

Evaluating the Value of Water Demand Forecasts for Real-Time Operation of Water Distribution Networks

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Water distribution networks (WDNs) are critical infrastructure tasked to meet urban water demands and ensure continuous supply. As urban population is rapidly growing, future water demand is expected to further increase, posing new challenges to the optimal design and operation of WDNs. Many recent studies developed different types of water demand forecasting models, including time series models and advanced machine learning. However, a notable gap exists between urban water demand forecasting and the optimal control of WDNs. Predictive models of water demand are primarily evaluated using forecast accuracy metrics, without an assessment of the operational value of water demand forecasts. Most of the literature on WDN control rather rely on assumptions of perfect knowledge of future water demand or approximate it with constant values based on past demands (e.g., average values).

In this study we develop a forecast-informed optimal control framework to evaluate the operational value of water demand forecasts WDNs. We first use water demand data collected for a period of 10 years (2007-2017) at 5-minute resolution from a real WDN in the Netherlands, along with consistent meteorological data, to develop water demand forecasting models. We implement and comparatively test multiple types of predictive models over different forecasting horizons (1/6/12 hours and 1/3/7/14 days ahead), including Seasonal Auto-Regressive Integrated Moving Average with eXogenous factors (SARIMAX), Multilayer Perceptron (MLP), Recurrent Neural Network (RNN), Long Short-Term Memory (LSTM) Networks and Light Gradient-Boosting Machine (LightGBM). We then integrate the best performing water demand forecasts in an economic nonlinear MPC framework to optimize the operations of the WDN. Eight pumps and one valve are controlled in the WDN to minimize pump energy costs in the network while meeting water demands and ensuring safety storage in 5 tanks. Our framework provides a general simulation-based optimization tool to assess the value of demand forecasts on the operations of WDNs. Deterministic forecasts are currently integrated in our MPC setup, while future work will look at integrating stochastic water demand forecasts and different operational objectives.