategies there is permanently suboptimal behavior, such as offset. The talk is meant to guide the audience through the design principles of Model Predictive Control (MPC) systems to cope with the presence of a structural mismatch between the actual plant and the MPC model. The general goal is to asymptotically reach the optimal behavior for the actual unknown plant.
The talk will be structured into two main parts. We start from the case of tracking, linear and nonlinear, MPC to build a general algorithm framework that guarantees offset-free tracking of piece-wise constant set-points in the outputs. To this aim, the nominal model is augmented with integrating states, referred to as disturbances, and a combined state and disturbance observer is consequently designed. We analyze the requirements and opportunities of this disturbance observer and discuss how other approaches, commonly thought to be different, are indeed particular cases of this general approach. In the second part, we focus attention on so-called economic MPC formulations, in which the cost function is not positive-definite around the optimal equilibrium. For this novel class of MPC systems, we present the recent results on offset-free design which includes, in addition to an augmented model as in tracking MPC, a suitable first-order modifier necessary to achieve matching of the necessary conditions of optimality. Computation of such modifiers requires, in principle, knowledge of plant gradient information, and therefore we discuss implementation strategies based on available input-output measurements only. These offset-free economic MPC algorithms are closely related to Real-Time Optimization methods, and hence the necessary lines of conjunction will be drawn.
Several examples of process control systems are presented as case studies to strengthen the main founding concepts and the recommended design practices. We conclude the lecture by sketching future research directions and open problems.

ABOUT THE SPEAKER

Gabriele Pannocchia received a Ph.D. in Chemical Engineering from the University of Pisa (Italy) in 2002, where he has been a Full Professor since 2020. Since 2022, Dr. Pannocchia has been Head of the School of Engineering of the University of Pisa. He held a Visiting Associate position at the University of Wisconsin - Madison (WI, USA) in 2000/2001 and in 2008. Dr. Pannocchia is the author of about 150 papers in international journals, book chapters, and proceedings of international conferences. Dr. Pannocchia is Senior Editor for the Journal of Process Control, served as Associate Editor of Automatica, and is Chair of the IFAC TC 2.4 (Optimal Control). Dr. Pannocchia was IPC co-chair of the IFAC Symposium DYCOPS 2013 held in Mumbai (India), Area Co-Chair/Associate Editor in IFAC DYCOPS 2016, IFAC World Congress 2017, IFAC NMPC 2018, UK Control 2018, IFAC World Congress 2020. He has been a plenary speaker at the 4th IEEE Colombian Conference on Automatic Control, at the 24th International Conference on Process Control (Slovakia), and a keynote speaker at several international congresses (IFAC DYCOPS 2010, IFAC NMPC 2015, IFAC DYCOPS 2016, IFAC ADCHEM 2018). Dr. Pannocchia was the NOC Chair of IFAC ADCHEM 2021 and IPC Chair of IFAC NMPC 2021. His research interests include model predictive control systems, process simulation and optimization, numerical optimization, multivariable systems identification, performance monitoring, and industrial implementations of advanced control systems.