Improving the identification of nitrogen oxides and ammonia using frequency modulation in sensors via multivariate statistical analysis of sensor data

Thesis Proposal Seminar

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References

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Outline

1. Problem description
2. Data description
3. Research questions
4. Potential methods
5. Potential problems

1. Problem description

Nitrogen oxides - NOx

- Nitric Oxide - NO
- Nitrogen Dioxide - NO2
- Usually produced by **combustion** processes.
- Detrimental for the environment: smog, acid rain, global warming.
- Detrimental for humans: asthma, other respiratory illnesses, heart disease.
- It is desired to reduce the amount of NOx emissions!

Ammonia - NH3

- Can be used to “neutralize" NOx via selective catalytic reduction (SCR).
  - 4 NO + 4 NH3 + O2 => 4 N2 + 6 H2O
  - 2 NO2 + 4 NH3 + O2 => 3 N2 + 6 H2O
  - NO + NO2 + 2 NH3 => 2 N2 + 3 H2O
- Nitrogen gas: harmless.
- Water: also harmless.
- However…

However…
Problem #1

- Ammonia itself is hazardous to the environment.
- Too much ammonia: reduction will occur, but there will be unnecessary ammonia emissions.
- Too little ammonia: reduction will occur partially. NOx emissions will occur.
- Therefore, it is also desired to correctly dose the amount of ammonia dosed into the SCR catalyst.
- How? Via **gas sensors!**
- One upstream of the SCR catalyst, and another downstream.
- They will measure the concentration of NOx at both positions, so that the ammonia can be correctly dosed.
- However…

However…

Problem #2

- Currently deployed sensors cannot differentiate between NO and NO2
  - Its concentrations vary significantly with time
- The sensor is also sensitive to ammonia
- One possible solution…

Temperature cycling

- Different substances depend differently on temperature regarding sensor interaction.
- Changing the sensor operating temperature will change its output signal.
- Sensor signal alone is normally not sufficient: computation of virtual variables (more on that later).
- One way to find individual gas concentrations

Frequency modulation

- Different substances depend differently on sensor operating frequency
- Analogous to temperature cycling regarding differentiation of gas species.
- Main topic of this this master’s thesis.

2. Data description

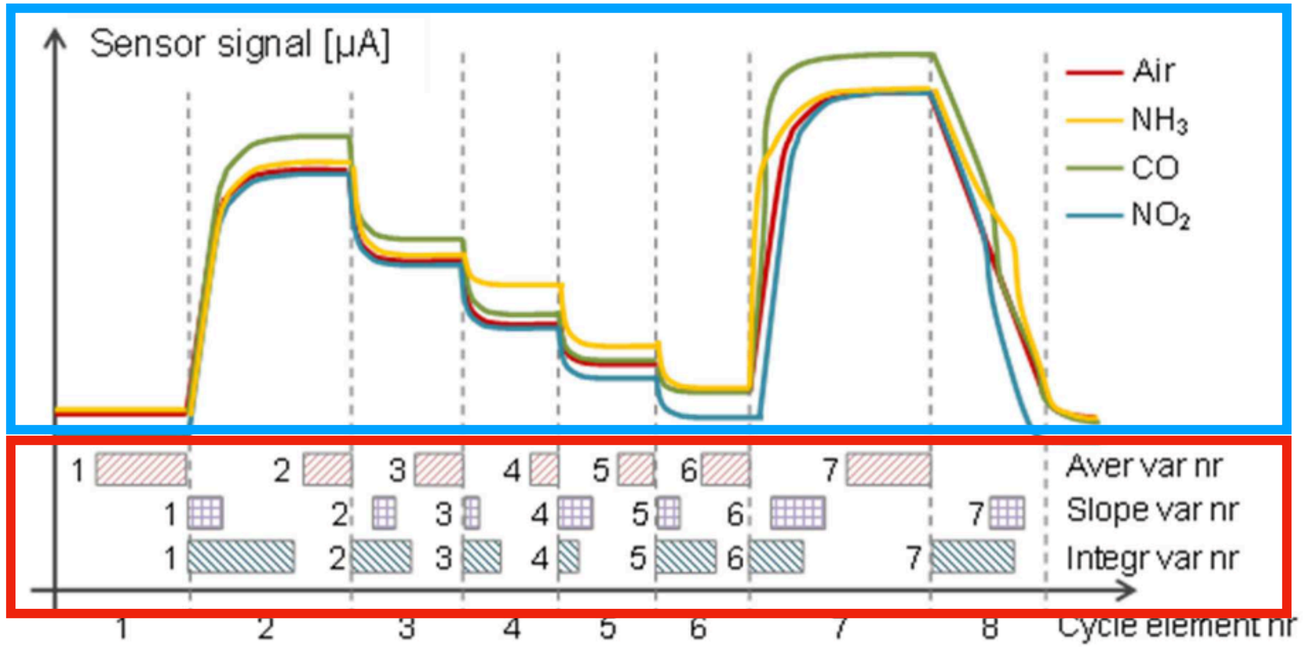
Data description

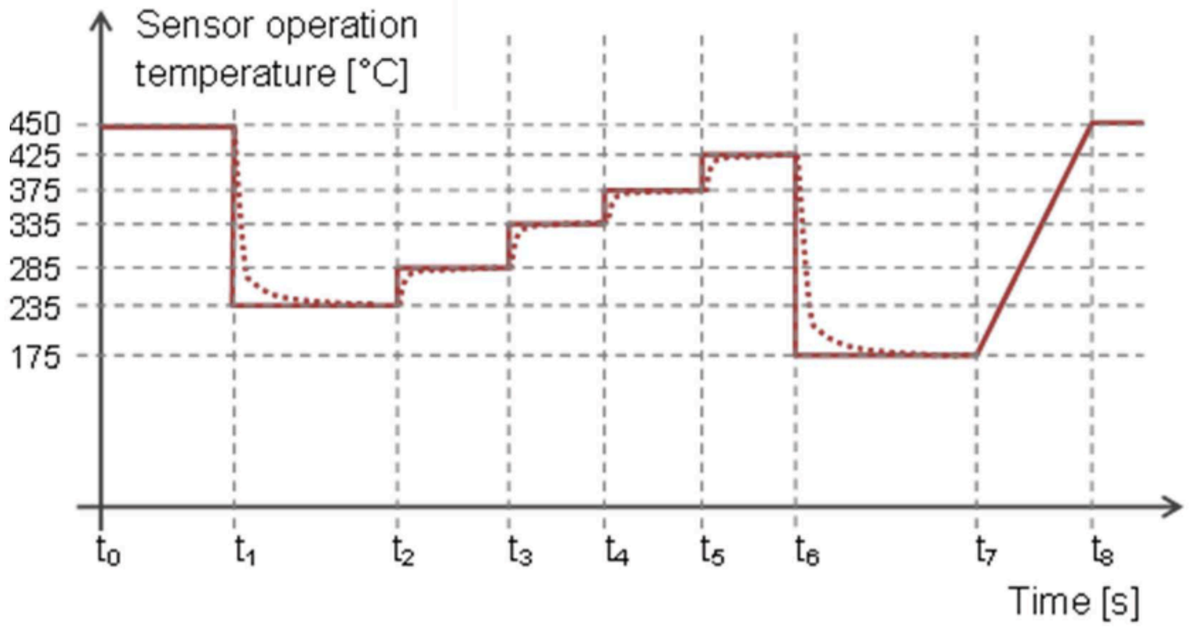
- At the time of submission of this presentation, **data is not yet available**. However, it should be available in the following week (first week of February).
- Experiments are being run.
- Data structure should be similar to temperature cycling experiments.
- Multivariate: Sensor response + “virtual features”.
- Structured, numerical data.

Data structure

Temperature cycling

Cycle nr (Observation)	A_1	A_2	A_3	…	A_n	S_1	S_2	S_3	…	S_n	I_1	I_2	I_3	…	I_n
1				…					…					…	
2				…					…					…	
3				…					…					…	
4				…					…					…	
5				…					…					…	
6				…					…					…	
7				…					…					…	
8				…					…					…	
9				…					…					…	
⋮	⋮	⋮	⋮	…	⋮	⋮	⋮	⋮	…	⋮	⋮	⋮	⋮	…	⋮
k				…					…					…	





- Virtual variables
- Sensor response
- Every cycle has multiple features

3. Research questions

Research questions

Tentative. Might be too ambitious due thesis' time constraints.

- Main question: Can frequency modulation be used to improve simultaneous identification of NO/NO2/NH3?
- Investigate/identify trends regarding the influence of frequency on identification of different gas species.
- Compare results to previous work on simultaneous monitoring of NOx/NH3.
- Investigate a few conceptually different classification methods on gas species separation.
- Try to estimate the effects of the work on reduction of emission in real applications.

4. Potential methods

Potential methods

Tentative. Open to suggestions. Will be updated as soon as data is acquired.

- It all boils down to a regression problem: individual gas concentrations
- Supervised learning: the controlled lab environment allows us to know the ground truth of the gas mixtures
- PCA
- LASSO, Ridge regression, Elastic Net

5. Potential problems

Potential problems

Tentative. Will be updated as soon as data is acquired.

- Sensor drift
- Noise

Thank you