A receding-horizon framework for optimal control and estimation of a common class of activated slduge plants

Otacílio B. L. Neto*, Michela Mulas†, Francesco Corona*

Increasing population and erosion of diversity exposes our planet to unsustainable stresses on renewable water resources. We observe an ever-increasing need for food and water to produce it, for drinking water, and for all kinds of water to be used in our society. Rethinking how water resources are managed must be at the forefront of our efforts to ensure their responsible use. Because central in a broad cycle in which water should be replenished at the same rate at which it is extracted from the resources, we are interested in municipal wastewater treatment plants and their use as water resource recovery facilities.

Water resource recovery refers to the selective capture of energy, reclaimed water, and nutrients from otherwise unused wastewater streams [1, 2]. As it alleviates the need for exploring natural resources, this practice is a main lever towards an equitable management of water resources. Being an infrastructure common to most urban areas, biological treatment through activated sludge processes is an important platform for recovering the resources from municipal wastewater. The optimal operation of wastewater treatment plants (WWTPs) have been extensively studied thanks to support tools that provide a simulation protocol for real-world facilities: The Benchmark Simulation Model no. 1 (BSM1, [3]), specifically, singled out as the reference platform for controlling activated sludge plants subjected to typical municipal influents. While the availability of the BSM1 has stimulated numerous control strategies for satisfying regulatory constraints, their performance for resource recovery is still under active research.

We research optimal control solutions to operate WWTPs as efficient water resource recovery facilities [4, 5, 6]. Towards this goal, we present an output model predictive controller that operates activated sludge plants to produce effluent water of specified quality on demand. The proposed controller solves a state-feedback model predictive control (MPC) problem in which the current process state and disturbances are determined by moving horizon estimation (MHE) over noisy measurements [7]. The tracking of the desired effluent profiles is enforced by stabilizing the system around optimal steady-state points that satisfy the output reference trajectories. We specialise the control problem by considering quadratic cost functions and linearisations of the process dynamics around each set-point. Similarly, we consider estimation problems with linearised dynamic constraints in which the initial state, disturbances, and measurement noise, have a Gaussian distributions. We overview the design of the controller, and then we illustrate their behaviour when operating a large-scale plant to produce water and sludge of varying quality. Given the generality of the approach, these controllers can also be configured to achieve alternative goals.

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*School of Chemical Engineering, Aalto University, Finland.

†Department of Teleinformatics Engineering, Federal University of Ceará, Brazil.