Detecting anomalous air flow-ammonia load ratios, using Gaussian process regression


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Outline

- Problem description
- Gaussian process regression (GPR), short intro
- GPR applied to WWTP
- Detected anomalies in full-scale WWTP
- Conclusions
Problem description

Ammonia load to ASP Bromma WWTP

Ammonia concentration (mg/L)

Time (h)
Problem description

Ammonia load to ASP Bromma WWTP

- On-line ammonia meas.
- Weekly lab analysis
Gaussian process - a stochastic process

$y(x)$
Gaussian process - a stochastic process

\[ y(x) \]

\[ x \]

\[ f(x|\mathbf{i}) \sim GP(m(x|\mathbf{i}), \text{cov}(y(x|\mathbf{i}), y(x|\mathbf{j}))) \]
Gaussian process regression

\[ y(x) \]
Gaussian process regression

\[ \text{cov}(x_i, x_j) = \mathbf{\beta} \exp[-\mathbf{\beta}^T (x_i - x_j)^2] \]
GPR applied to WWTP problem

- Estimate ratio:
  Air flow / ammonia load

- Steps:
  - Select training data
  - Select covariance function
  - Perform regression
  - Evaluate new data based on GPR predictions

- ”Tiny problem”, find suitable hyper parameters. Here, we used a Sequential Monte Carlo approach, marginalising the hyper parameters*

Problem specification

Ammonia load to ASP Bromma WWTP

- On-line ammonia meas.
- Weekly lab analysis
GPR applied to WWTP

Air flow - ammonia load ratio

Air flow (Nm³/h)

Ammonia load (g/s)
GPR applied to WWTP

Air flow - ammonia load ratio

Air flow (Nm³/h) vs. Ammonia load (g/s)
GPR applied to WWTP

Air flow - ammonia load ratio

Ammonia load (g/s)

Air flow (Nm$^3$/h)
Identified anomalies (1/3)

By-pass of active sludge process during storm events
Identified anomalies (2,3/3)

Ammonia load to ASP Bromma WWTP

Drift in ammonia sensor
Identified anomalies (2,3/3)

Ammonia load to ASP Bromma WWTP

Maintenance of digesters, increased sludge conc.
Conclusions

- Gaussian process regression can be a valuable tool for fault detection.
- Estimating hyper parameters is crucial but might not be simple in real applications. Sequential Monte Carlo approach is one solution.
- The proposed method could be improved by including additional sensors, however increased data might reduce interpretability.
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