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Probabilistic forecasting and scenario generation of pumped discharge in polder systems

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The Netherlands is a low-lying country in the Rhine-Meuse delta. Because a large part of the Netherlands is situated below sea level, proper management of local and national waterways is a necessity. Polders are used to manage groundwater levels, drain excess rainwater and store water for droughts. Typically, pumping stations in local Dutch polders pump water up to a drainage canal (in Dutch: 'boezem').

The Noordzeekanaal—Amsterdam-Rijnkanaal (NZK-ARK) is one such drainage canal, receiving discharge from the Rhine and four local water authorities. The canal connects with the North Sea in IJmuiden, through a pumping station and a set of undershot gates. The combination of pump and gate discharge allow the canal to discharge excess water to the North Sea when the sea water level is both higher and lower than the water level in the canal.

Pump and gate discharge is scheduled through Model Predictive Control (MPC), where reliable forecasts are necessary to reliably schedule discharge. The objectives for the control system of the gates and pumps are likely to become more complex in the future. For example, the availability of renewable energy, or electricity prices are to be taken into account when scheduling pump discharge. Research has shown that regular MPC can lead to suboptimal schedules when uncertainty is introduced, for example leading to high energy costs. Stochastic MPC allows for the consideration of uncertainty in decision making, optimising control actions over a set of possible scenario's.

One way of generating these scenarios is by using a probabilistic forecasts. A Quantile Regression Deep Neural Network (QR-DNN) can be used to forecast quantiles of a forecast variable. When enough quantiles are considered, a Cumulative Distribution Function (CDF) can be constructed. A Bayesian Network (BN) is a graph-structured network that can estimate multi-dimensional Probability Density Functions by conditionalizing random variables according to a user defined structure and observed data. The BN can be applied to sample from the marginal CDF's generated by the QR-DNN, while respecting autocorrelation or considering exogenous variables that are not yet considered by the QR-DNN.

In this research, we apply probabilistic forecasting methods to generate pump discharge scenarios

that can be used in a stochastic MPC for the NZK-ARK. We use actual data from the four local water authorities discharging into the NZK-ARK, and apply a QR-DNN to generate marginal CDF's of the expected pump discharge into the NZK-ARK. A BN is then applied to generate scenarios by conditionalizing the marginal CDF's and take multidimensional samples with autocorrelation.