Integrating fault detection methods in monitoring wastewater quality

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Summary

- Introduction
- Objectives
- Materials and methods
- Results
- Discussions
- Conclusions and future work

Introduction

- Monitoring water quality:
  - Application of sensors in WRRFs or other systems (rivers, sewers).

River Dommel in Eindhoven

Station pil*EAU*te at Université Laval

Introduction

- Monitoring water quality:
  - Application of sensors in WRRFs or other systems (rivers, sewers).
  - Measurement of several parameters.

NH_4-N

NO_3-N

COD

O_2

T°

TSS

pH

Turbidity

NO_2-N

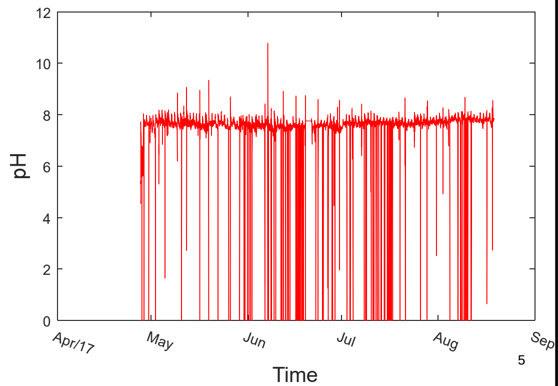
Conductivity

Flow

Introduction

- Monitoring water quality:
  - Application of sensors in WRRFs or other systems (rivers, sewers).
  - Measurement of several parameters.
  - Collection of long time series.
    - Typical loss of data due to problems: 5 – 60 % (Alferes et al., 2013)

# datapoints	1 923 054
Sampling frequency	2 seconds



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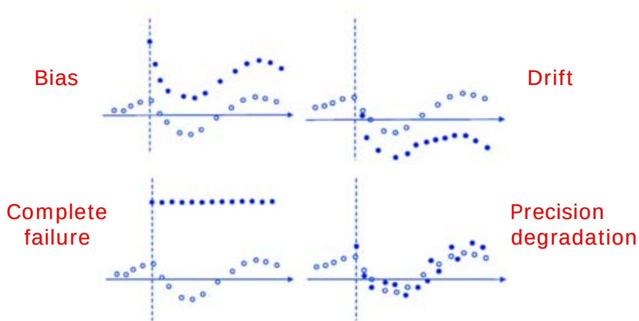

(Yoo et al, 2008)

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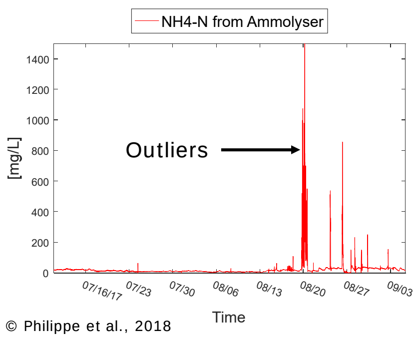
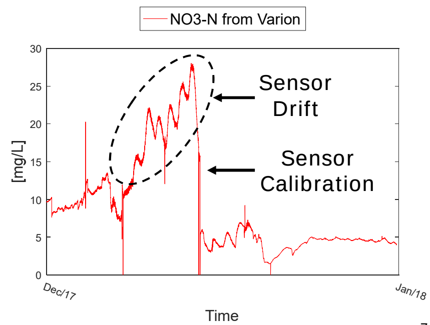




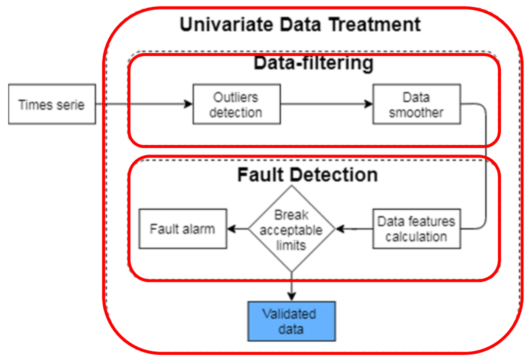
Introduction

- Data management complexity:
  - Many sensors and many variables measured.
  - Collection of long time series.
    - Typical loss of data due to problems: 5 – 60 % (Alferes et al., 2013).
  - Difficulties to identify sensor faults.

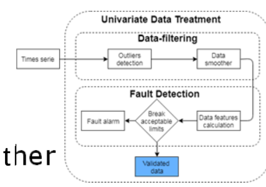
Our solution: A framework to detect outliers and isolate faults to improve data quality.

Materials and Methods

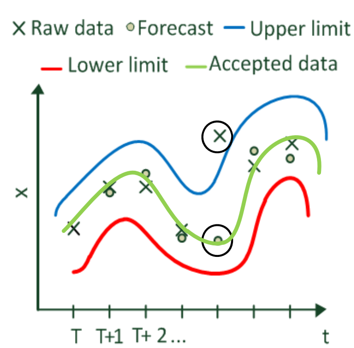
- General and modular Framework.
- Two main steps: Data-filtering and Fault detection.



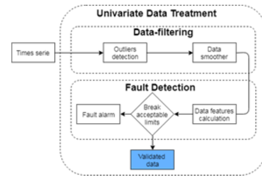
Materials and Methods



- Data-filtering: Outlier detection and Data smoother
  - 11 parameters (4 - 5 parameters to tune).
  - Outlier detection:
    - For each data point:
      - Estimate the average of the signal
      - Compare the observed value to the average
      - Decide whether or not to keep it
  - Data smoother:
    - Moving Average over n points



Materials and Methods



- Fault detection:
  - Scores
    - Sign run-test: Check randomness of error

      $$sign\,(accepted\ data\ - smoothed\ data)$$

    - Slope: Change realistic.

      $$\frac{dx}{dt} \cong \frac{(x_{i+1} - x_i)}{dt}$$

    - Standard deviation: Noise of data.

      $$std = accepted\ data\ - smoothed\ data$$

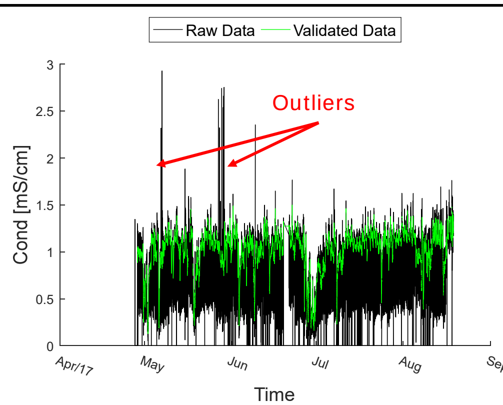
    - Range [Min – Max]: Realistic values.

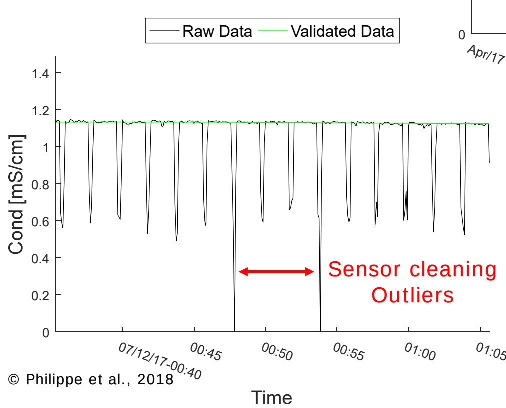
      $$x_i > Max\ or\ xi > Min \rightarrow xi\ is\ a\ fault$$

  - Data validation
    - 8 parameters to tune.

Results

- Conductivity
- WRRF

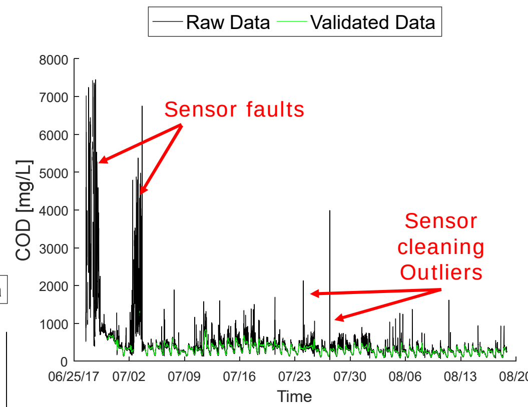


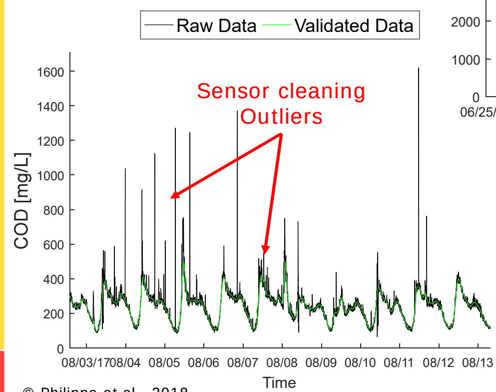


Variables	
# Datapoints	1 923 054
% Outliers	10.53
% Lost data	16.72

Results

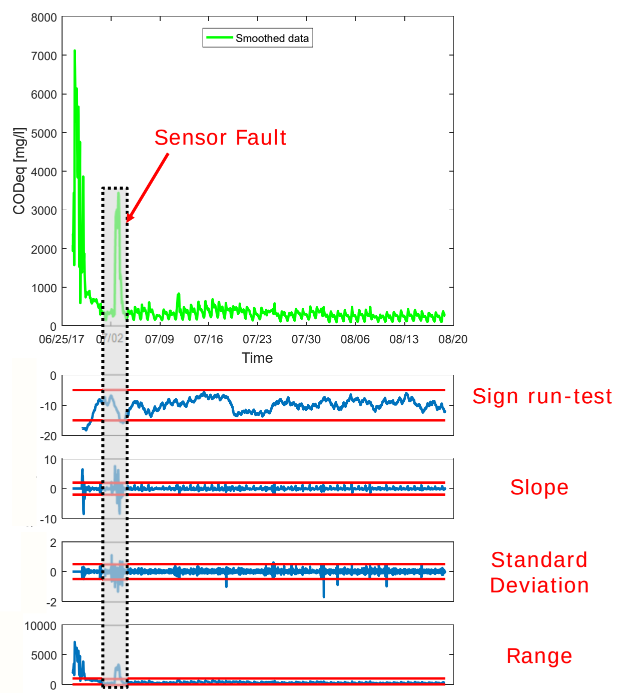
- COD measured by spectrometer
- Sewer system





Variables	
# datapoints	38 347
% Outliers	8.43
% Lost data	16.28

Results



Discussion

- Method: **Modular** and **automated** data filtration and validation.
  - Outlier detection: EWMA, Neural network, Custum-made method.
  - Data smoother: Moving average, Custum-made method.
  - Fault detection: Slope, range, standard deviation, sign run-test, Custum-made test.

- **Good data** :
  - Improve the maintenance (Sensor cleaning): Pro-active maintenance
    - Indicate when the sensor have to be cleaned

Conclusions and future work

- Method: **Modular** and **automated** data filtration and validation
- Parameters to be tuned:
  - Outliers: 11 parameters (4-5 important parameters).
  - Data validation : 8 parameters.
- **Good data** for next stage:
  - Modelling,
  - Control,
  - Pro-active maintenance,
  - Etc.

- Future work:
  - Multivariate data validation (i.e. PCA),
  - Gap filling in time series.

Thank you for your attention

Questions ?

References

Alferes, J., Tik, S., Copp, J., & Vanrolleghem, P. A. (2013). Advanced monitoring of water systems using in situ measurement stations: data validation and fault detection. *Water Science and Technology*, *68*(5), 1022–1030.

Yoo, C. K., Villez, K., Van Hulle, S. W. H., & Vanrolleghem, P. A. (2008). Enhanced process monitoring for wastewater treatment systems. *Environmetrics*, *19*(6), 602–617.