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Optimal In-Sensor-Experiments for On-line Model Selection and Parameter Estimation

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Abstract

The typical characteristics of biological wastewater treatment processes – their nonlinear and time-varying nature – impose considerable strains on control systems installed for their optimal performance: time-varying parameters in the process models that are integrated in modern control systems should be updated and the nonlinearity requires that either adaptive linear controllers are applied (with additional adjustment needed to cope with changing operating points) or that nonlinear controllers are devised.

Sensors play a key role in such control loops: They are not only needed to indicate deviations from desired behaviour to the regulator, but they must also provide the necessary data for adjustment of the control laws to the changing process conditions.

The work presented was aimed at developing sensor technology capable of providing this information. Special attention was paid to make sure that this information would be easy to incorporate in the models on which the control system is based. More specifically, a methodology was sought that would facilitate the on-line modelling of the interaction between wastewater and activated sludge. Because it is relatively hard to obtain sufficiently rich information from a plant that operates in closed-loop, a new approach is introduced consisting of what has been termed *In-Sensor-Experiments*. The main characteristic of this approach is that the information on process behaviour is no longer obtained directly from the plant, but from a sidestream sensor in which small-scale experiments are performed which are relevant to the behaviour of the full-scale process. In such sensing device, the excitation signals can be chosen without restriction and, consequently, process behaviour can be characterized under much wider conditions than possible in the treatment plant itself. Hence, if model-based interpretation of the sensor data is applied, rather sophisticated nonlinear models can be identified allowing to devise more elaborate control strategies.

Because the changes in wastewater composition are rather important, *not only the parameters but also the structure of the models* describing the wastewater/sludge interaction are subject to change. Therefore the model identification encompasses both model structure characterization and parameter estimation.

The hardware of the sensor allows to *adjust the In-Sensor-Experiments* in such a way that the highest possible information content is obtained under the time-varying conditions the sensor is confronted with. The *on-line optimal experimental design* (OED) methods that will be presented are the heart of the *Adaptive Sensor Concept*. It will be shown that optimal experiments can be proposed for structure characterization (OED/SC) and parameter estimation (OED/PE).

A very important part of the development work was due to the need to fulfill the real-time requirement imposed by the on-line operation of the adaptive sensor. Real-life experimental results will illustrate the potential of the adaptive sensor concept for the control of activated sludge wastewater treatment plants.