Towards Environmental Monitoring with Mobile Robots

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Summary

- Design of a Pollution Monitoring Robot
Summary

- Design of a Pollution Monitoring Robot
- Experimental Evaluation
Summary

- Design of a Pollution Monitoring Robot
- Experimental Evaluation
  - initial observations
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- Design of a Pollution Monitoring Robot
- Experimental Evaluation
  - initial observations
  - research results based on this experimental platform
Background
1 Environmental Monitoring with Mobile Robots

- Monitoring with Autonomous Sensor Networks
  - continuous collection of measurements
    - gas concentration, air flow, temperature, humidity
  - central integration into one consistent model
Advantages of Using Mobile Sensor Nodes

- fewer sensors are necessary (expensive ones can be used)
- rapid deployment (less expensive)
- optimisation of coverage wrt the task (sensor planning)
- adaptation to changing environmental conditions
- compensation for inactive sensors
- can be used at dangerous places
- robots useful for other tasks
- accurate positioning
Gas Distribution Modelling

- build a "truthful" representation of the gas distribution from a sequence of observations
1 Gas Distribution Modelling

- Gas Distribution Modelling
  - build a "truthful" representation of the gas distribution from a sequence of observations

- What is a Good Model?
  - "compatible" with observed environmental conditions
  - allows to infer hidden parameters
    - average concentration
    - gas source location
  - explain and predict observations (infer concentration levels)

- Gas Distribution Modelling is Very Challenging!
1 Gas Distribution Modelling

- Point Measurements
  - sensitive sensor surface is typically small (often < 1cm$^2$)
1 Gas Dispersal in Natural Environments

Chaotic Gas Dispersal

- diffusion
- advective transport
- turbulent transport

[Smyth and Moum, 2001]
Related Work
2 Approaches to Statistical GDM

Experimental Evaluation

- in relatively small environments
- using a global localisation system or odometry
  - inflexible set-up

2 Approaches to Statistical GDM

- Experimental Evaluation
  - carefully controlled environmental conditions
    - artificial ventilation

Design of the Pollution Monitoring Robot
### 3 Pollution Monitoring Robot Design

- **Pollution Monitoring Robot "Rasmus"**
  - **iRobot ATRV – JR** (all terrain robot)

![Robot with anemometer and "e-nose"](image-url)
3 Pollution Monitoring Robot Design

Pollution Monitoring Robot "Rasmus"

- iRobot ATRV – JR (all terrain robot)
- Player to interface sensors and actuators
  - amcl, wavefront and vfh Player drivers for localization and navigation

3 Pollution Monitoring Robot Design

- Electronic Nose
3 Pollution Monitoring Robot Design

- **Electronic Nose**
  - array of five SnO₂ based gas sensors
  - actively ventilated

<table>
<thead>
<tr>
<th>Model</th>
<th>Gas Detected</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Figaro TGS 2600</td>
<td>Hydrogen, Carbon Monoxide</td>
<td>2</td>
</tr>
<tr>
<td>Figaro TGS 2602</td>
<td>Ammonia, Hydrogen Sulfide, VOC</td>
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</tr>
<tr>
<td>Figaro TGS 2611</td>
<td>Methane</td>
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<tr>
<td>Figaro TGS 2620</td>
<td>Organic Solvents</td>
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</table>
3 Pollution Monitoring Robot Design

- Anemometer
Anemometer

- Young 81000
- 3-d ultrasonic anemometer
- range: 2 cm/s – 40 m/s
- resolution: 1 cm/s
3 Pollution Monitoring Robot Design

- Anemometer
  - Young 81000
  - 3-d ultrasonic anemometer
  - range: 2 cm/s – 40 m/s
  - resolution: 1 cm/s
  - placement?
    - as close as possible to the gas sensors
    - as undisturbed as possible
    - compromise between these needs
Experiments and First Results
3 Experiments

- Outdoor Experiments
3 Experiments

Outdoor Experiments

- source: small cup filled with Ethanol
- pre-defined sweeping trajectory (5cm/s)
- measurements while driving
- measurements while robot was stopped (10s)
3 Experiments

- Outdoor Experiments
  - concentration: dark (low) to bright (high) and red area (highest)
  - overlaid wind measurements
  - wind strength from blue to red
3 Experiments

Outdoor Experiments

- concentration: dark (low) to bright (high) and red area (highest)
- overlaid wind measurements
- wind strength from blue to red
3 Experiments

- 3-Room Experiments

Images of robots in different rooms, illustrating the experiments.
3 Experiments

3-Room Experiments

- enclosed indoor area
- wide passage between the rooms
- gas distribution monitored in the whole area: $14 \times 6 \text{ m}^2$
- little exchange of air with the "outer world"
- gas source placed in the middle of the central room
3 Experiments

- 3-Room Experiments
Ongoing Work
5 Ongoing Work

Classification Of Odours with Mobile Robots

M. Trincavelli, S. Coradeschi and A. Loutfi, Classification of Odours with Mobile Robots Based on Transient Response. IROS 2008, pp 4110 – 4115.

5 Ongoing Work

- Kernel GDM+V $\rightarrow$ Gas Distribution + Variance
  - estimate distribution mean and variance

5 Ongoing Work

- GDM Using Sparse Gaussian Process Mixture Models
  - estimate distribution mean and variance

5 Ongoing Work

Comparison of Gas Distribution Models

- first sweep
  - learn hyper-parameters
  - compute map

- second sweep
  - compute data likelihood of samples

<table>
<thead>
<tr>
<th>Dataset</th>
<th>NLPD, GPM</th>
<th>NPLD, Kernel</th>
<th>GDM+V</th>
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</thead>
<tbody>
<tr>
<td>3-rooms</td>
<td>-1.54</td>
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<td>corridor</td>
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<tr>
<td>outdoor</td>
<td>-1.77</td>
<td>-1.75</td>
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</tbody>
</table>
Summary and
Future Work
6 Summary

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Future Work

- use wind information in the gas distribution mapping process
- optimal sensor planning
- 3-d maps
- 4-d maps
- ...

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Thank you!