Odour Environmental Monitoring and E-nose Classification: Standards and Laboratory Experimental Procedures

Tutorial

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Tutorial Objectives

- Understand what an odour is from a scientific perspective
- Introduce electronic noses (e-nose)
- Analyze the role of multivariate analysis
- Present standards and methodologies
- Describe laboratory experimental procedures

Ettore Massera

- Physicist – 27+ years of professional activity
- Expert in chemical sensors, IOMS and electronic noses
- Active contributor to UNI, CEN, ISO and IEEE SA

Italian National Agency for New Technologies, Energy and Sustainable Economic Development

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Part 1 – who am I

Advanced Technologies Applied to Air Sensors

- Solid-state gas and particulate sensors
- Nanostructured materials for air quality
- Artificial olfaction and IOMS systems

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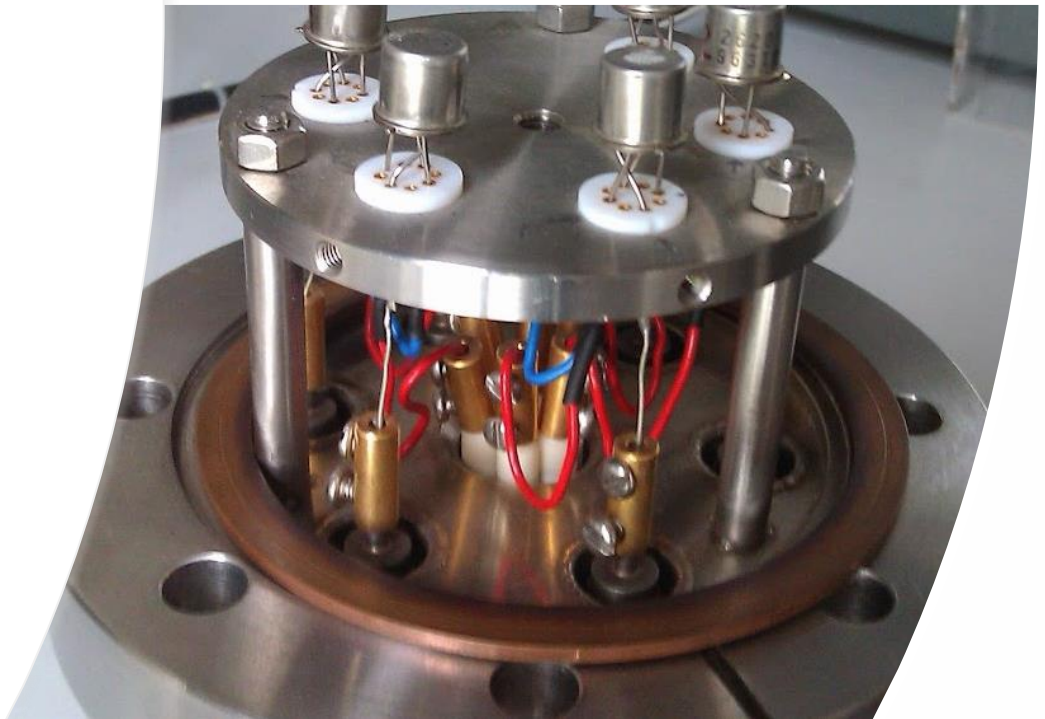
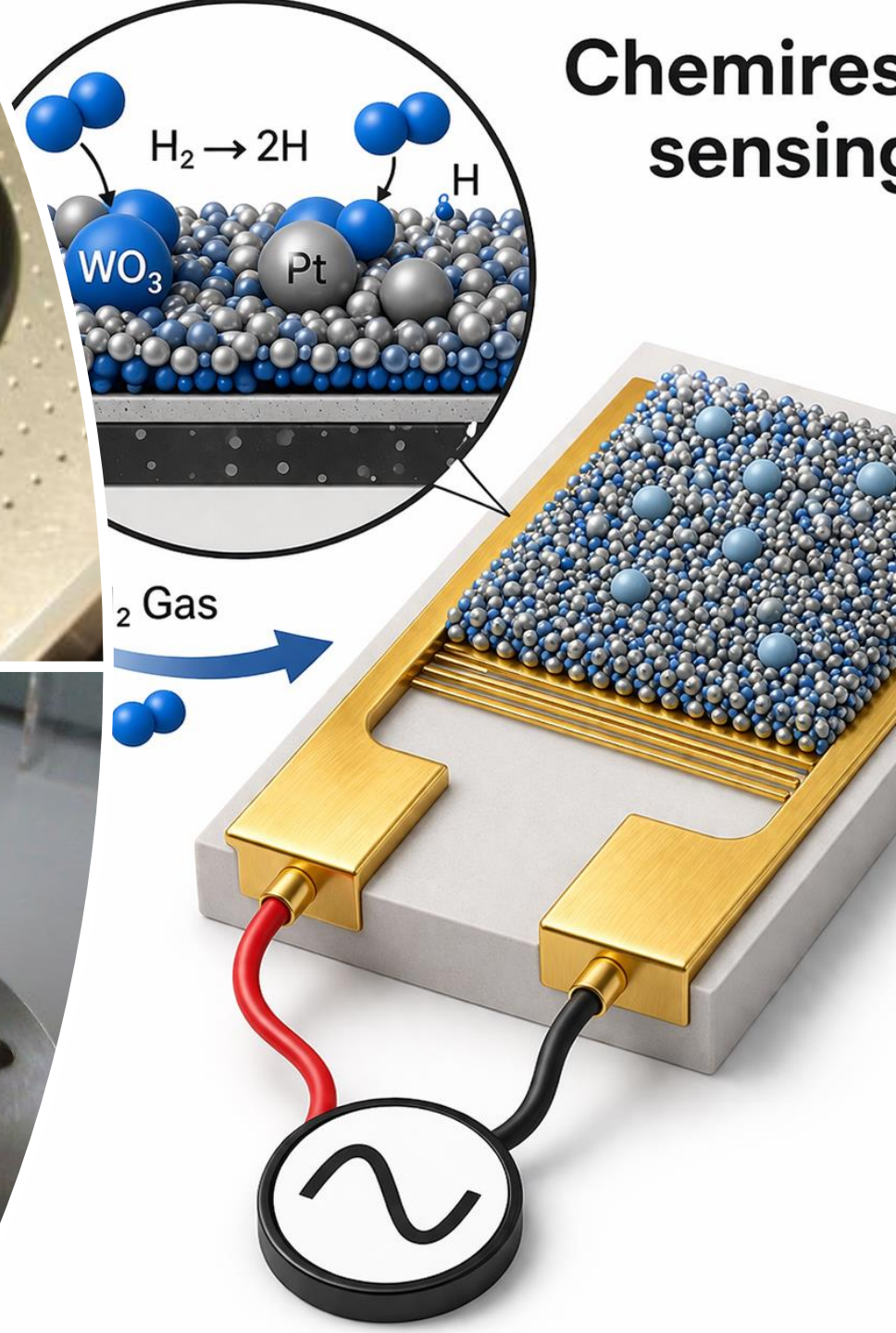
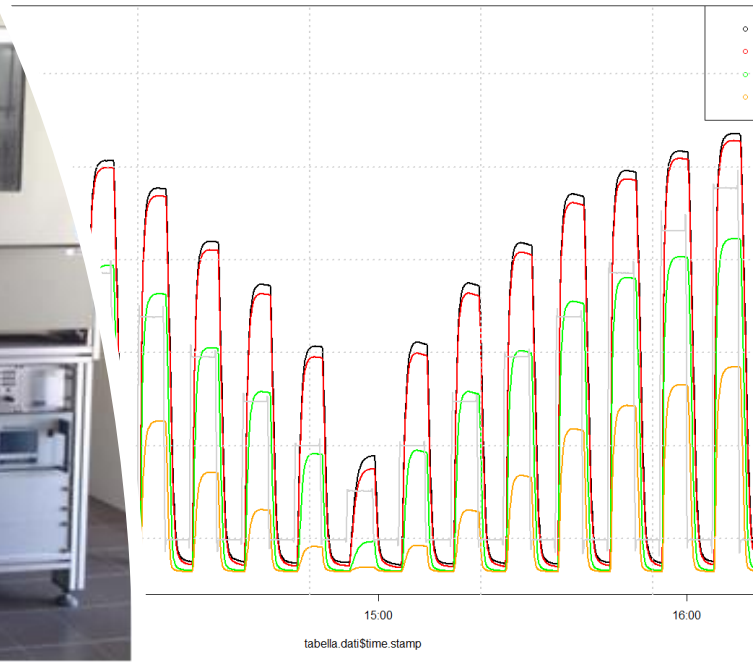




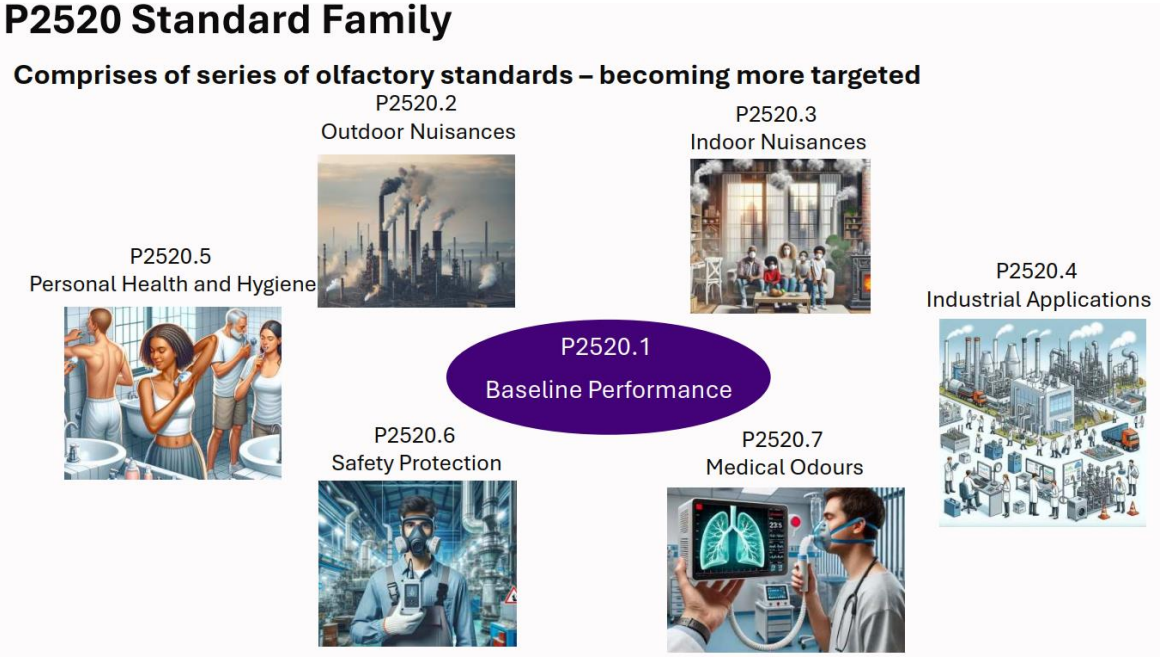
Facilities and Activities

- Controlled atmosphere sensor characterization
- Semi-analytical instruments (GC-IMS, LCR, GDS)
- Low-TRL research with experimental validation
- Projects on IOMS classification and sensor metrology



Role in ISOEN 2026 Tutorial

- Link between IOMS technology and standards
- Experience in odour detection and monitoring regulations
- IEEE SA P2520.1 and EN 13725 alignment
- Key question: Artificial vs human olfaction



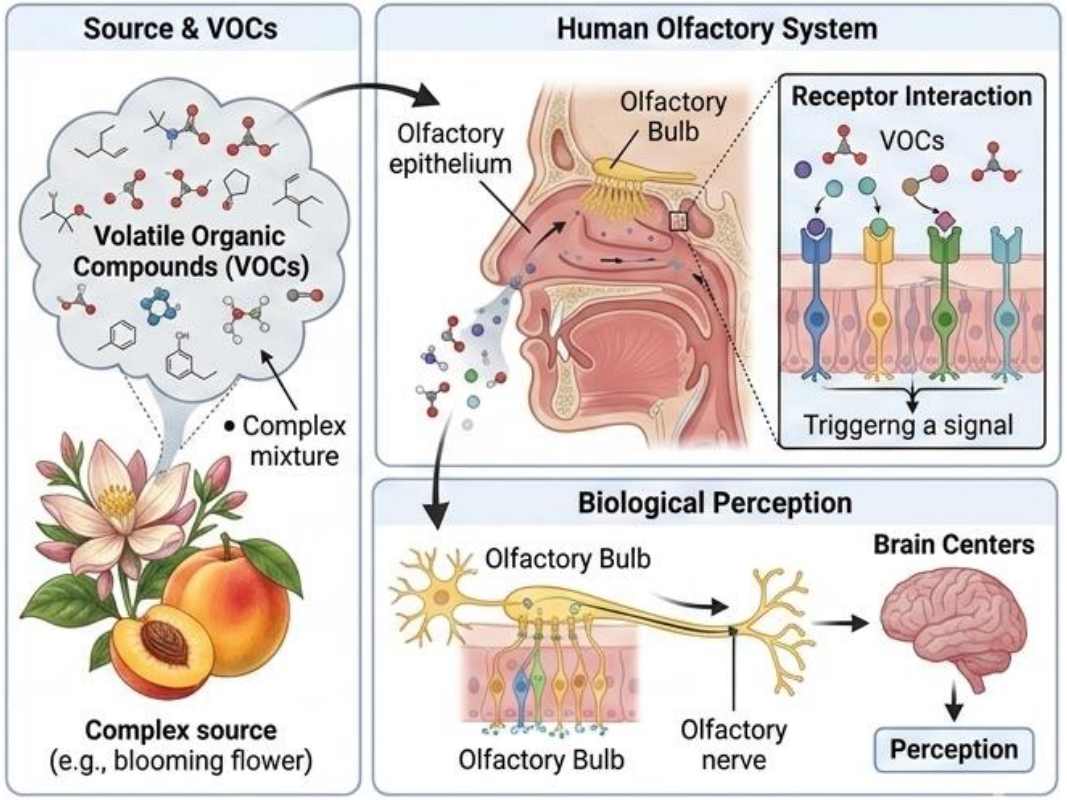
The Environmental Problem

- Odorous emissions (industry, waste, agriculture)
- Impact on quality of life
- Difficulty of continuous monitoring
- Limitations of traditional methods (human panels)
- 👉 Need for automated and reliable instruments

What is an Odour?

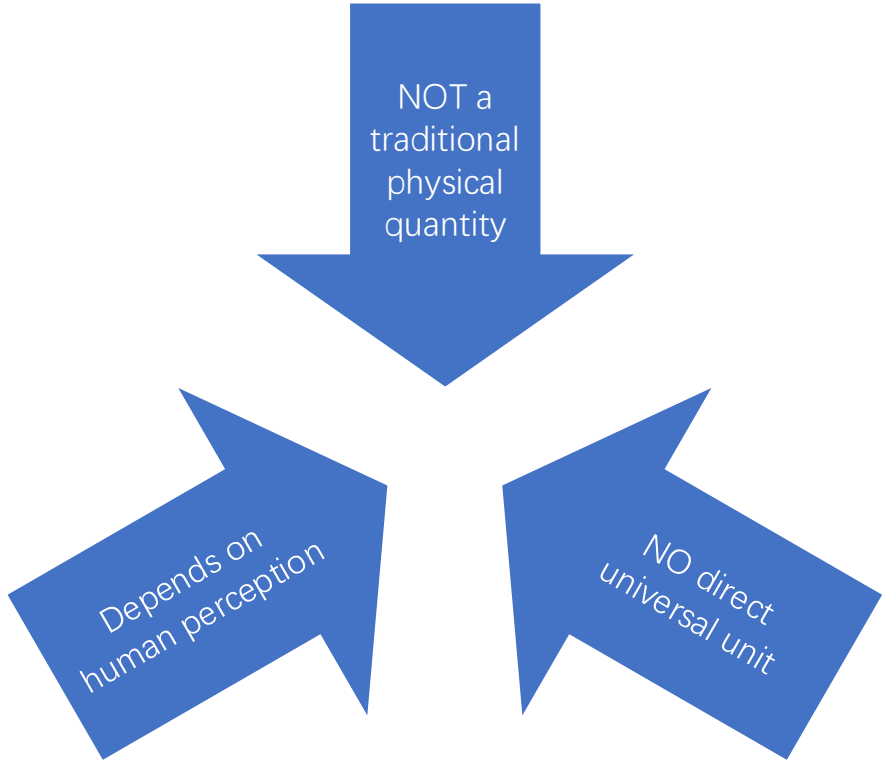
- Complex mixture of volatile compounds (VOCs)
- Interaction with the human olfactory system
- Subjective perception

→ Odour = combination of chemical phenomenon and biological perception



First Key Concept

Is odour a measurable quantity?

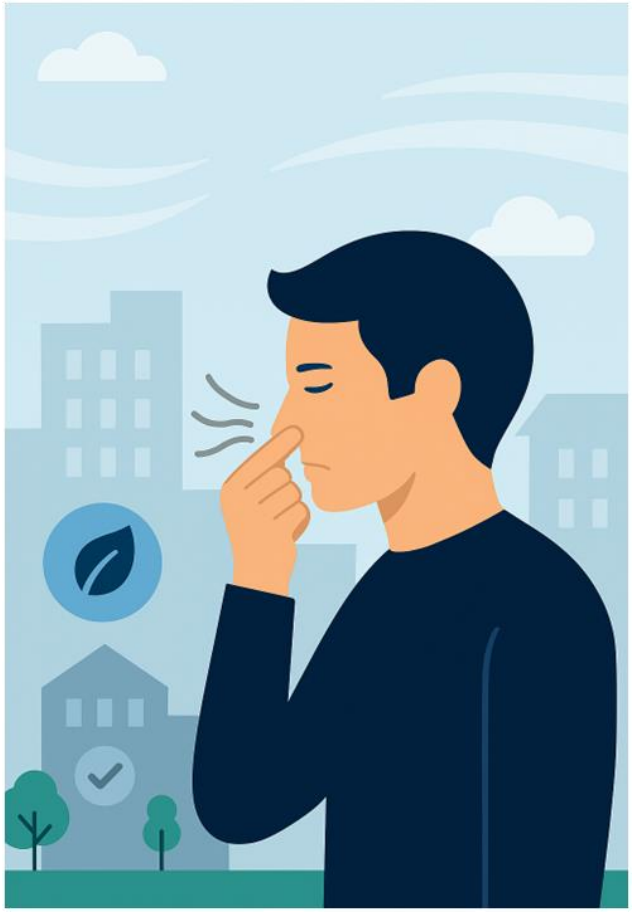


✓ **Indirect measurement:**

- Odour concentration (ouE/m³)
- Dynamic olfactometry

Regulatory Framework and Current Initiatives

- **EN 13725:2022** – Odour concentration measurement (EU reference standard)
- Italian Guidelines on Odorous Emissions (2023) – Art. 272-bis D.Lgs. 152/2006
- D-NOSES (H2020) – Overview of odour regulations in Europe
- Global Review of Odour Regulations (MDPI, 2021)
- **MOMS24**: webinar marathon on odor management around the world

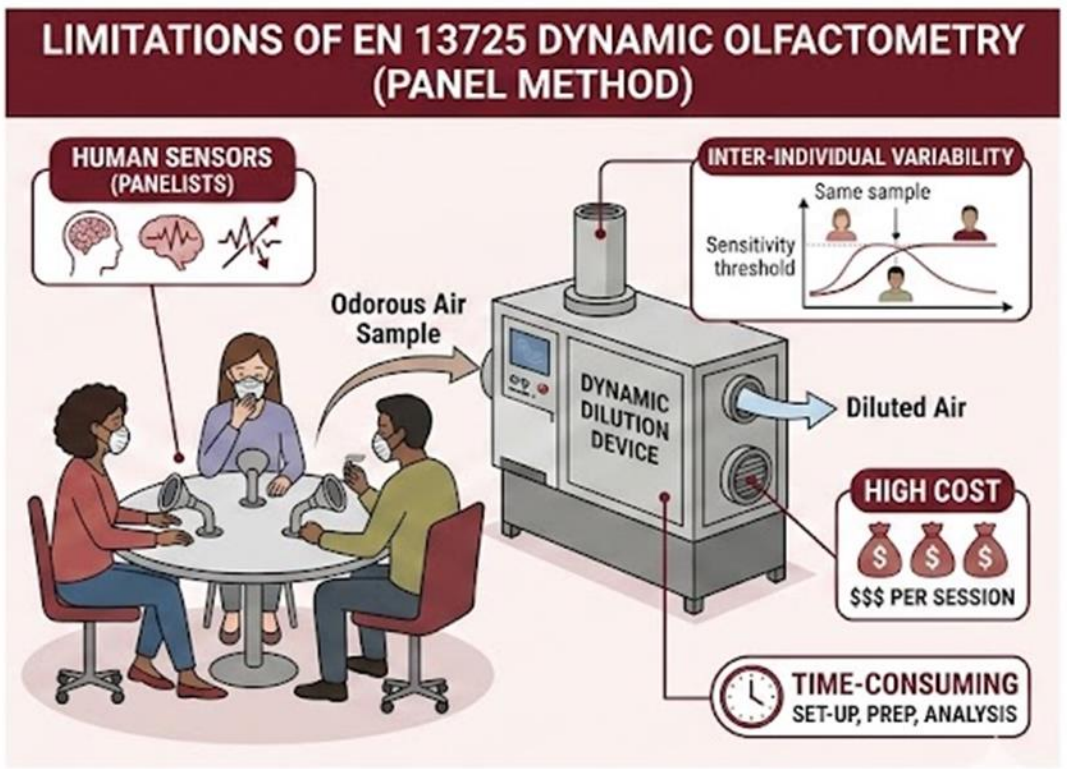


Few words on EN13725

Limitations of Traditional Methods

- Inter-individual variability
- Low reproducibility
- High cost and time demand
- Not suitable for continuous monitoring

→ Need for an instrumental approach



Second Key Concept

Are there instruments that record odours?

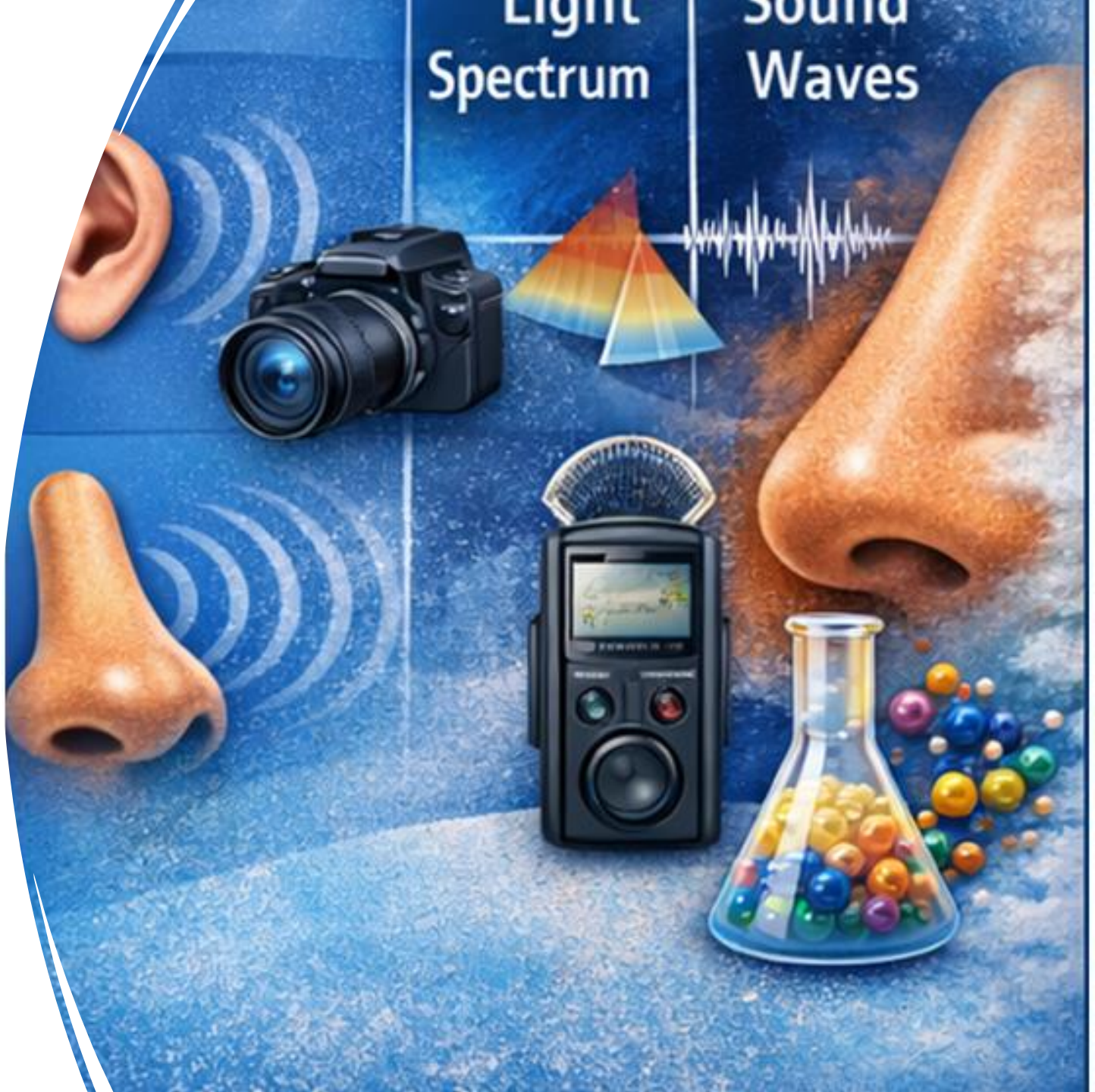
Analogywith other sensing system:

- Microphone → sound
- Camera → image

❓ Odour → ??

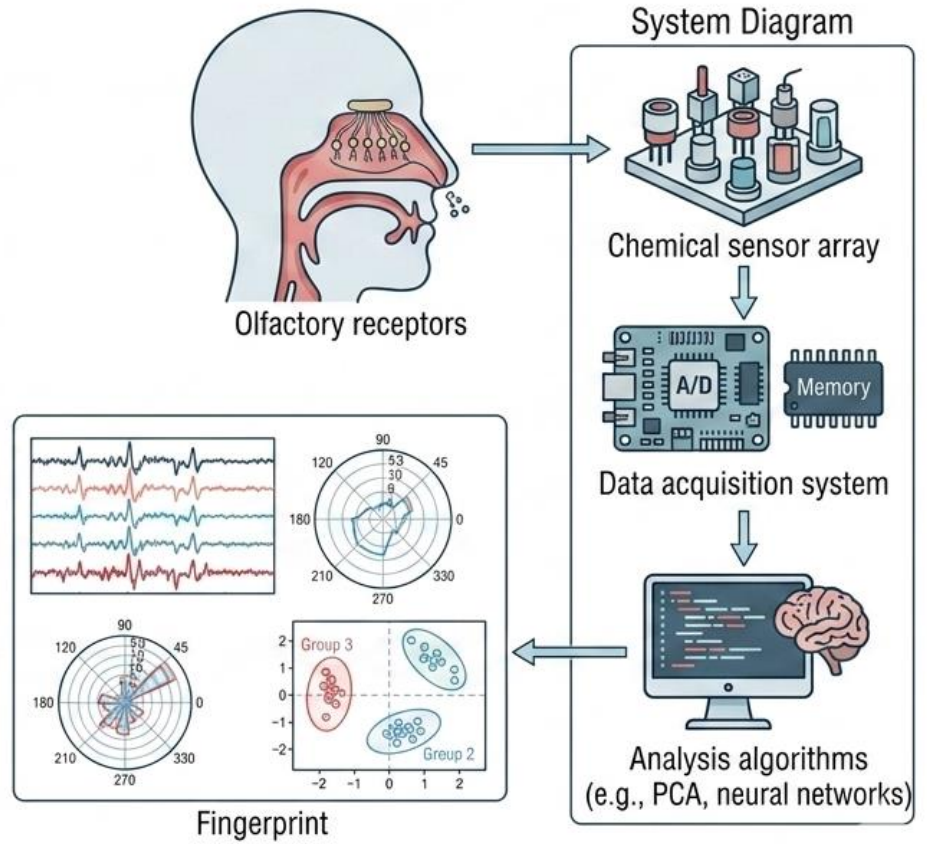
✓ Answer:

- ~~Analytical Instrument for chem analysis~~
- Electronic nose (e-nose)



What is an Electronic Nose

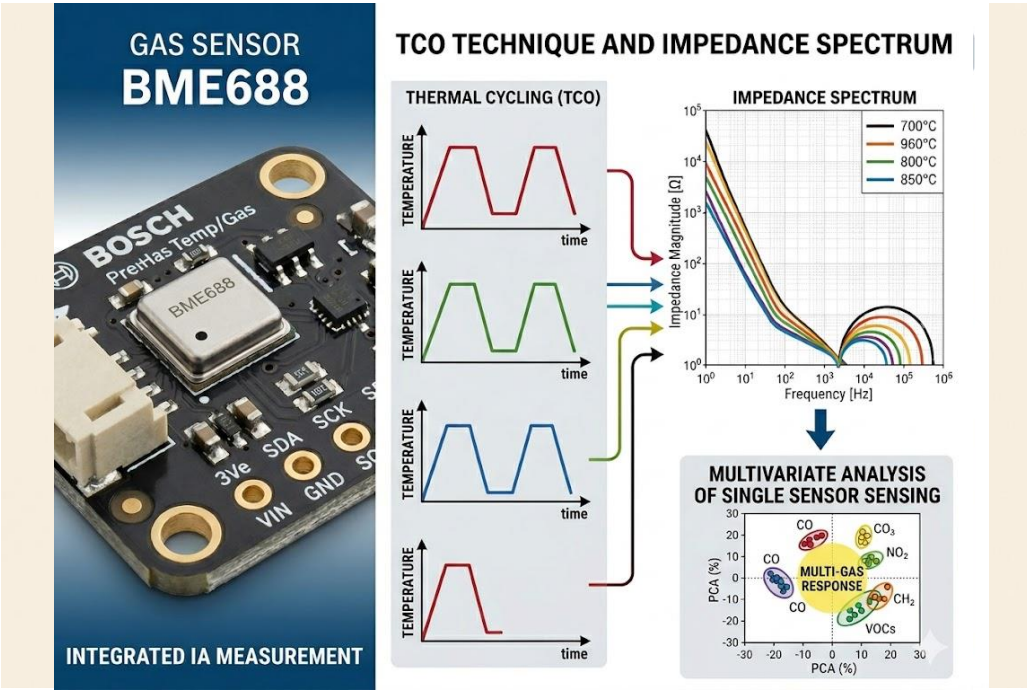
- System composed of:
  - Chemical sensor array
  - Data acquisition system
  - Analysis algorithms
- Output:
  - Multidimensional signature (fingerprint)



Sensors Architecture

- Chemical Sensors array
  - MOS
  - Polymer-based
  - Electrochemical
- Hybrid Sensors array
  - PID
  - IMS
- Gas Chromatography combined with solid-state detectors
- Multivariate Analysis of single sensors

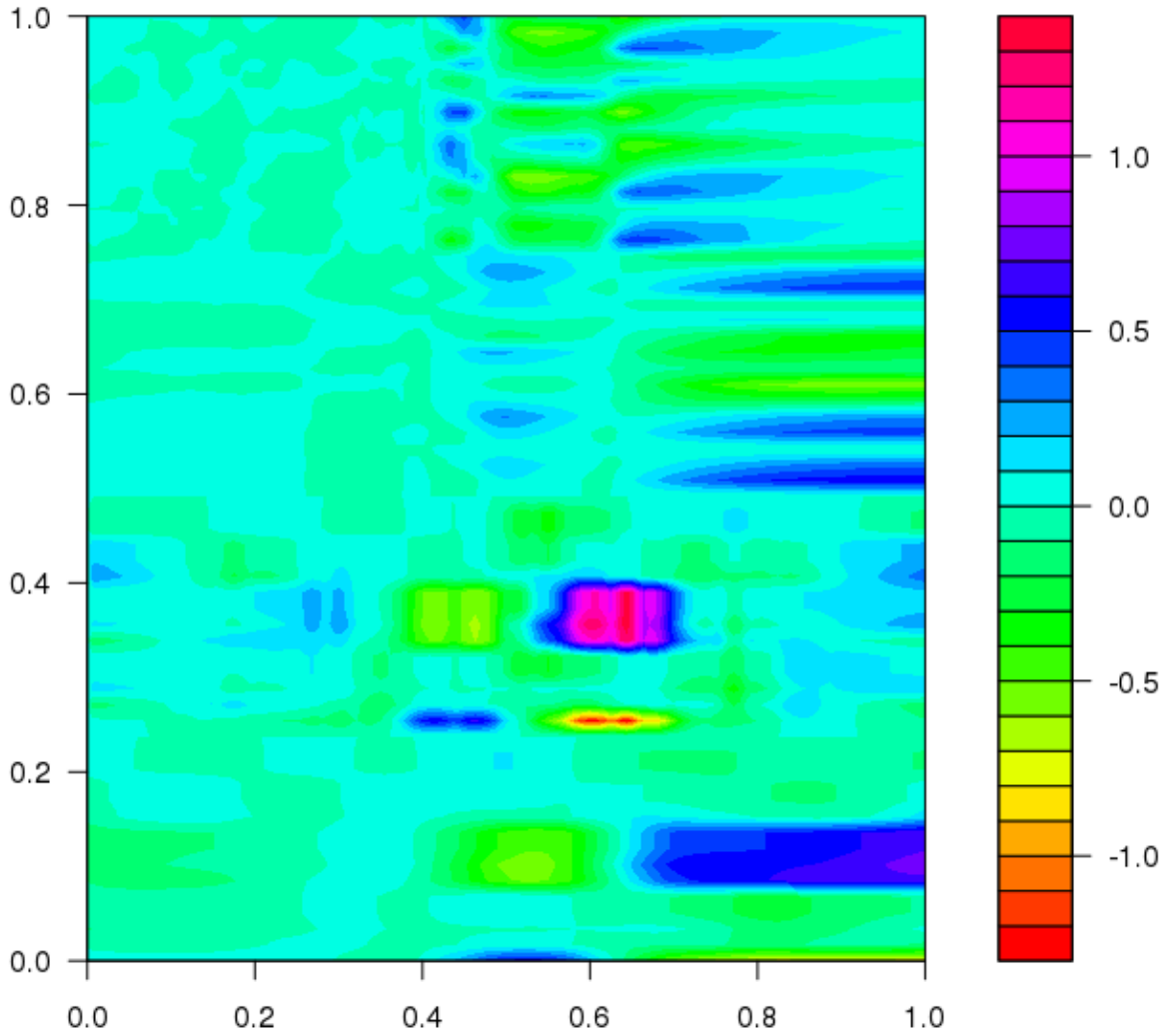
- Closed or Open architecture
- Carrier air or Zero Air



System Response

- Each sensor → electrical signal
- Combination of signals → pattern

→ “Odour fingerprint”



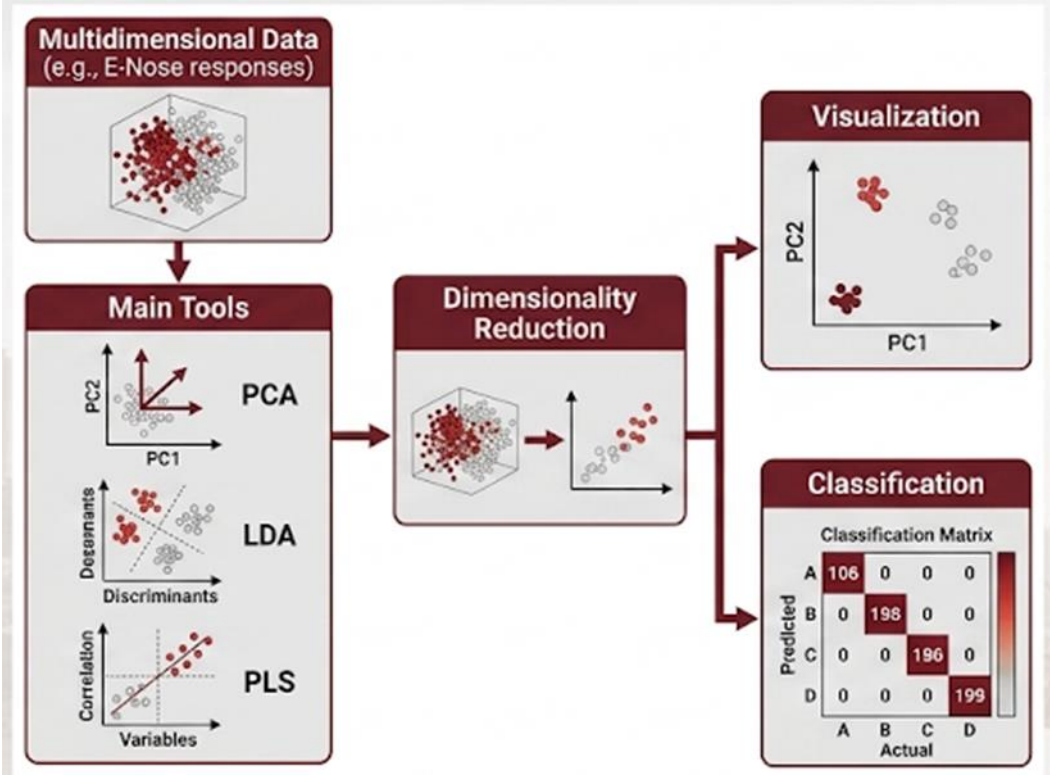
Multivariate Analysis

Main tools:

- PCA (Principal Component Analysis)
- LDA (Linear Discriminant Analysis)
- PLS (Partial Least Squares)

Functions:

- Dimensionality reduction
- Visualization
- Classification

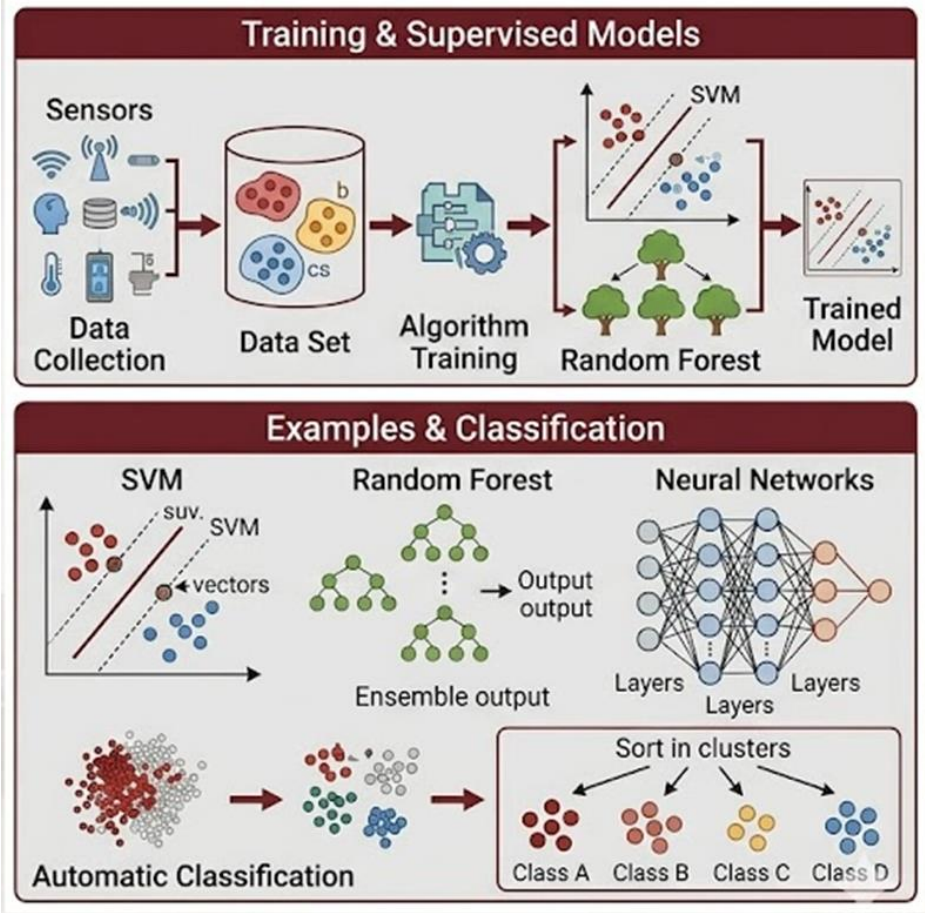


Machine Learning

- Training on known datasets
- Supervised models
- Automatic classification

Examples:

- SVM
- Random Forest
- Neural Networks



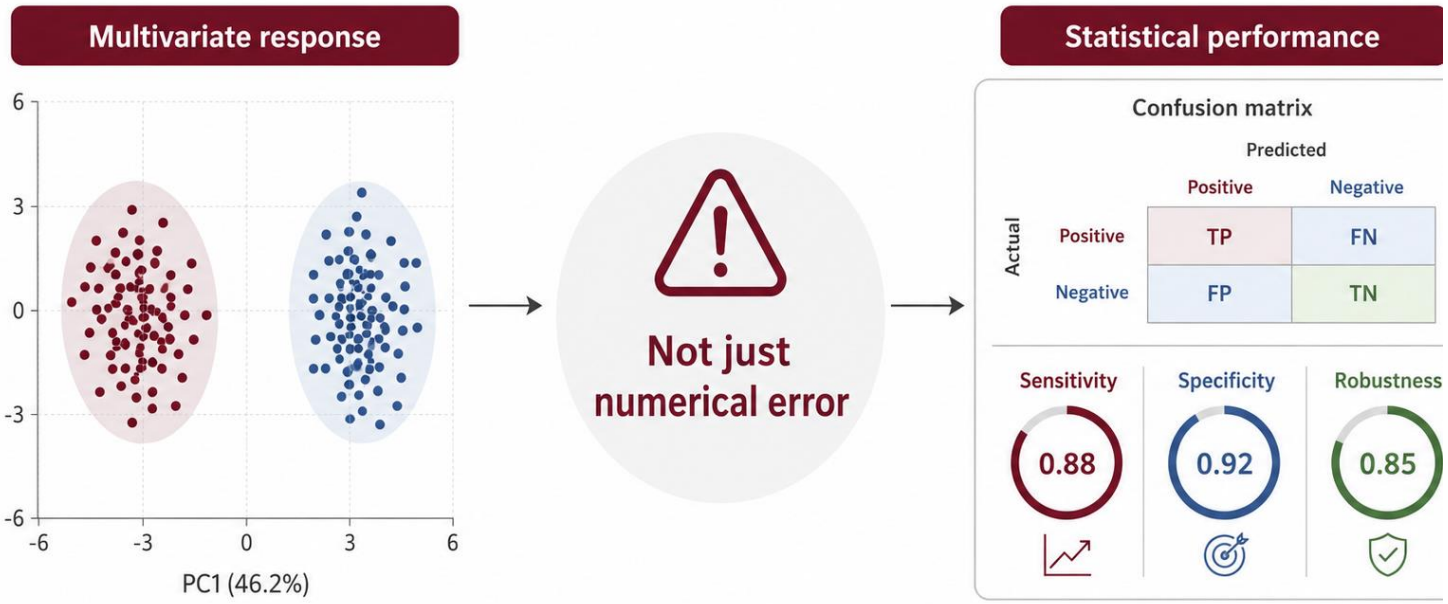
Third Key Concept

Metrology on Multivariate data

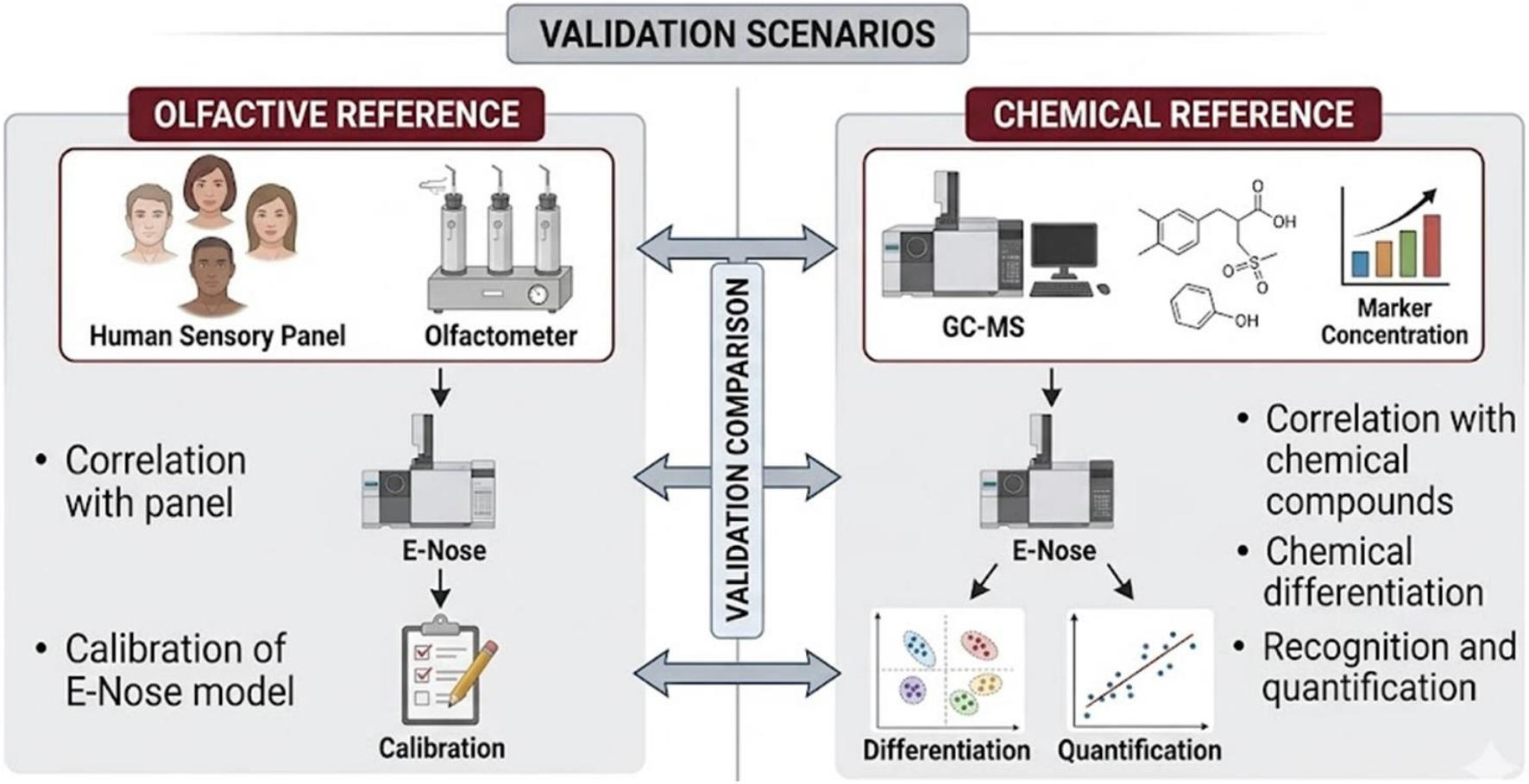
- How do we evaluate accuracy?

Not just numerical error

➡ Statistical performance evaluation required



Validation Against Reference



Performance Metrics

OLFACTIVE REFERENCE

- Confusion matrix
- Precision and recall
- F1-score

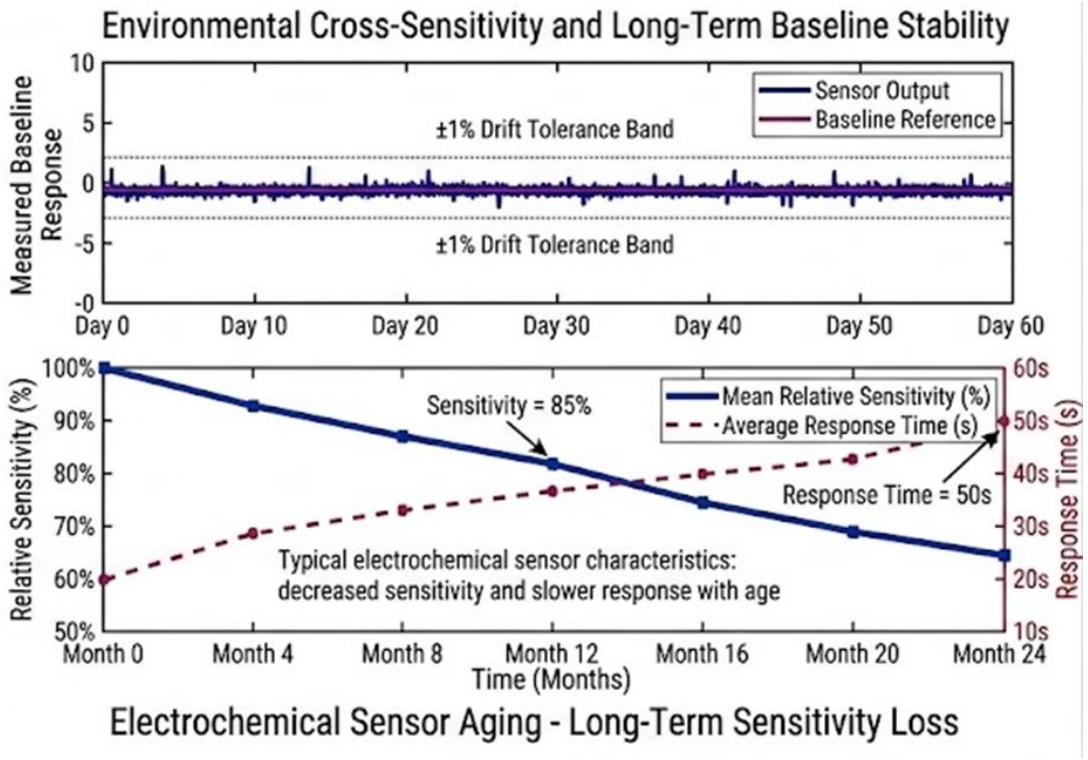
CHEMICAL REFERENCE

- Precision
- Accuracy
- Clustering
  - PCA
  - Silhohuette Coefficient

Repeatability and Stability

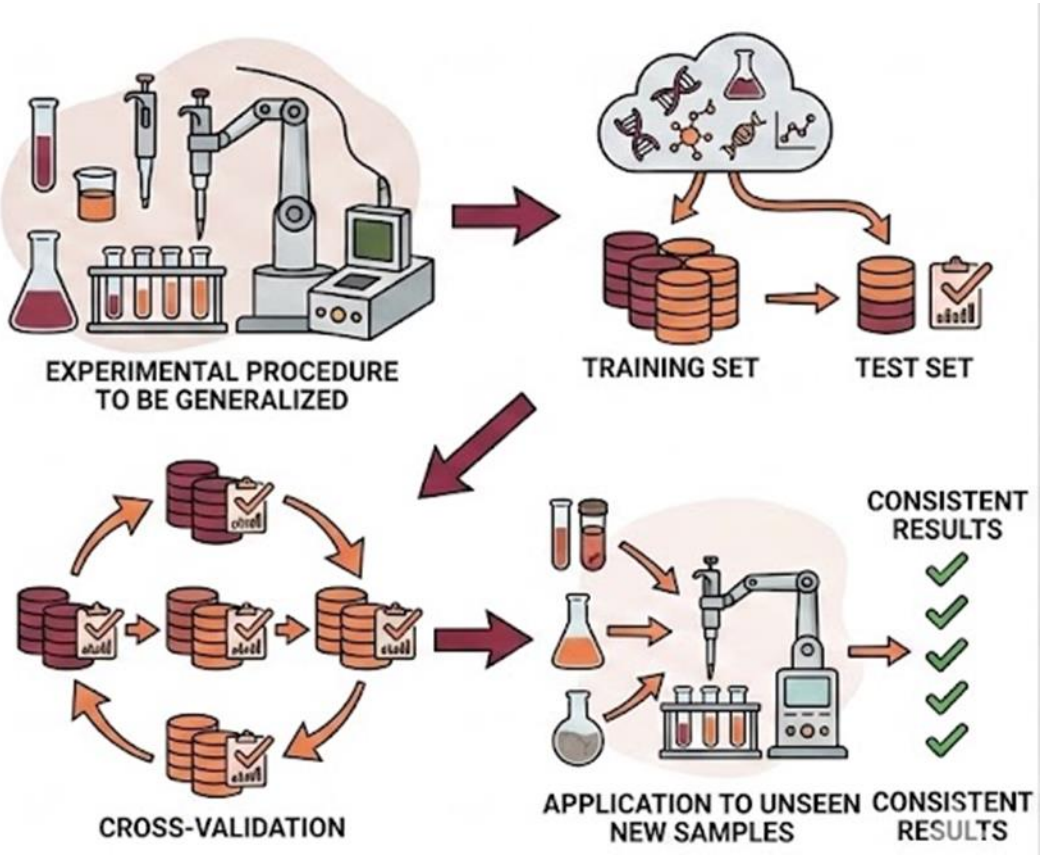
Sensor drift

- Influence of temperature/humidity
- Long-term testing
  - Sensors aging



Generalization Capability

- Training set vs test set
- Cross-validation
- Robustness on new samples



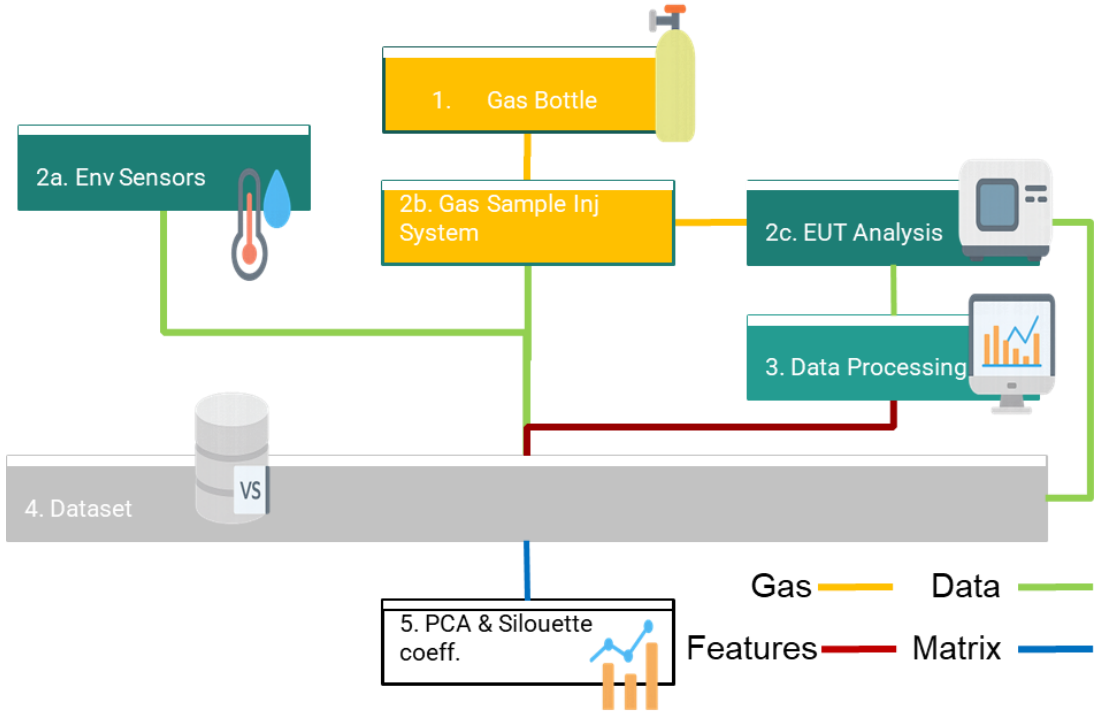
International Standards

Importance of standardization

- Controlled procedures
- Data quality
- Reproducibility of experiments

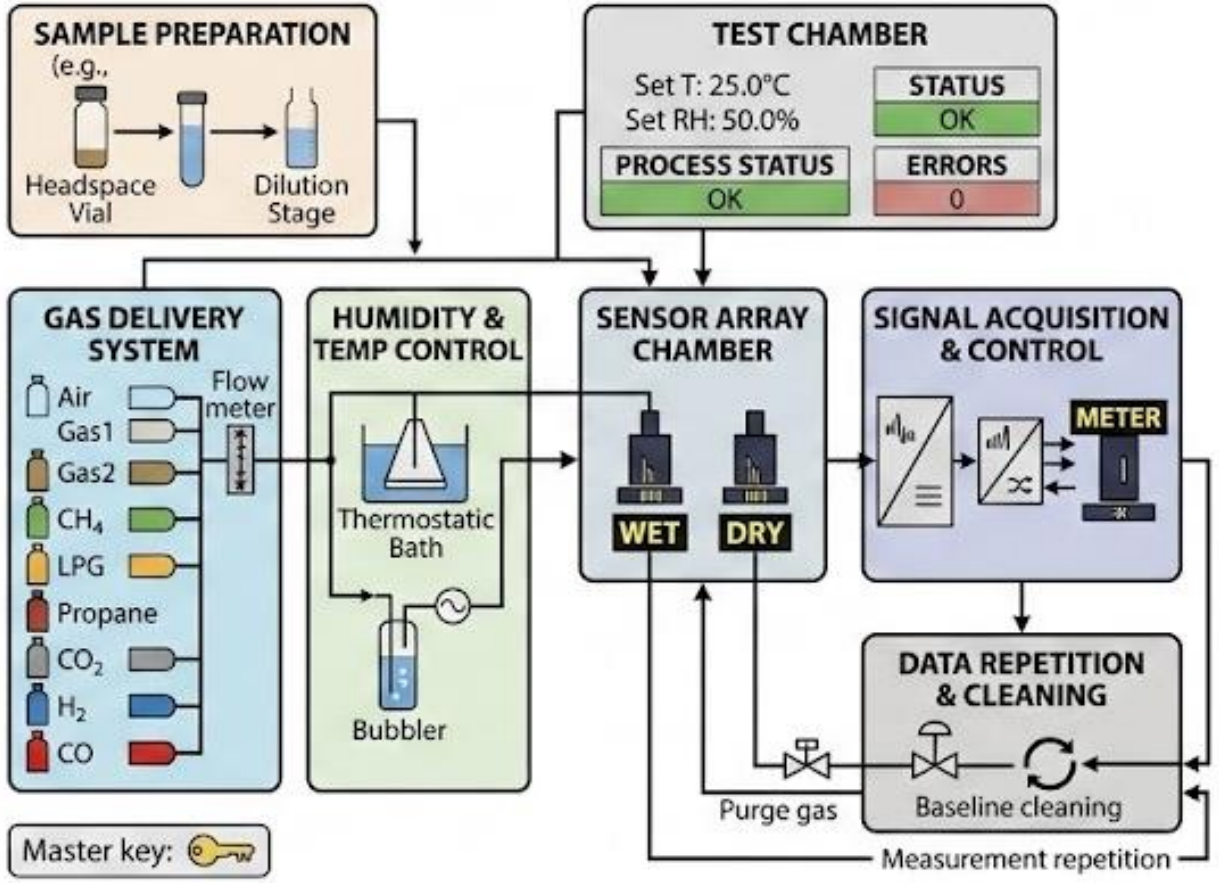
Experimental Setup

- Measurement chamber
- Air sampling system
- Temperature and humidity control
- Data acquisition system



Laboratory Procedure

1. Sample preparation
2. Sensor stabilization
3. Signal acquisition
4. Baseline cleaning
5. Measurement repetition



Dataset

Dataset generation:

- Pre-processing
- Normalization
- Drift correction
- Noise filtering

Enhancement:

- Feature selection
- Environmental data integration
- Labelled data

Case Study – IEEE SA P2520.1 application

- Laboratory benchmark and Classification of e-noses