Author: Gaida, Daniel
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Part I

Dynamic Real-Time Optimization

Introduction

In this first part of the thesis three of the four key ingredients of dynamic real-time optimization (RTO) are discussed in detail:

- Multi-Objective Nonlinear Model Predictive Control (MONMPC) (Chapter 2)
- Multi-Objective Optimization Algorithm (Chapter 3)
- State Estimation Method (Chapter 4)
- Dynamic Process Model (Chapter 7)

The fourth item, namely the dynamic process model, is not dealt with in this part, but in Chapter 7.

In **dynamic real-time optimization** a dynamic simulation model is used to develop a predictive control. In general a RTO system is an upper-level control that provides a setpoint to a lower-level control (Engell, 2007). In the upper-level control the simulation model is used to predict the future economics of the controlled plant, whereas an optimization method generates the setpoint, so that future profits are maximized. The lower-level control holds the controlled variable around the given setpoint. Usually the setpoints are created on a medium time-scale (hours to days) whereas the lower-level control acts on a shorter time-scale such as seconds to minutes, cf. Darby et al. (2011).

Multi-objective nonlinear model predictive control is used in the RTO scheme to continually find optimal substrate feed trajectories over a prediction horizon. The objective function usually comprises terms to maximize the profit, minimize the ecological impact, and to maintain the plant stable at all times. Using the model of the process, different feed trajectories can be evaluated, whereas only the optimal trajectory is applied to the real biogas plant for a much shorter control sampling time. Excellent overviews about nonlinear model predictive control can e.g. be found in Morari and H. Lee (1999), Findeisen et al. (2003), Johansen (2011) and Mayne et al. (2000).

Multi-objective optimization algorithms are used to solve the optimization problem stated by the MONMPC. As the optimization problem is nonlinear, the focus is put on global optimization methods, such as multi-objective evolutionary algorithms (Fleming and Purshouse, 2002).

State estimation methods can be used to estimate the system state of a process, if the state can not be measured directly. As this is the case for a typical biogas plant, a state estimator will be an integral part of the dynamic RTO scheme.