A STRATEGY FOR RAPID WWTP PERFORMANCE EVALUATION COMBINING DETERMINISTIC AND BLACK-BOX MODELS

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The performance of wastewater treatment plants (WWTP) can be evaluated by simulating plant behavior over a wide range of operating conditions. Such plant performance evaluations could be useful during the design phase of new plants, during retrofitting of existing plants or in simulation studies of integrated urban water systems. Rather long dynamic influent time series containing a wide range of influent disturbances are needed to allow a simulation-based WWTP performance evaluation of sufficient quality. In practice, the number of scenarios that can be evaluated is mainly limited by the simulation speed of existing deterministic models of the processes in the treatment plant (Ráduly *et al.*, 2005). In this abstract a strategy for rapid performance evaluation is presented, combining an influent disturbance generator with a deterministic WWTP model and artificial neural networks (ANNs). The schematic representation of the approach described is illustrated in Fig.1. The ANNs are trained on a limited sequence of simulated data generated with the deterministic WWTP model, and are aiming at substituting the deterministic WWTP model. Once the training phase is completed, the influent model is connected to the ANN. The influent model contains a number of stochastic elements, and thus enables creating a large set of influent disturbance scenarios (e.g. a number of rainfall events with a broad rainfall depth and duration range), such that a wide range of different influent conditions can be evaluated with the fast ANN model of the plant.

The influent model module (Gernaey *et al.*, 2005), was originally developed as an influent disturbance scenario generator to be included in future extension of the IWA/COST simulation benchmark plant (Copp, 2002; Jeppsson *et al.*, 2004). It includes simple representations of the typical phenomena that are observed in full-scale WWTP influent flow rate, concentration and temperature data: (1) Diurnal phenomena; (2) Weekend effects (e.g. lower pollutant loads); (3) Seasonal phenomena reflecting typical effects from the sewer system and urban drainage, (e.g. increased infiltration in the rainy season compared to the dry season); (4) Holiday periods (e.g. with a lower average wastewater flow rate); (5) Rain events.

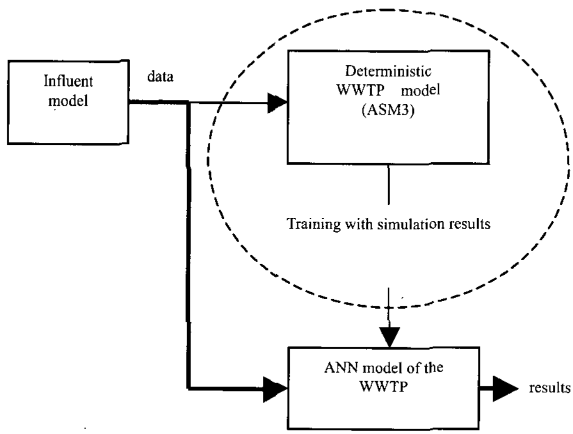

Fig. 1 Scenario evaluation scheme

For the deterministic part of the treatment plant module, the Activated Sludge Model No. 3 (ASM3) (Henze *et al.*, 2000) was implemented in Matlab/Simulink. For this case study, the plant lay-out specifications of the IWA/COST benchmark plant were chosen (Copp, 2002), since it is well-known in the modeling community and it is well-documented too. An ASM3 version of the benchmark plant model was implemented, combining 5 activated sludge tanks in series with an internal recirculation and a one-dimensional 10-layer settler model. Six months of training data – simulation data resulting from the WWTP model coupled with the influent module – was used to train simple back-propagation ANNs to reproduce plant behavior. The trained ANNs can basically be considered as the "model of the model", i.e. a black-box model that gives similar response to the inputs as the original model. The influent module was subsequently coupled with the ANN, and the WWTP processes were thus simulated by the trained ANN for the remainder of the influent time series (20 years of dynamic data). The advantage of applying ANNs is the high simulation speed: in practice simulation time was reduced by a factor of 35, even when including the time needed for ANN training. ANN prediction accuracy was investigated by comparing ANN predictions with simulation results obtained with the deterministic model. Effluent ammonium, BOD_5 and total suspended solids concentration was good when compared to deterministic WWTP model predictions (correlation coefficient > 0.95), whereas prediction of effluent COD and total nitrogen concentrations was less satisfactory (correlation coefficient > 0.80) but still within acceptable limits.

The modeling approach presented here, coupling influent disturbance scenario generation with deterministic and black-box WWTP modeling, enables a rapid evaluation of WWTP performance. The simulation speed of the ANN creates the possibility of treatment plant performance evaluation over a very broad range of influent conditions, which is useful for example in studies aiming at WWTP design or retrofitting. The simulation time reduction is also useful when for example replacing a deterministic WWTP model by the ANN during simulation-based evaluation of integrated urban water system scenarios.

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