MODEL REDUCTION AND IDENTIFICATION OF WASTEWATERTREATMENT PLANTS – A SUBSPACE APPROACH

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Abstract **--In this paper, a low-order linear time-invariant (LTI) state-space model that describes the nitrate concentrations in both anoxic and aerobic zones of an activated sludge wastewater treatment plant (WWTP), for biological treatment of municipal sewage, is identified around a given operating point (a model with lumped parameters). Several subspace identification methods, such as CCA, N4SID, MOESP and DSR are applied and their performance are compared, based on performance quality criteria, in order to select the best-reduced model. The selected model is validated with a data set not used in the identification procedure and it describes well the complex dynamics of the process. This model is asymptotically stable and it can be used for control, optimization, prediction and monitoring purposes. In this work the ASWWTP-USP benchmark is used as a data generator. This benchmark simulates the biological, chemical and physical interactions that occur in a complex activated sludge plant.**

Keywords **--subspace identification methods, reduced order models, state-space models, activated sludge process, wastewater treatment.**

I. INTRODUCTION

Advanced engineering applications require suitable mathematical models. System identification deals with the problem of obtaining “approximate” models of dynamic systems from measured input-output data. This issue is of interest in a variety of applications, ranging from chemical process simulation and control to identification of vibrational modes in flexible structures. The most traditional system identification techniques are the prediction error method (PEM) and the instrumental variable method (IVM). These methods are primarily used with the so-called black-box model structures (Viberg, 1995). However, several important problems remain to be solved. The PEM has excellent statistical properties provided the “true” PEM estimate can be found. Nevertheless, computing the PEM model can sometimes be overwhelmingly difficult. In general, a multi-dimensional non-linear optimization problem must be solved. On the other hand, the IVM attempts to deliver parameter estimates by only solving linear systems of equations. However, the use of these models is quite cumbersome in the general multivariable case, and the numerical reliability may be unacceptably high for complex cases involving large system orders and many outputs (Viberg, 2002). The preferred model structure for complex problems is therefore a state-space model.

Subspace methods have their origin in state-space realization. Subspace identification method is a technique that has been developed since the late 80’s. It has attracted much attention, owing to its computational simplicity and effectiveness in identifying dynamic state-space linear multivariable systems. These algorithms are numerically robust and do not involve non-linear optimization techniques, i.e., they are fast (non-iterative) and accurate (since no problems with local minima occur). The computational complexity is modest compared to PEM, particularly when the number of inputs and outputs is large. Because applications of large dimensions are commonly found in the process industry, subspace identification methods are very promising in this field. As a result, a large number of successful applications of subspace identification methods for simulated and real processes have been reported in the literature. A general overview of the state-of-the-art in subspace identification methods is presented in De Moor *et a*l. (1999) and Favoreel *et a*l. (2000).

In this paper, a low-order LTI state-space multivariable model that describes the nitrate concentrations in the anoxic and aerobic zones of an activated sludge process is estimated around an operating point. Several subspace identification methods are applied and their performances are compared in order to select the best-obtained model. It can be used to control the process, e.g., as in Lindberg (1997), where a multivariable control algorithm based on a subspace model is used to regulate an activated sludge process. Previous performance comparisons of several subspace methods, applied to other processes, can be found in Abdelghani *et a*l. (1998), Katayama *et a*l. (1998) and Favoreel *et a*l. (1999).

In this work, the ASWWTP-USP (Activated Sludge Wastewater Treatment Plant – University of São Paulo) benchmark (Sotomayor *et a*l., 2001a) is used as a data generator. This benchmark simulates the biological, chemical and physical interactions that occur in a complex activated sludge plant.