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Potential Use of Deep Learning Techniques in Data-driven Surrogate Modelling of Urban Drainage Simulators

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In this research, we investigated the potential application of deep learning (DL) techniques in data-driven surrogate modelling of urban drainage simulators. Surrogate modelling or emulation is a strategy to accelerate the input-output mapping of computationally expensive simulators in order to facilitate applications such as real-time control, uncertainty analysis, calibration, sensitivity analysis and so forth. In this study, the key research question is to define (a/ the) suitable DL technique(s) to emulate urban drainage simulators to accelerate time series predictions with a low accuracy cost. Over the last few years, Deep Learning has applied to many problems, in many cases, DL outperformed the previous work. To the best of our knowledge, the application of DL as a data-driven surrogate modelling method, in which the inputs and outputs of interest are in multivariate time series format is one of the very few attempts been made in the urban drainage modelling domain. We applied both Recurrent Neural Networks (RNN) and its refined version Long-Short-Term-Memory (LSTM) for sequential data (time series) prediction. A small combined urban drainage network in Luxembourg developed in the InfoWorks ICM® simulator was selected as a case study. One-year-long input and output time series data with 10 minutes resolution were generated by the simulator to be used in training and validation of the deep networks. We focused on surrogate modelling for input-output mapping in a combined sewer overflow (CSO) location in the case study. The inputs were including time series of 1) the rainfall within the catchment; 2) daily dry weather flow and NH4 patterns; and 3) the outflow to downstream by a control pump. The output time series to predict were: 1) total wastewater volume at the CSO location; 2) the emitted CSO volume in case of occurrence; and 3) the NH4 concentration at the storage tank. For the quantification of the emulation error, Nash-Sutcliffe efficiency (NSE) and Volumetric Efficiency (VE) between the simulator and emulator (surrogate model) prediction time series were calculated as the loss function. The results showed that, DL training for wastewater quality prediction (NH4 time series in this case) is more challenging in comparison to wastewater quantity prediction, due to the nonlinearity of the sequential data. Comparing both DL methods, the trained RNN outperformed the LSTM network regarding prediction accuracy and loss values for the specific case study in this research.