Creating Gas Concentration Gridmaps with a Mobile Robot

Achim Lilienthal, Tom Duckett
University of Tübingen, WSI / Örebro University, AASS
Contents

1) Motivation
2) Mobile Nose: Main Problems
3) Creating Concentration Gridmaps
4) Experimental Setup
5) Some Results
6) Conclusions
Motivation – Mobile Nose Research

Mobile Nose - Research
- physical properties of gas transport
- understand how animals use odours to navigate

Mobile Nose - Applications
- gas distribution mapping (hazardous waste sites)
- gas source localisation
Gas Source Localisation – Main Problems

- Instantaneous Distribution ≠ Average Distribution

Smyth & Moum 2001

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
3 Gridmaps vs. Concentration Gridmaps

- Occupancy Gridmap
  - cells represent the belief that an area is occupied
  - considerable overlap between single measurements

- Concentration Gridmap
  - cells represent the relative concentration on average
  - measurements cover a very small area
  - measurements depend on the past
3 Creating Concentration Gridmaps

- Extrapolate on the Measurements
  - Gaussian density function
    \[ f(\vec{x}) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2}{2\sigma^2}} \]

- Justification
  - smooth time-constant structures of the gas distribution
  - implicit integration due to the sensor characteristics
Creating Concentration Gridmaps

Displacement of Cells

\[ \delta_t (i, j) = \vec{x} (i, j) - \vec{x}_t \]
3 Creating Concentration Gridmaps

- Displacement of Cells

\[ \delta_t^{(i,j)} = \vec{x}^{(i,j)} - \vec{x}_t \]

- Determine Weightings

\[ \omega_t^{(i,j)} = \begin{cases} 
    \mathcal{E} \left( \delta_t^{(i,j)} \right) & : \delta_t^{(i,j)} \leq R_{co} \\
    0 & : \delta_t^{(i,j)} > R_{co}
\end{cases} \]
Creating Concentration Gridmaps

Displacement of Cells

\[ \delta_t^{(i,j)} = \mathbf{x}^{(i,j)} - \mathbf{x}_t \]

Determine Weightings

\[
\omega_t^{(i,j)} = \begin{cases} 
\mathcal{E} \left( \delta_t^{(i,j)} \right) : \delta_t^{(i,j)} \leq R_{co} \\
0 : \delta_t^{(i,j)} > R_{co}
\end{cases}
\]

\[ R_{co} = 3 \sigma \]

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
Creating Concentration Gridmaps

Update Weighting Table

\[ W_t(i, j) = W_{t-1}(i, j) + \omega_t(i, j) \]
3  Creating Concentration Gridmaps

- Update Weighting Table

\[ W_{t}^{(i,j)} = W_{t-1}^{(i,j)} + \omega_{t}^{(i,j)} \]

- Update Weighted Readings

\[ WR_{t}^{(i,j)} = WR_{t-1}^{(i,j)} + r_{t} \omega_{t}^{(i,j)} \]

\[ r_{t} = \frac{R_{t} - R_{\text{min}}}{R_{\text{max}} - R_{\text{min}}} \]

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
Creating Concentration Gridmaps

- Update Cells

\[ c_t^{(i,j)} = \frac{WR_t^{(i,j)}}{W_t^{(i,j)}} : W_t^{(i,j)} \geq W_{\text{min}} \]

- Next Timestep
Creating Concentration Gridmaps

- Extrapolation on Sequential Readings
Creating Concentration Gridmaps

Extrapolation on Sequential Readings
3 Creating Concentration Gridmaps

- Constant Weight along the driven Path
Creating Concentration Gridmaps

- Low Velocity $\rightarrow$ Higher Weight
Creating Concentration Gridmaps

Extrapolation on Sequential Readings
4 Experimental Setup – Mark III Mobile Nose

Stereo Architecture

- 2 equivalent sets
  - Figaro TGS 2600
  - Figaro TGS 2610
  - Figaro TGS 2620
- 40 cm separation
- suction fans
4 Experimental Setup – Environment

- Laboratory Room, No Air Condition

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
4. Experimental Setup – Data Acquisition

- Requirements
  - path should roughly cover the designated area
  - uniform exploration is not necessary
  - passing particular points from different directions

→ Predefined Path

→ Concentration Mapping while Searching
Experimental Setup – Data Acquisition

- Predefined Path – Rectangular Spiral
5 Results

- Predefined Path – Rectangular Spiral

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
5 Results

- Predefined Path – Rectangular Spiral
Gas Source Localisation

- Predefined Path – Sweeping – $w = 80$ cm

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
5 Results

- Predefined Path – Sweeping Movement
5 Results

Reactive Strategy – Braitenberg Vehicle

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
5 Results

- Reactive Strategy – Braitenberg Vehicle
5 Gas Source Localisation

- Reactive Strategy – Braitenberg Vehicle

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
Gas Source Localisation

- Reactive Strategy – Braitenberg Vehicle

Achim Lilienthal (WSI, Tübingen / AASS, Örebro)
6 Conclusions

- new algorithm to create concentration gridmaps
  - shows time-invariant structures of gas distributions
  - overcomes the problem of little overlap of measurements
  - takes into account the „memory effect“
  - stable representation after ~ 10 - 25 min.

- localisation facility
  - max. concentration often provides a good estimate
Creating Gas Concentration Gridmaps with a Mobile Robot

Achim Lilienthal, Tom Duckett

Thank you!