Real Time Updating in Distributed Urban Rainfall Runoff Modelling - DTU Orbit (17/12/2018)

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When it rains on urban areas the rainfall runoff is transported out of the city via the drainage system. Frequently, the drainage system cannot handle all the rain water, which results in problems like flooding or overflows into natural water bodies. To reduce these problems the systems are equipped with basins and automated structures that allow for a large degree of control of the systems, but in order to do this optimally it is required to know what is happening throughout the system. For this task models are needed, due to the large scale and complex nature of the systems. The physically based, distributed urban drainage models (DUDMs) are the most detailed models available of the urban drainage system. They contain a virtual replica of the main parts of the hydraulic system and can therefore potentially be used to estimate the hydraulic conditions anywhere in the system.

In order to produce useful estimates of the conditions in the system the models are highly dependent on the rainfall data used as model forcing. The rainfall estimates from raingauges as well as weather radar are, however, very uncertain for the spatial and temporal scale required for urban runoff simulations. This is especially so for the convective events of the summer. Therefore a method was developed for adjusting radar rainfall estimates using raingauge measurements in areas with an existing dense network of raingauges. The result was much improved rainfall estimates, which proved good enough to allow quantitative overflow modelling.

As with raingauge data the acquisition of online radar data is an economic expense and therefore it is necessary to be able to prioritise whether to invest in one or the other. In a theoretical study the impact of choosing one type of rainfall data over the other for models that are being updated from system measurements was studied. The results showed that the fact alone that it takes time for rainfall data to travel the distance between gauges and catchments has such a big negative effect on the forecast skill of updated models, that it can justify the choice of even very uncertain radar data over raingauge data.

Rainfall estimates will never be perfect and nor will the models. Therefore model estimates will continue to be uncertain. The uncertainty within the models can be reduced by means of data assimilation (DA) that correct the models based on comparisons between model estimates and system observations. The only current existing operational DA method for DUDMs is the Mouse Update tool, which works by correcting the water levels locally in the model at the observed sites. In a case study this simple DA tool proved to have some ability to improve downstream flow forecasts when it was used to update the water level in multiple upstream basins. This method is, however, not capable of utilising the spatial correlations in the errors to correct larger parts of the models. To accommodate this a method was developed for correcting the slow changing inflows to urban drainage systems that relate to infiltrating water. The method works by estimating a linearised version of the model response, which is used to control the correction by the DA scheme in such a way that model stability is ensured without dampening the correction more than necessary. A case study showed that this method can significantly improve a DUDMs forecast ability when a large part of the runoff from a catchment comes from infiltrating water. The proposed method is computationally efficient since it does not require additional model simulations. The method is, however, limited to adjusting the inflow to the hydrodynamic model and is not capable of updating the water levels in pipes and basins explicitly.

The statistical data assimilation method the Ensemble Kalman Filter (EnKF) was investigated as a tool to update all the state variables in a DUDM. The method was tested in synthetic experiments as well as in a real data case study. The results confirmed that the method is indeed suitable for DUDMs and that it can be used to utilise upstream as well as downstream water level and flow observations to improve model estimates and forecasts. Due to upper and lower sensor limits many sensors in urban drainage systems (and elsewhere) do not measure the quantity they are observing continuously. A new method was developed for utilising this kind of range-limited observations better when using the EnKF. The method works by counteracting the ensemble in spreading into to observable range when the lack of observations indicate that the quantity is outside this range. Synthetic experiments using a linear reservoir cascade model showed that the method can significantly improve model forecasts when observations frequently are outside the observable range. An experiment with a simplified DUDM showed that the method is suitable for assimilating range-limited water level observations from an overflow structure. This thesis contributes some important stepping stones towards the online usage of physically based, distributed urban drainage models for both estimation and forecasting purposes. Provided that a good model exists for an urban area with weather radar data coverage, the principles are now outlined for synthesising most of the data from the system into an online model.

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