Model predictive control of urban drainage systems: A review and perspective towards smart real-time water management

Model predictive control (MPC) can be used to manage combined urban drainage systems more efficiently for protection of human health and the environment, but examples of operational implementations are rare. This paper reviews more than 30 years of partly heterogeneous research on the topic. We propose a terminology for MPC of urban drainage systems and a hierarchical categorization where we emphasize four overall components: the “receding horizon principle”, the “optimization model”, the “optimization solver”, and the “internal MPC model”. Most of the reported optimization models share the trait of a multiobjective optimization based on a conceptual internal MPC model. However, there is a large variety of both convex and non-linear optimization models and optimization solvers as well as constructions of the internal MPC model. Furthermore, literature disagrees about the optimal length of the components in the receding horizon principle. The large number of MPC formulations and evaluation approaches makes it problematic to compare different MPC methods. This review highlights methods, challenges, and research gaps in order to make MPC of urban drainage systems accessible for researchers and practitioners from different disciplines. This will pave the way for shared understanding and further development within the field, and eventually lead to more operational implementations.

Using the Ensemble Kalman Filter to update a fast surrogate model for flow forecasting

Many cities face issues with rain induced flooding and combined sewer overflows, which can be addressed by using hydrodynamic models. These models are often simplified in a real-time setting to make them faster, and their performance can be improved by using data assimilation. In this study we use the Ensemble Kalman Filter to update a simplified model of a small area of Copenhagen, Denmark. The model is evaluated using perfect rain data for one summer month in 2016, and flow forecasts are used to quantify the performance
of the update. We found that the 1-60 minutes forecast can be improved by updating the model. Having a small noise on the rain gives slightly worse results on a short forecast horizon and slightly better forecasts on a longer horizon. The forecast performance is also dependent on which model parts are updated.

**General information**

Publication status: Published  
Organisations: Department of Environmental Engineering, Urban Water Systems, DHI Water - Environment - Health  
Contributors: Lund, N. S. V., Mazzoleni, M., Madsen, H., Mark, O., Mikkelsen, P. S., Solomatine, D., Borup, M.  
Pages: 710-714  
Publication date: 2018

**Host publication information**

Title of host publication: Proceedings of the 11th International Conference on Urban Drainage Modelling  
Place of publication: Palermo, Italy  
Editor: Mannina, G.  
Keywords: Data assimilation, Surrogate model, Flow forecasting  
Electronic versions:  
UDM18_revisedPaper_133_v2.pdf  
Source: PublicationPreSubmission  
Source-ID: 154486131  
Research output: Chapter in Book/Report/Conference proceeding  
Research: peer-review

**Advancing from underground to above-ground model predictive control in urban drainage**

**General information**

Publication status: Published  
Organisations: Department of Environmental Engineering, Urban Water Systems  
Number of pages: 4  
Publication date: 2017  
Peer-reviewed: Yes  
Event: Abstract from 14th IWA/IAHR International Conference on Urban Drainage 2017, Prague, Czech Republic.  
Source: PublicationPreSubmission  
Source-ID: 137754849  
Research output: Contribution to conference  
Research: peer-review

**From vision to operation - Smart real-time control of water systems in Aarhus, Denmark**

**General information**

Publication status: Published  
Organisations: Department of Environmental Engineering, Urban Water Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, DHI Water - Environment - Health, Technical University of Denmark, Aarhus Water  
Number of pages: 3  
Pages: 2338-2340  
Publication date: 2017

**Host publication information**

Title of host publication: 14th IWA/IAHR international conference on urban drainage  
Place of publication: Prague, Czech Republic  
Publisher: IWA Publishing  
Article number: ICUD-0501  
Electronic versions:  
Lisbeth.pdf  
Research output: Chapter in Book/Report/Conference proceeding  
Research: peer-review

**Model predictive control for urban drainage: testing with a nonlinear hydrodynamic model**

**General information**
Evaluation of Maximum a Posteriori Estimation as Data Assimilation Method for Forecasting Infiltration-Inflow Affected Urban Runoff with Radar Rainfall Input

High quality on-line flow forecasts are useful for real-time operation of urban drainage systems and wastewater treatment plants. This requires computationally efficient models, which are continuously updated with observed data to provide good initial conditions for the forecasts. This paper presents a way of updating conceptual rainfall-runoff models using Maximum a Posteriori estimation to determine the most likely parameter constellation at the current point in time. This is done by combining information from prior parameter distributions and the model goodness of fit over a predefined period of time that precedes the forecast. The method is illustrated for an urban catchment, where flow forecasts of 0–4 h are generated by applying a lumped linear reservoir model with three cascading reservoirs. Radar rainfall observations are used as input to the model. The effects of different prior standard deviations and lengths of the auto-calibration period on the resulting flow forecast performance are evaluated. We were able to demonstrate that, if properly tuned, the method leads to a significant increase in forecasting performance compared to a model without continuous auto-calibration. Delayed responses and erratic behaviour in the parameter variations are, however, observed and the choice of prior distributions and length of auto-calibration period is not straightforward.
**Projects:**

**Optimized real-time management of interacting water systems for a smarter city**
Lund, N. S. V., PhD Student, Department of Environmental Engineering
Mikkelsen, P. S., Main Supervisor
Borup, M., Supervisor
Helwigh, O. M., Supervisor
Madsen, H., Supervisor
Bauer-Gottwein, P., Examiner
Gennari, M. G. C., Examiner
Savic, D. A., Examiner
Samfinansierede - Virksomhed
01/07/2016 → 28/08/2019
Award relations: Optimized real-time management of interacting water systems for a smarter city
Project: PhD

**Prizes:**

**2nd prize winner in Green Challenge at the Technical University of Denmark: Project 817: Reducing overflow to River Aarhus by using MPC - Master thesis, idea category**
Nadia Schou Vorndran Lund (Recipient)
Department of Environmental Engineering, Urban Water Systems

Description
Student conference at the Technical University of Denmark

Details
Awarded date: 24 Jun 2016
Prize: Prizes, scholarships, distinctions