RÉGION SUD PROVENCE ALPES CÔTE D'AZUR

(1) im2np

Institut Matériaux Microélectronique Nanosciences Provence

(2) LIS LABORATOIRE D'INFORMATIQUE & SYSTÈMES UMR 7020

NANOZ

Data Analysis-Based Gas Identification with a Single Metal Oxide Sensor Operating in Dynamic Temperature Regime.

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IARIA

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Thesis on “Ultra-sensitive and selective detection system for indoor and outdoor air quality monitoring.“

Research master's degree on"Microsensor and detection systems" in 2017 at Aix-Marseille University.

Outline

1. Context
2. Methodology
3. Experimental
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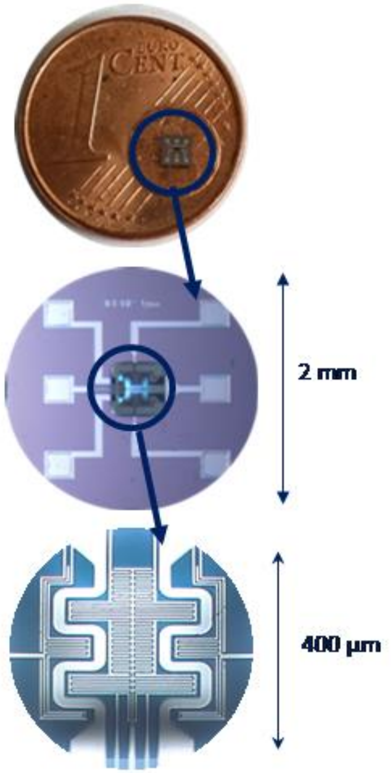
5. Conclusion



Context

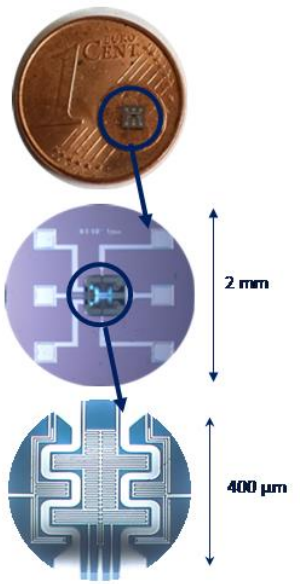
Introduction

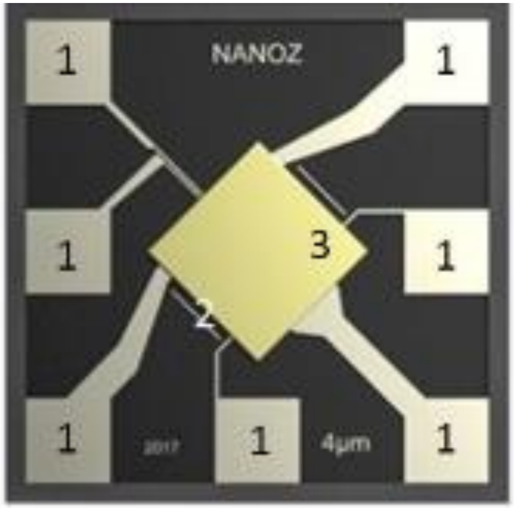
Air quality monitoring in real time.

- Target gases: NO_2, CO, O_3

- Measurement conditions: low flow(100sccm), constant concentration.

- One single MOX sensor.





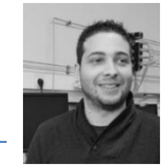
IM2NP-NANOZ sensor device [1]

1- Contact pads.

2- SiO_2 membrane.

3- WO_3 sensing layer covering the two heaters and the four detection zones.

[1] K. Aguir, M. Bendahan, V. Laithier Martini, "Capteur à gaz à couche sensible chauffée", patent N° FR 13 59494, 2013



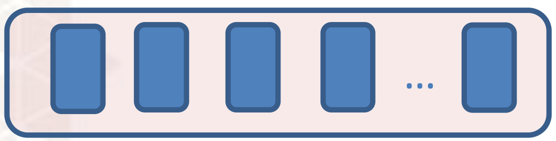
Metal oxide (MOX) gas sensors

Purpose

- ❑ High sensitivity
- ❑ Stability
- ❑ Attractive life time
- ❑ Low-cost

- ❑ **Low selectivity**

multi sensors array



Each sensor specializes in a target gas. Few parameters to be used (recovery time, response time, sensitivity…)

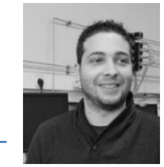
Improvement selectivity

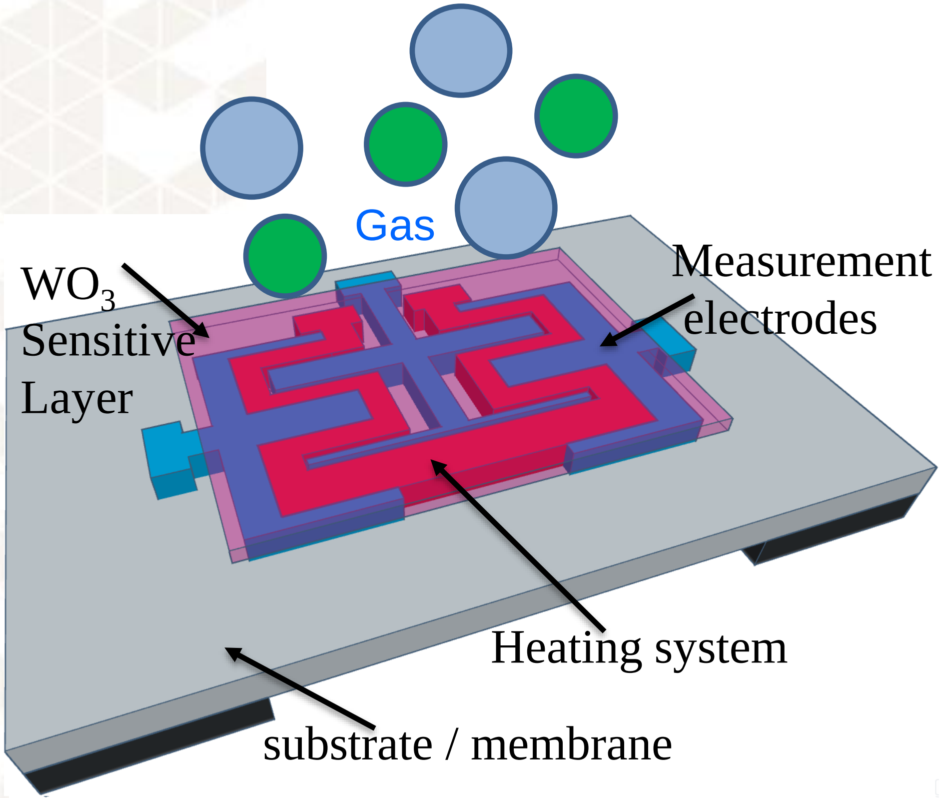
one single sensor

Only one sensor ➔ change sensor parameters (polarization, temperature ...) ➔ obtain several different information for each gas.

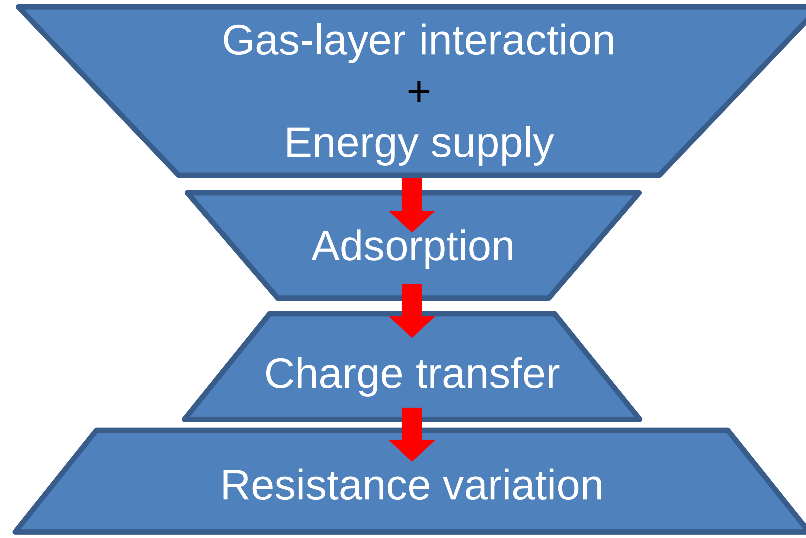
Multivariable analysis

Context

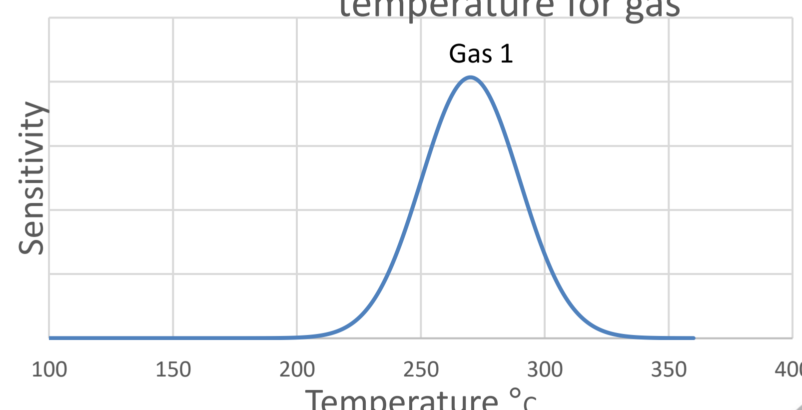




MOX gas sensors



sensor sensitivity as a function of temperature for gas



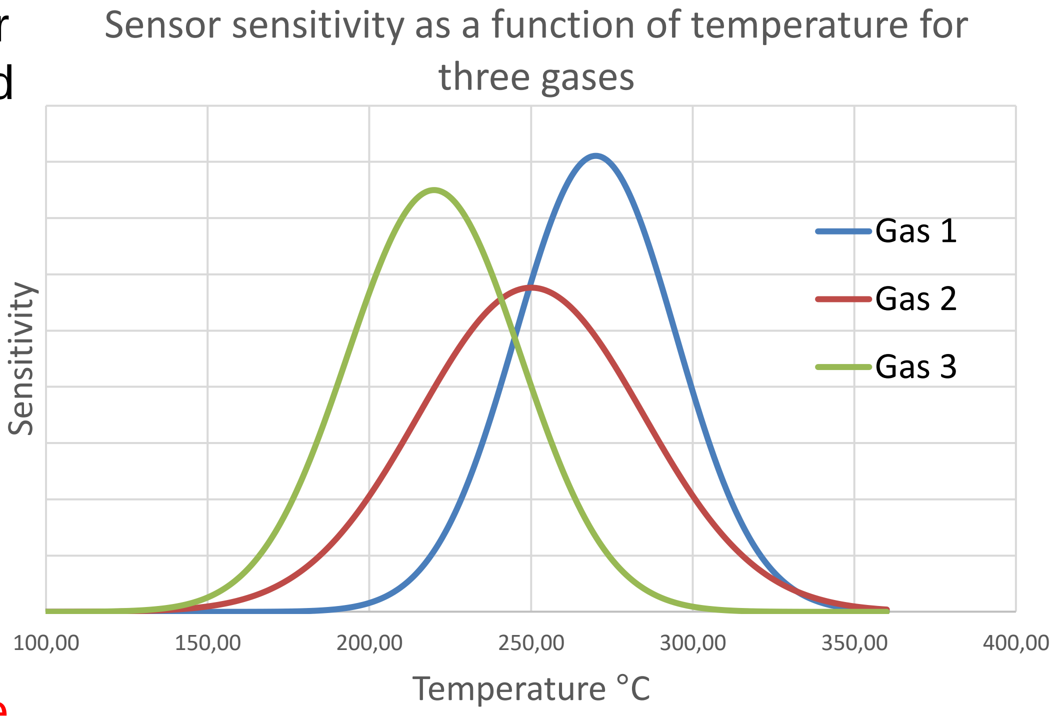
temperature affects response:
-allows gas absorption and desorption
-for a targeted gas, the sensitivity presents a maximum depending on the temperature.

Context

Importance of temperature

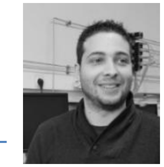
What is the advantage of temperature modulation for a single sensor?

- For each gas, the temperature for which sensitivity is maximum, and the value of this maximum are different.
- A sensor working at several temperatures ⇔ several sensors working at a single temperature.



Temperature modulation gives more information with a single sensor.

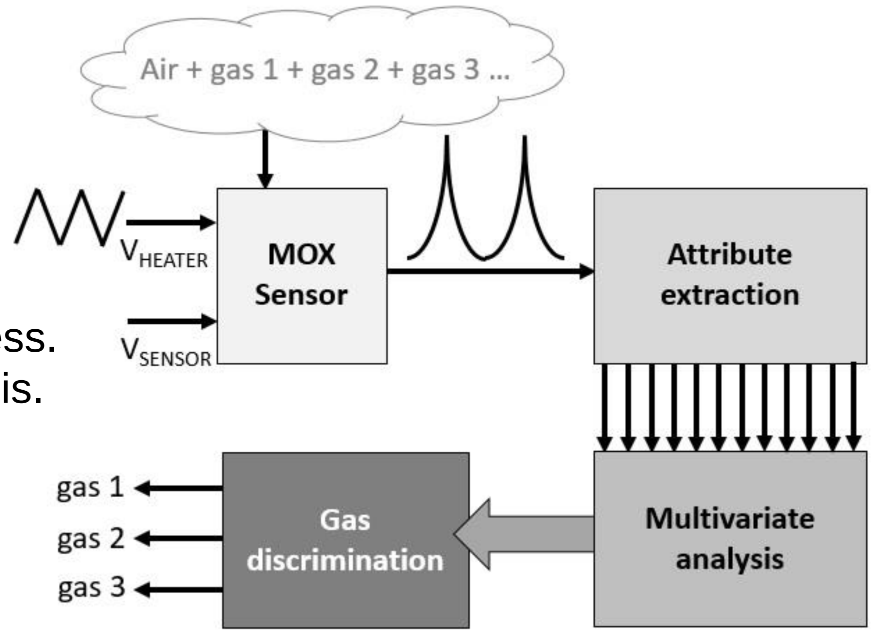
Methodology



Methodology

- Create database.

- Increase the database by extrating the temporal attributes of the obtained signal.

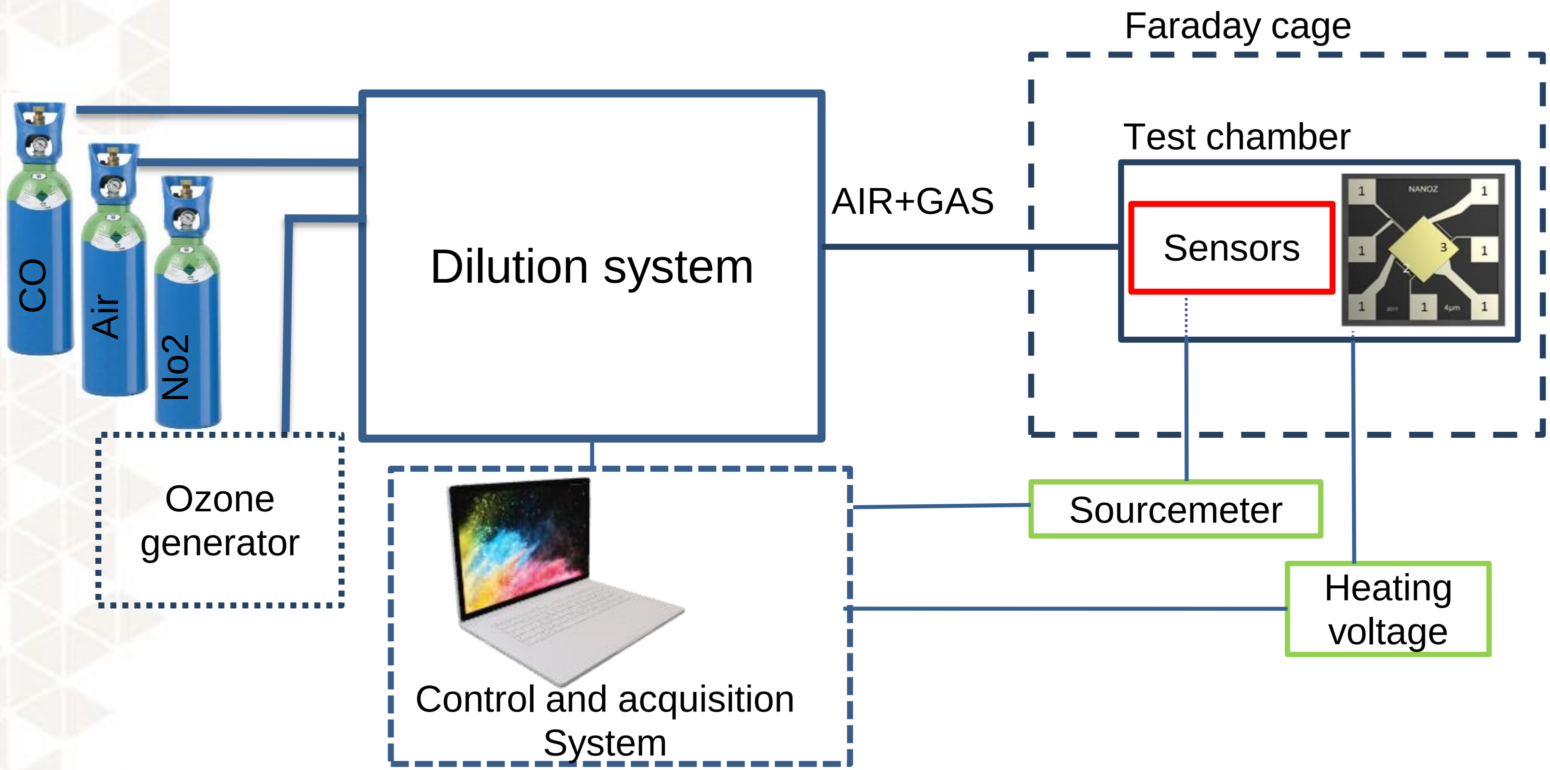


- peak to peak value.
- mean value.
- RMS value.
- the third standardized moment called skewness.
- the fourth standardized moment called kurtosis.
- the crest factor.
- the shape factor.
- the variance.

- Use principal component analysis to extract only useful information.

Experimental

Test bench



- ➔ Concentration range: 20 ppb to 20 ppm.
- ➔ The gas concentration from gas cylinder is controlled by flowmeters, valves and mixer.
- ➔ The WO_3 thin sensing layer was deposited by reactive magnetron RF sputtering.

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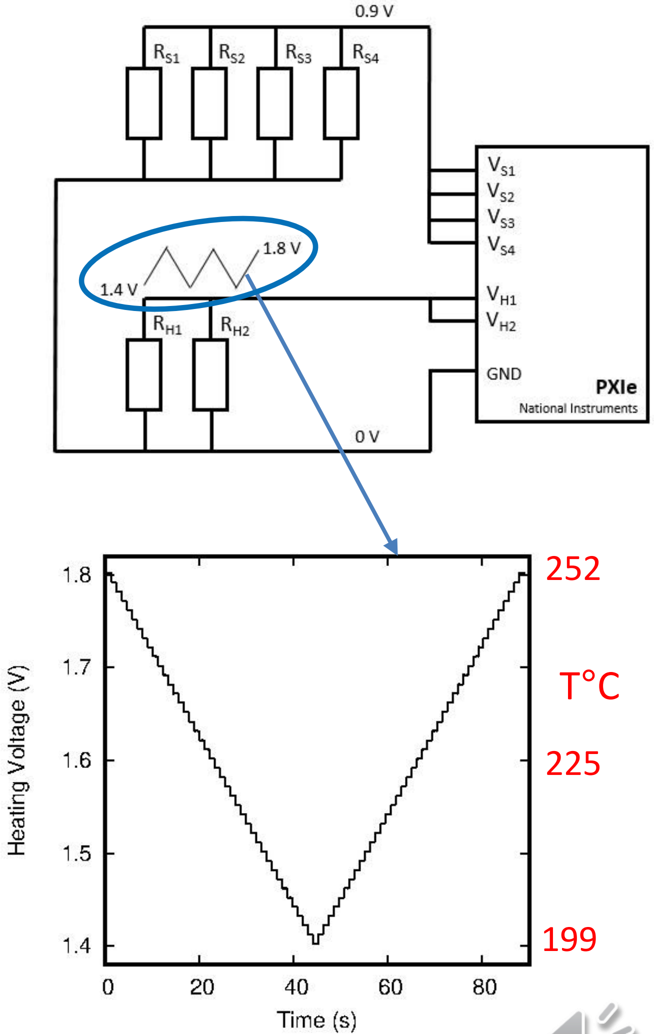
Experimental

Protocol

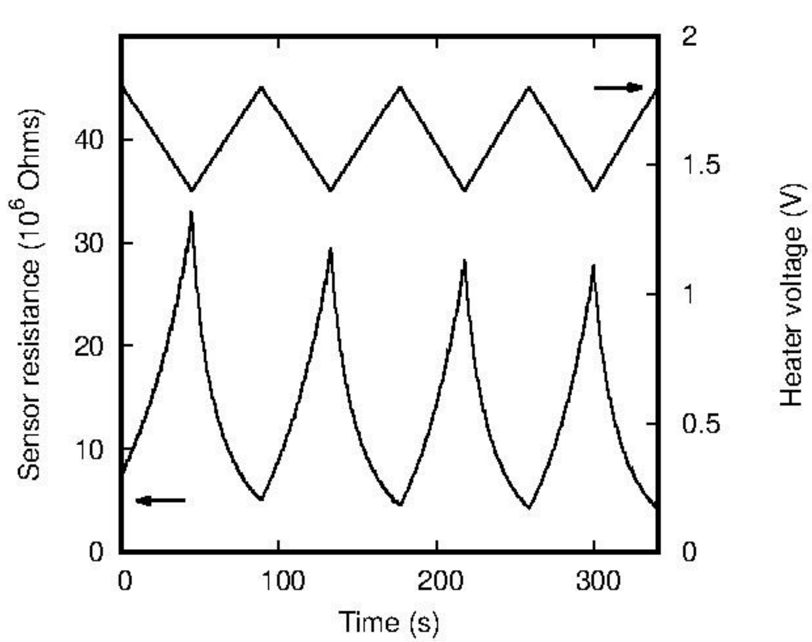
- The sensor device has two distinct heaters and four detection zones offering several operating modes in single or multi-sensors.
- The two integrated heaters are powered by a staircase waveform which varies sensor temperature from 199°C to 252°C.
- The temperature variation between each step is 1.3°C and the duration of each step is 1s with 10 measurements/s.

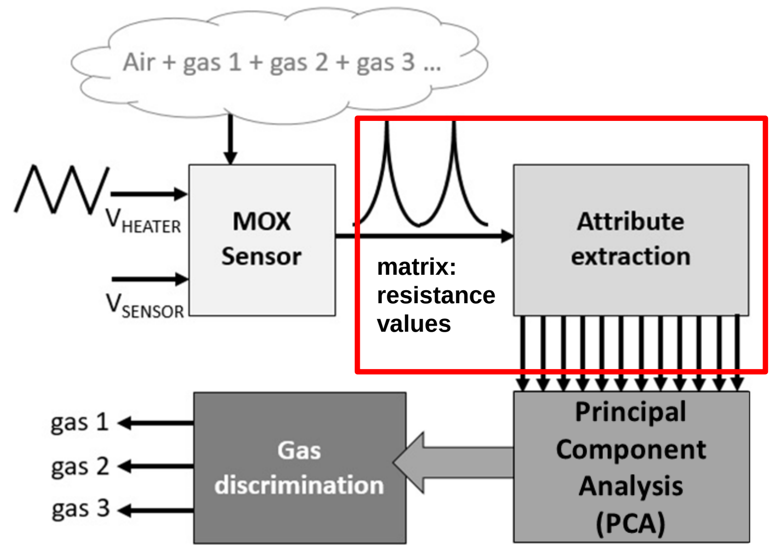


Results

Creation of database

Sensor response to triangular temperature variation.
Example for 160 ppb of O_3.





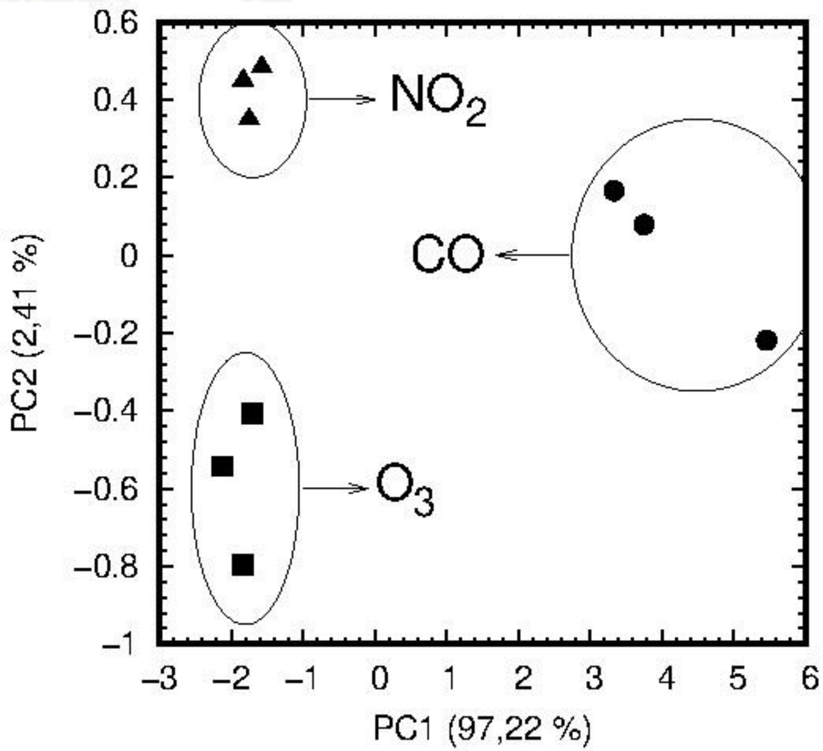
The gas microsensor was exposed to 3 concentrations of three different gases characteristic of the air quality.

Gases	Concentrations		
	C1	C2	C3
NO_2	200 ppb	400 ppb	800 ppb
O_3	80 ppb	110 ppb	160 ppb
CO	2 ppm	8 ppm	16 ppm

The proposed gas discrimination method is based on the characterization of the temporal attributes of the signal including statistical parameters.

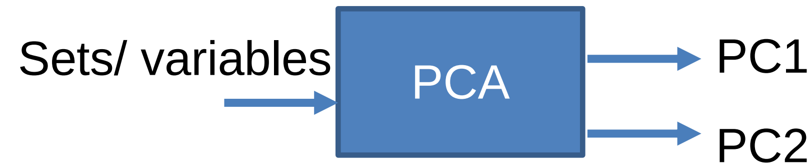
Results

The ability to discriminate several gases is evaluated by the principal component analysis (PCA):



Reduced using principal component analysis

PCA is a commonly used unsupervised and robust pattern recognition approach for analysis of multivariable data.



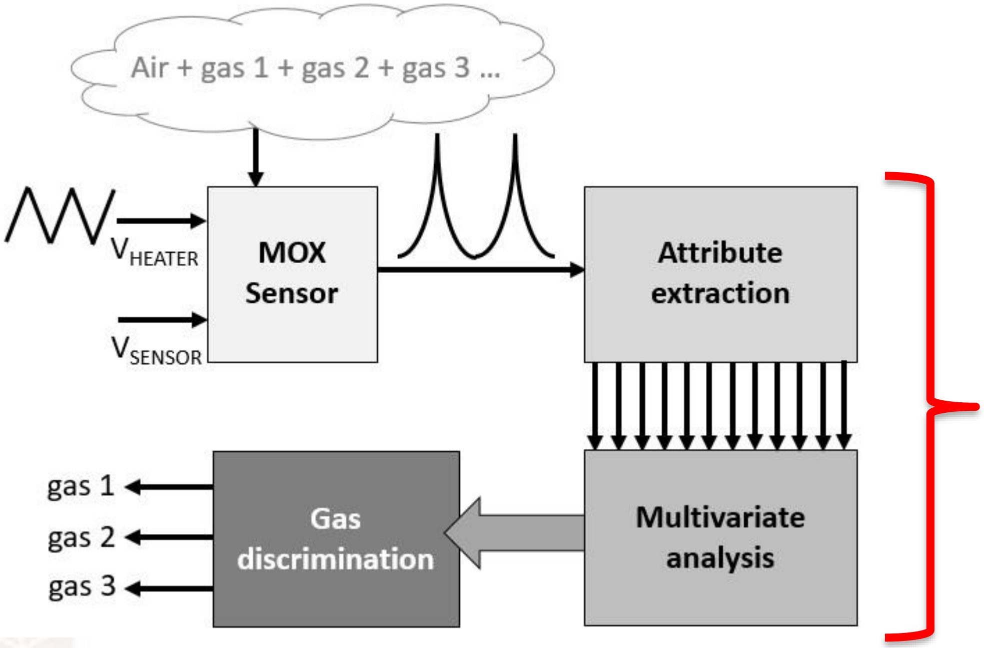
Sets: gas concentrations
Variables: temporal attributes

3 separate zones: one zone by gas

A clear discrimination is possible between the three studied gases **using one single sensor**.

Conclusion

Conclusion of the study



- Temperature modulation
- Database
- Extraction temporal attributes
- Reduced using PCA
- Gas discrimination

The PCA multivariable analysis method, applied to all data, has shown that it is possible to discriminate NO_2, O_3 and CO using one single MOX sensor.

Current and future works: Increase the database by adding more gas concentrations and mixing the gases with each other and with humidity. Apply and test classification algorithms such as Support Vector Machines, k Nearest Neighbors or Neural Networks.

Conclusion

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Thank you for attention