Mark III Mobile Nose –
A Stereo Electronic Nose
for a Mobile Inspection Robot

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1) Introduction

- Mobile Nose
  - cover larger scale environments
  - electronic watchman with smelling ability, …
  - use in rescue robots
  - detection
  - localisation
  - identification
2) Set-Up of the Mark III Mobile Nose

- metal oxide gas sensors
  - doped semiconducting surface layer
  - heating element

- pros and cons
  - high sensivity
  - inexpensive
  - low selectivity
  - long recovery
2) Set-Up of the Mark III Mobile Nose

- stereo architecture
  - 2 equivalent sets
    - Figaro TGS 2600
    - Figaro TGS 2610
    - Figaro TGS 2620
  - 40 cm separation
2) Set-Up of the Mark III Mobile Nose

- use of suction fans
  - Papst 405F (8 m³/h)
  - sensors behind a covering bar
2) Set-Up of the of the Mark III Mobile Nose

- use of a "septum"
  - fans directed against each other
  - decrease the rate of air exchange
3) Dynamic Response Experiment

- dynamic response of the mobile nose
- step stimulus by opening a bottle
3) Dynamic Response Experiment

- dynamic response of the mobile nose
- step stimulus by opening a bottle

wait for 20s
3) Dynamic Response Experiment

- dynamic response of the mobile nose
- step stimulus by opening a bottle

open the bottle for 10 s
3) Dynamic Response Experiment

- dynamic response of the mobile nose
- step stimulus by opening a bottle

wait for 120s
3) Dynamic Response Experiment

- dynamic response of the mobile nose
- step stimulus by opening a bottle

repeat on other side
4) Sensor Model

- assume first-order sensor model
- exponential rise and decay
4) Sensor Model

- assume first-order sensor
- exponential rise and decay
5) Evaluation

- non-linear fitting: Marquardt-Levenberg
  - gnuplot implementation can be used
  - parameter values
  - asymptotic standard error
5) Evaluation

- combining individual fits
  - assuming Gaussian distribution with different $\sigma_i$
  - maximum likelihood estimator
  - weighted averaging

\[
\bar{x} = \frac{\sum \omega_i x_i}{\sum \omega_i} \quad \quad \omega_i = \frac{1}{\sigma_i^2}
\]

\[
\bar{\sigma}^2 = \frac{\sum \omega_i}{(\sum \omega_i)^2 - \sum \omega_i^2} \sum \omega_i (x_i - \bar{x})
\]
6) Results - No Fans

$\tau_r \approx 1.93 \pm 1.18 \text{ s}$

$\tau_d \approx 28.88 \pm 6.02 \text{ s}$

TGS 2620, $2 \times 6$ trials
6) Results - Fans

\( \tau_r \approx 1.85 \pm 0.71 \text{ s} \)

\( \tau_d \approx 9.90 \pm 2.14 \text{ s} \)

\( \tau_r \approx 1.91 \pm 0.96 \text{ s} \)

\( \tau_d \approx 10.20 \pm 0.75 \text{ s} \)
6) Results - Fans

- \( \tau_r \approx 1.85 \pm 0.71 \text{ s} \)
- \( \tau_d \approx 9.90 \pm 2.14 \text{ s} \)

TGS 2620, 2×6 trials
6) Results - Fans and Septum

\[ \tau_r \approx 1.91 \pm 0.96 \text{ s} \]

\[ \tau_d \approx 9.90 \pm 2.14 \text{ s} \]

TGS 2620, 2×9 trials
7) Conclusions

- method to determine dyn. response parameters
  - experiment
  - evaluation
- first-order sensor model is appropriate
7) Conclusions

- design of the Mark III Mobile Nose introduced using fans doesn't change response time ...
  \[ \tau_r \approx 2 \text{s} \]
- ... but rather speeds up recovery
  \[ \tau_d^{(\text{no fans})} \approx "20 \text{s}" \]
  \[ \tau_d^{(\text{fans})} \approx 11 \text{s} \]
- separation of airstreams is needed
8) Applications - Turbulence

- problem of turbulence

Smyth & Moum 2001
8) Applications - Turbulence

- instantaneous distribution
8) Applications - Gas Concentration Mapping

- mapping algorithm to combine gas sensor readings
8) Applications - Gas Concentration Mapping

- mapping algorithm to combine gas sensor readings

15 min
8) Applications - Gas Concentration Mapping

- mapping algorithm to combine gas sensor readings

30 min
8) Applications - Gas Concentration Mapping

- mapping algorithm to combine gas sensor readings

60 min
8) Applications - Gas Concentration Mapping

- mapping algorithm to combine gas sensor readings

120 min
8) Applications - Gas Concentration Mapping

- mapping algorithm to combine gas sensor readings

178 min
8) Applications - Gas Concentration Mapping

"av. max. concentration - source" distance
8) Applications - Gas Concentration Mapping

- evolution
8) Applications - Reactive Gas Source Localisation - PL

- smelling Braitenberg vehicle

"Permanent Love"
8) Applications - Reactive Gas Source Localisation - PL

- smelling Braitenberg vehicle

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8) Applications - Reactive Gas Source Localisation - EL

- exploration & gas concentration peak avoiding

“AExploring Love”
8) Applications - Reactive Gas Source Localisation - EL

- exploration & gas concentration peak avoiding

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8) Applications - Curvature Mapping

- curvature mapping
  - use current tangent
  - increase grid cells the robot turns away from
    - by a fixed amount
    - proportional to the curvature of the path
8) Applications - Curvature Mapping