A generalized Dynamic Overflow Risk Assessment (DORA) for urban drainage RTC

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The urban drainage system in Storm- and Wastewater Informatics (SWI)
The bricks of integrated control

The SWI approach

Radar

Catchment

WWTP

Control Strategy

Rainfall predictions

Runoff predictions

$Q_{\text{max}}$ to WWTP
The Dynamic Overflow Risk Assessment (DORA) control strategy

- Control strategy developed to benefit from outcomes of SWI project
  - Considers uncertainty in rainfall and runoff predictions
  - Consider spatial heterogeneity of rainfall
- Optimizes the system by minimizing a global cost function
  - Possible to prioritize areas of the catchment
  - Possible to add additional objectives (flooding risk, energy consumption, etc.)
Detention basins

- Inflow from upstream \( (Q_F) \)
- Outflow \( (Q_{OUT}) \)
- Inflow from catchment \( (Q_{IN}) \)

Critical volume

- Available volume for storage

Uncertain
\[ V_{B,i} \]

Defined by upstream basin(s)

Controlled by DORA

Inflow-outflow
\[ T_{cr} \cdot (Q_{IN} - Q_{OUT}) \]

Must be maximized

**DORA – definitions (1)**
DORA – definitions (2)

- Runoff volume
- Uncertainty on volume prediction
- Overflow probability
Probability of overflow volume is calculated

Risk is calculated by using a linear overflow-cost function

\[ C_{F,i} = \int_{V_{CR,i}}^{\infty} C(V_{F,i}) \cdot p(V_{F,i}) \, dV_{F,i} \]
\[ \text{Cost} = \sum_{i=1}^{N_{basin}} (C_{cr,i} + C_{F,i} - C_{hor,i}) \]

**Cost due to water already fallen in the catchment**

**Cost due to forecasted runoff**

Discount accounting for qualitative uncertainty
(we don’t know everything about the future)

Forecast horizon, \( T_{hor} \)
Overflow cost function

Overflow cost is defined according to the sensitivity of receiving waters.

Bathing area

Not sensitive
Overflow cost function

Overflow cost is defined according to the sensitivity of receiving waters.

- Bathing area
- Not sensitive

A genetic algorithm finds flows that minimize overflow risk.
A theoretical example
Inspired by Aarhus - Marselisborg catchment
Aarhus – case study
Priority of basins
Analysis of MPC in Marselisborg

- Simplified model
  - Wateraspects (hydrological model)
  - Perfect forecast (same data used for forecast and runoff)

- Analysis based on a 5-year period
  - 25 biggest overflow events simulated

- Four scenarios
  - Default
  - Local control (based on water level in connected basins)
  - DORA without rain forecasts
  - DORA with forecasts
Aarhus – Volume reduction
25 events

CSO volume [thousand m$^3$]
- default
- traditional
- DORA no forecast
- DORA

Total
Aarhus – Cost reduction
25 events
Performance against return period

Cost reduction

Cost reduction [%] vs. Tr [yr]

-50% -25% 0% 25% 50% 75% 100%

traditional
Performance against return period

Cost reduction

Cost reduction [%]

Tr [yr]

traditional

-50%

-25%

0%

25%

50%

75%

100%

0.1 1 10
Performance against return period
Cost reduction

Cost reduction [%]

Tr [yr]

traditional
DORA no for

0% 25% 50% 75% 100%

0 0.1 1 10
Performance against return period
Cost reduction

Forecast worsen situation (1-2 cases)

Cost reduction [%] vs. Tr [yr]

- traditional
- DORA no for
- DORA

Cost reduction: -50% to 100%
Tr [yr]: 0.1 to 10

Forecast worsen situation (1-2 cases)
How does uncertainty in flow prediction affect the MPC integrated control?

Which method for runoff flow prediction gives better results?

Fixed uncertainty bounds

Vs

Dynamic estimation of uncertainty bounds (stochastic models – Löwe et al. Session 1.2)
Can we predict the WWTP capacity in the next hours?

Can modelling of WWTP capacity improve the performance of the system?
**Conclusion**

- A generalized approach for control of urban water system including uncertainty is now available.
- DORA allows the prioritization of discharge points.
- Analysis on a theoretical catchment showed the benefit of global control with respect to local RTC.
- Multi-objectives cost functions can be used according to the major issues in the system (flooding, energy saving, pollution, etc.).
- DORA allows the development of integrated dynamic Model Based Control (SWI concept).

More will come…stay tuned on SWI.
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Performance against return period

Cost reduction

Forecasts worsen the performance?
Event 1995-09-03
Without forecasts

Filling degree

- CB
- MO
- FI
- TR
- HA
- MV
Event 1995-09-03
With forecasts

Filling degree

- CB
- MO
- FI
- TR
- HA
- MV

Filling [%]

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

09:45 14:15 18:45 23:15 03:45 08:15 12:45

Filling degree chart showing various events and their corresponding filling degrees.