aass

ÖREBRO
UNIVERSITET

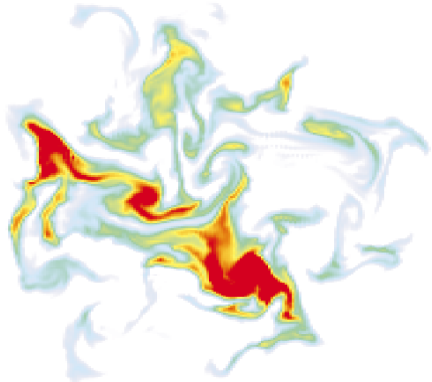
Creating Gas Concentration Gridmaps with a Mobile Robot

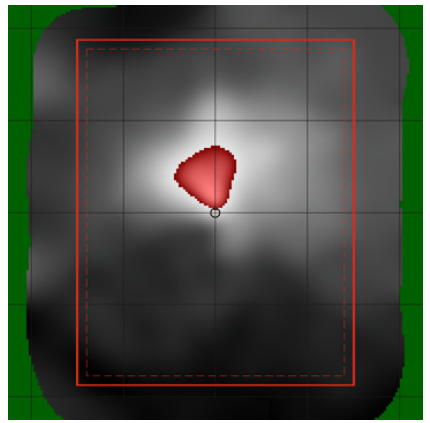
Achim Lilienthal, Tom Duckett

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





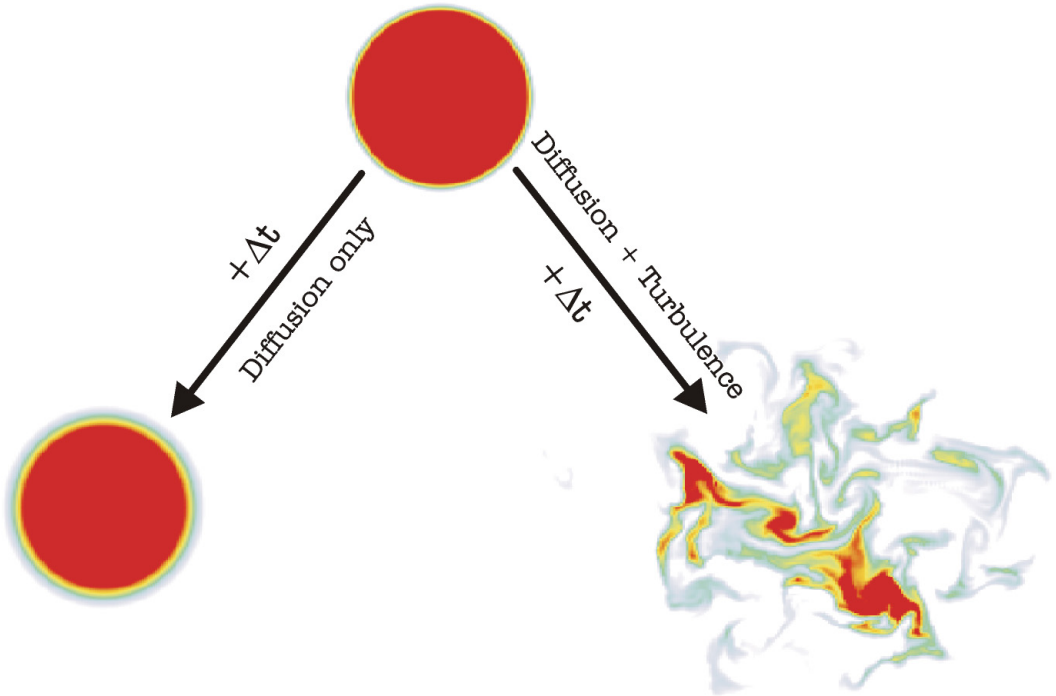
1 Motivation – Mobile Nose Research

- 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

2 Gas Source Localisation – Main Problems

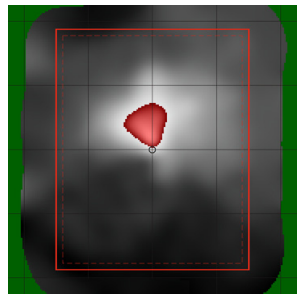
- Instantaneous Distribution ≠ Average Distribution



Smyth & Moum 2001

3 Gridmaps vs. Concentration Gridmaps

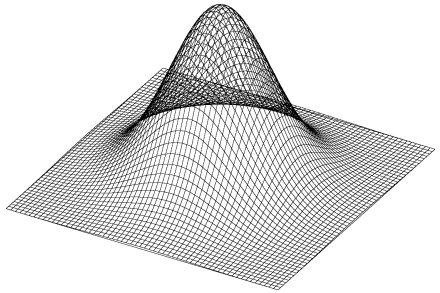
- Occupancy Gridmap
  - cells represent the belief that an area is occupied
  - considerable overlap between single measurements
- Concentration Gridmap
  - cells represent the relative concentration on average
  - measurements cover a very small area
  - measurements depend on the past



3 Creating Concentration Gridmaps

- Extrapolate on the Measurements
  - Gaussian density function

$$f\left(\vec{x}\right) = \frac{1}{2\,\pi\,\sigma^2}\, e^{-\frac{\vec{x}^2}{2\,\sigma^2}}$$

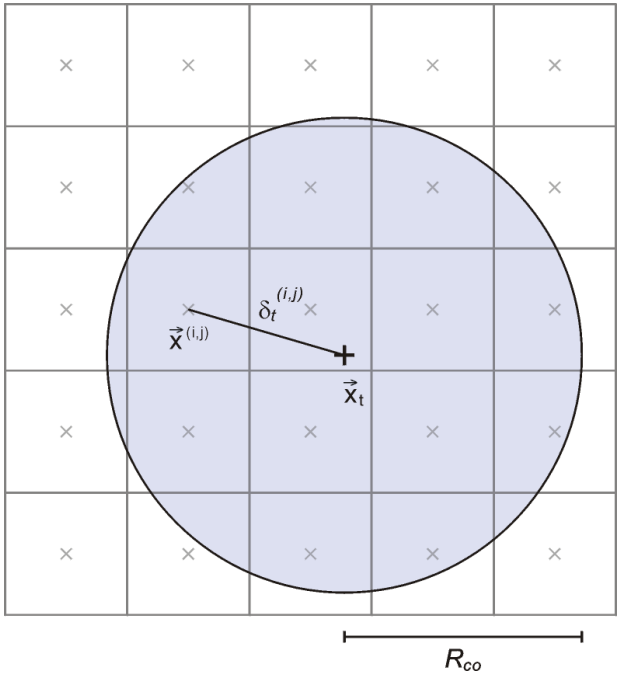


- Justification
  - smooth time-constant structures of the gas distribution
  - implicit integration due to the sensor characteristics

3 Creating Concentration Gridmaps

- Displacement of Cells

$$\vec{\delta}_t^{(i,j)} = \vec{x}^{(i,j)} - \vec{x}_t$$



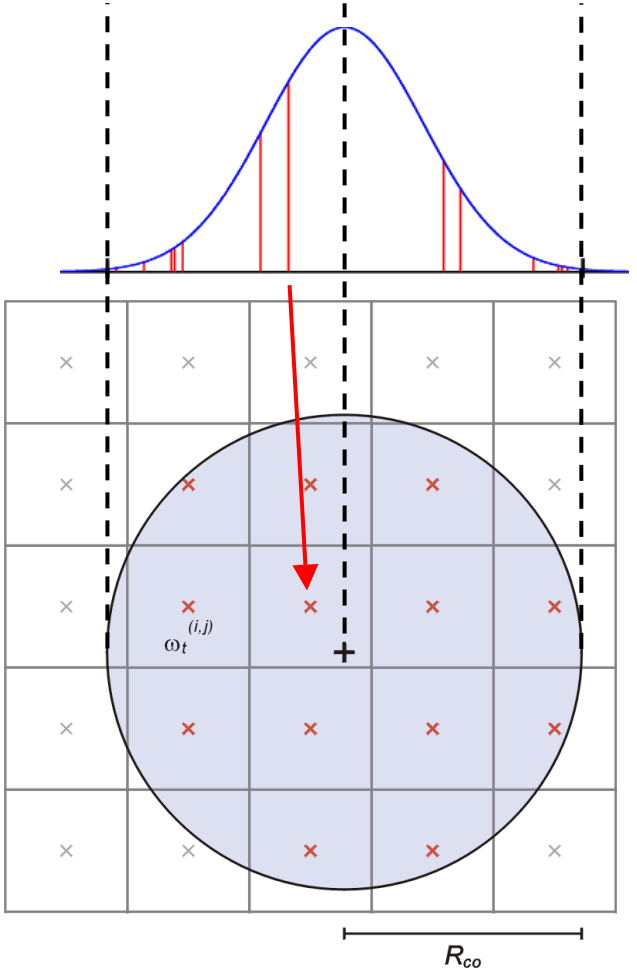
3 Creating Concentration Gridmaps

Displacement of Cells

$$\vec{\delta}_t^{(i,j)} = \vec{x}^{(i,j)} - \vec{x}_t$$

Determine Weightings

$$\omega_t^{(i,j)} = \begin{cases} f\left(\vec{\delta}_t^{(i,j)}\right) : \delta_t^{(i,j)} \leq R_{co} \\ 0 : \delta_t^{(i,j)} > R_{co} \end{cases}$$



3 Creating Concentration Gridmaps

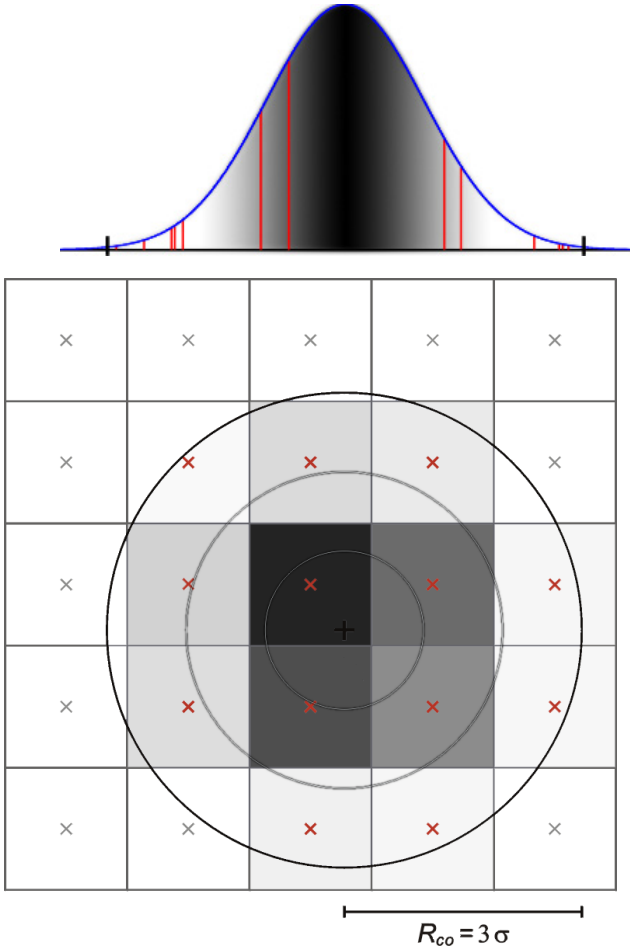
Displacement of Cells

$$\vec{\delta}_t^{(i,j)} = \vec{x}^{(i,j)} - \vec{x}_t$$

Determine Weightings

$$\omega_t^{(i,j)} = \begin{cases} f\left(\vec{\delta}_t^{(i,j)}\right) : \delta_t^{(i,j)} \leq R_{co} \\ 0 : \delta_t^{(i,j)} > R_{co} \end{cases}$$

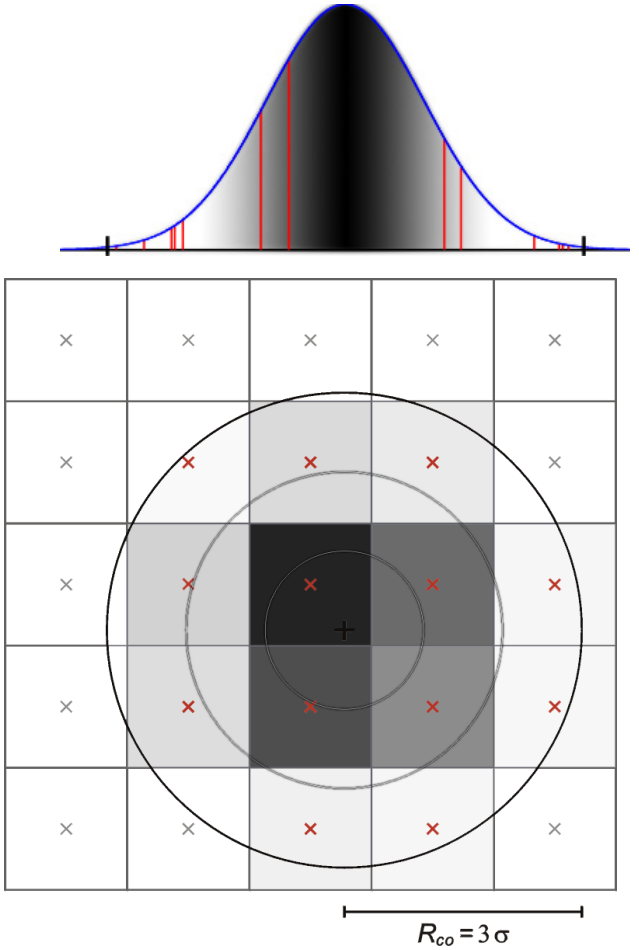
$$R_{co} = 3\,\sigma$$



3 Creating Concentration Gridmaps

- Update Weighting Table

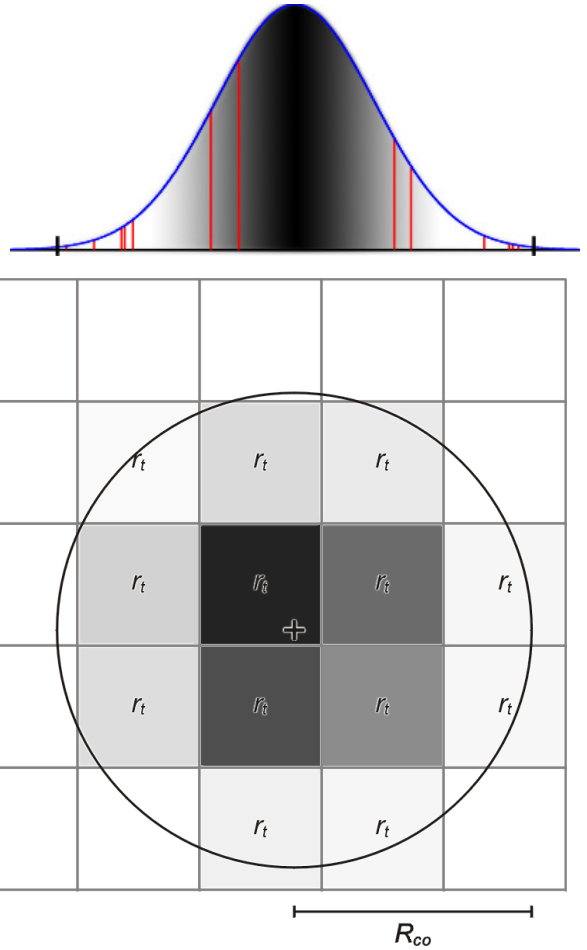
$$W_t^{(i,j)} = W_{t-1}^{(i,j)} + \omega_t^{(i,j)}$$



3 Creating Concentration Gridmaps

Update Weighting Table

$$W_t^{(i,j)} = W_{t-1}^{(i,j)} + \omega_t^{(i,j)}$$



Update Weighted Readings

$$\mathbf{WR}_t^{(i,j)} = \mathbf{WR}_{t-1}^{(i,j)} + r_t\,\omega_t^{(i,j)}$$

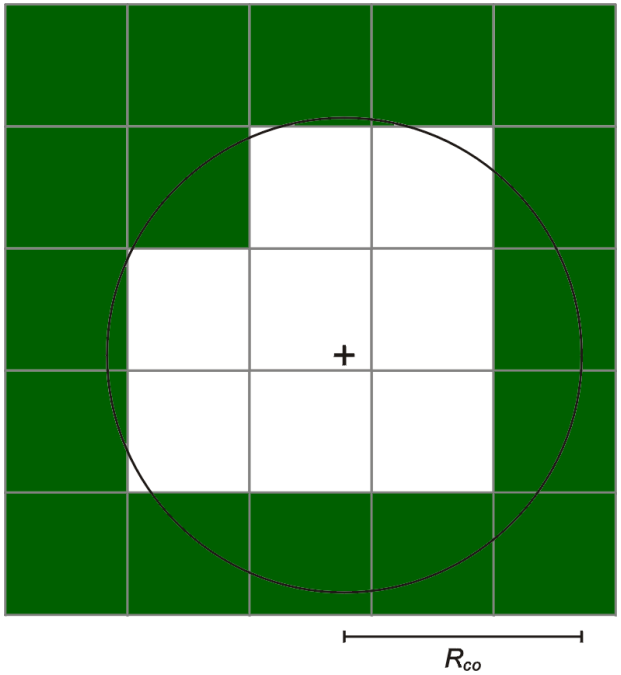
$$r_t = \frac{R_t - R_{\min}}{R_{\max} - R_{\min}}$$

3 Creating Concentration Gridmaps

- Update Cells

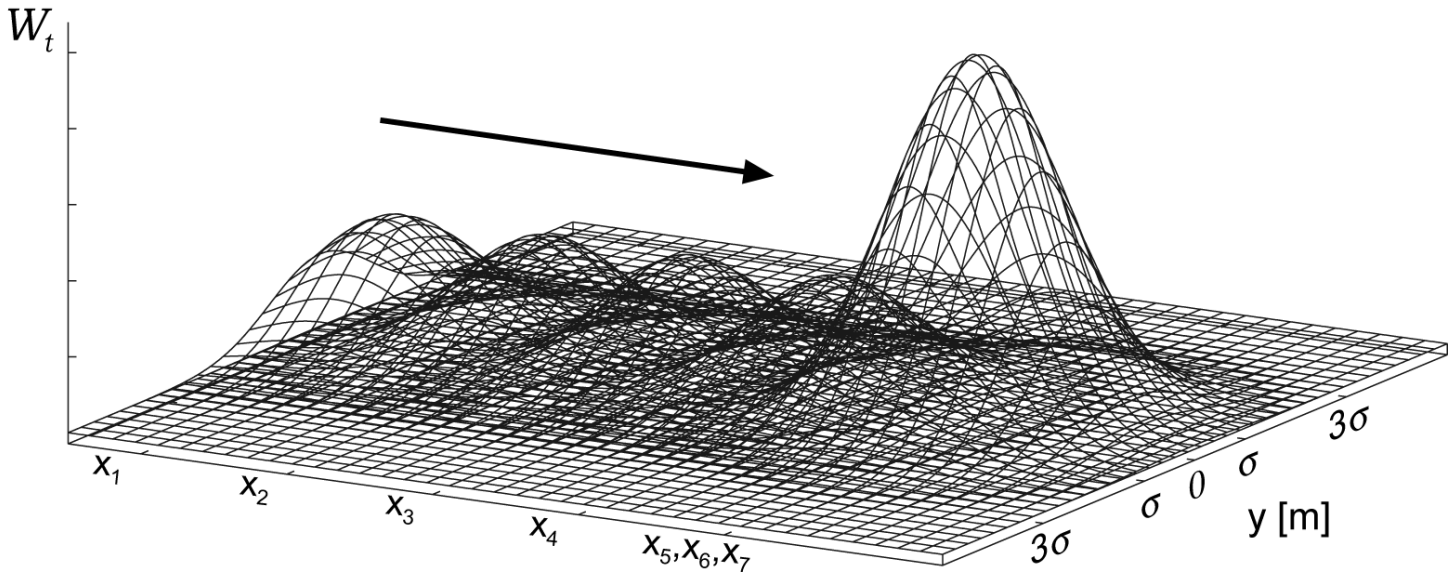
$$c_t^{(i,j)} = \frac{WR_t^{(i,j)}}{W_t^{(i,j)}} \quad : \quad W_t^{(i,j)} \geq W_{\text{min}}$$

- Next Timestep



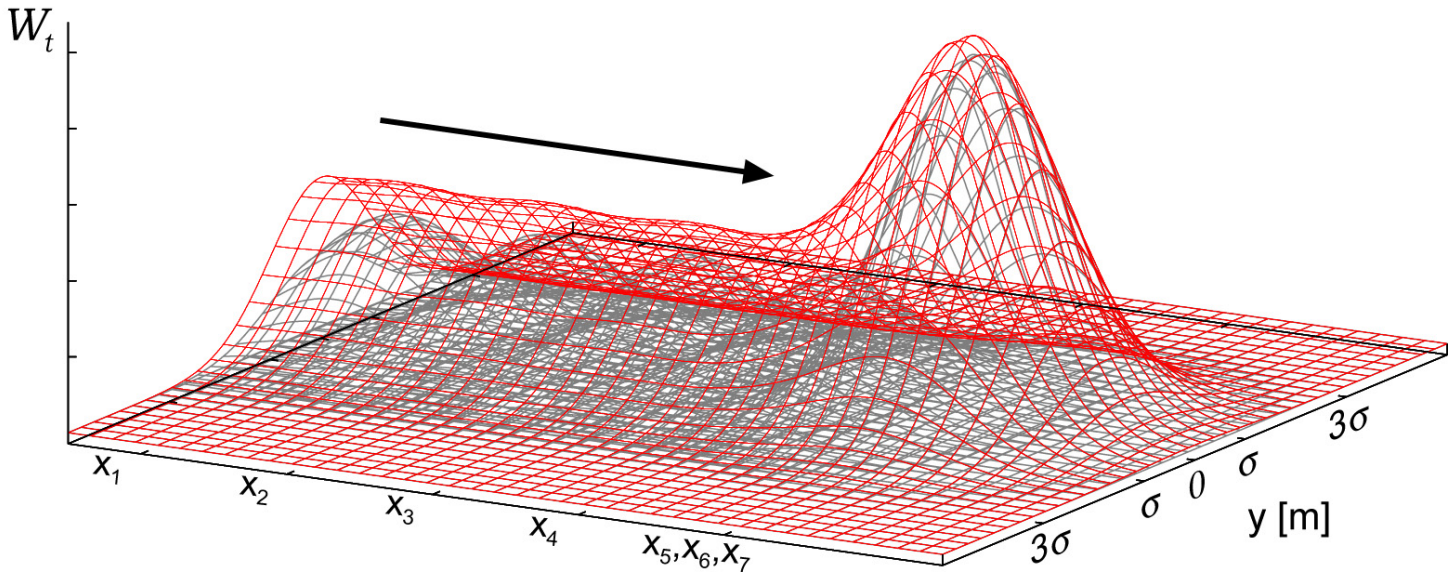
3 Creating Concentration Gridmaps

- Extrapolation on Sequential Readings



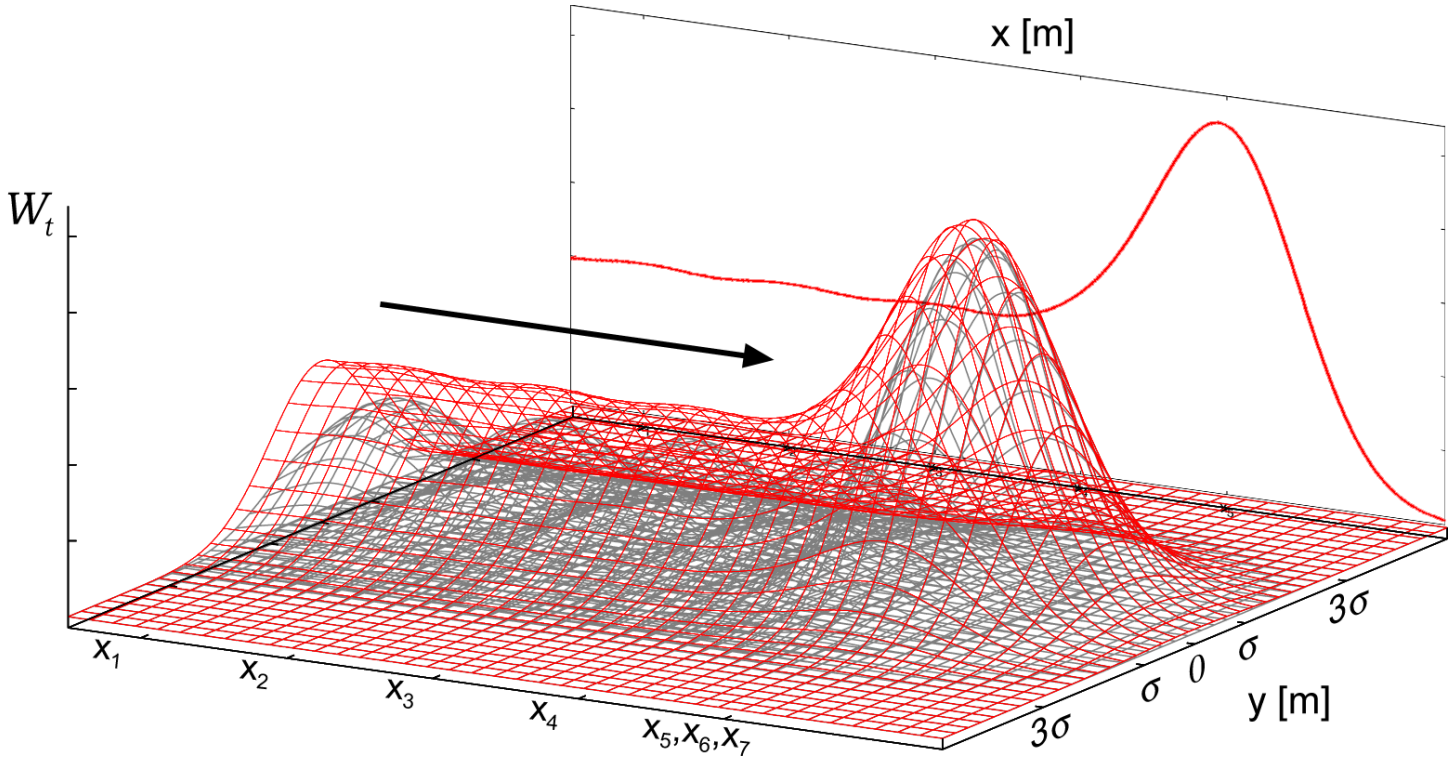
3 Creating Concentration Gridmaps

- Extrapolation on Sequential Readings



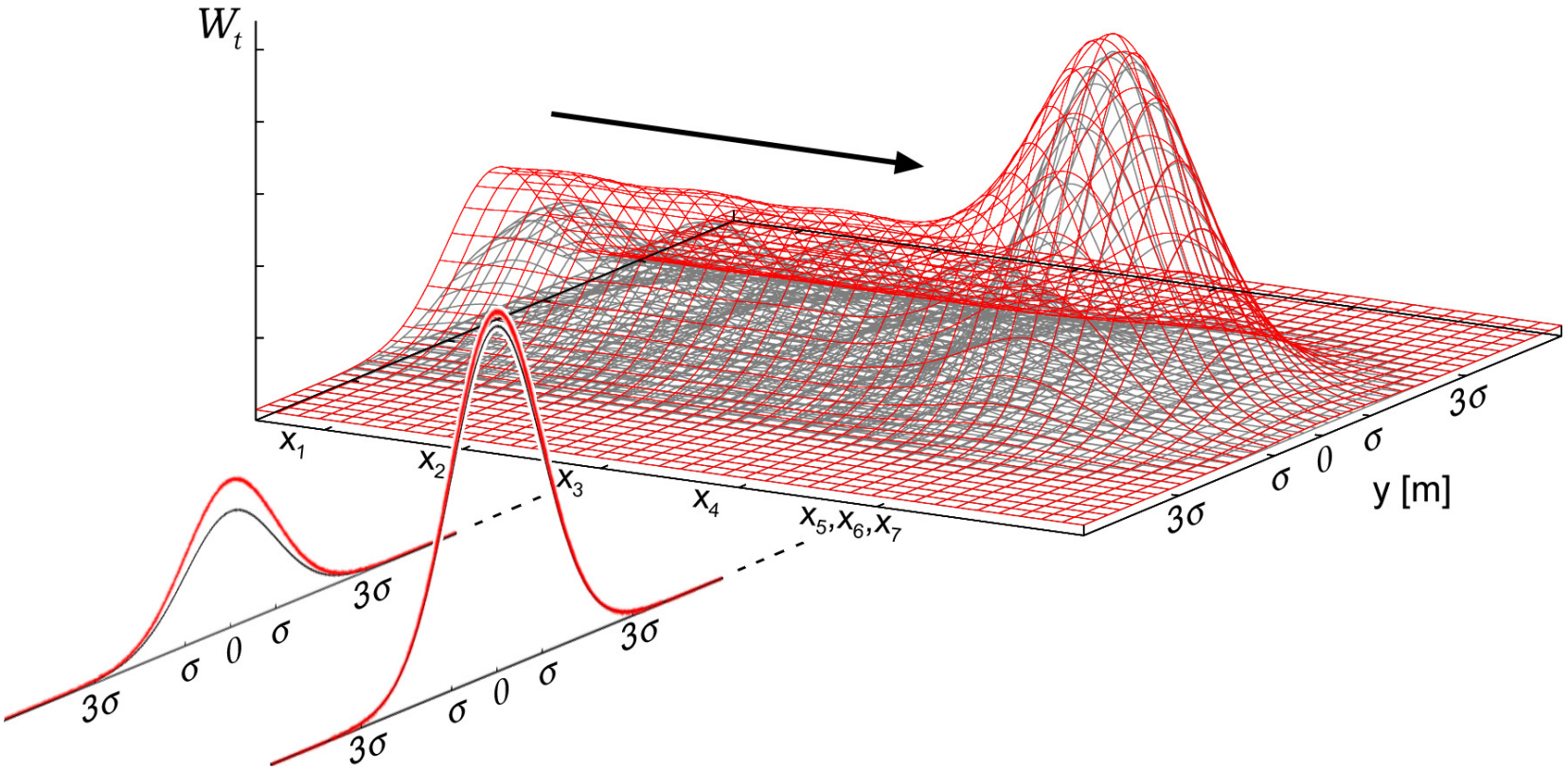
3 Creating Concentration Gridmaps

- Constant Weight along the driven Path



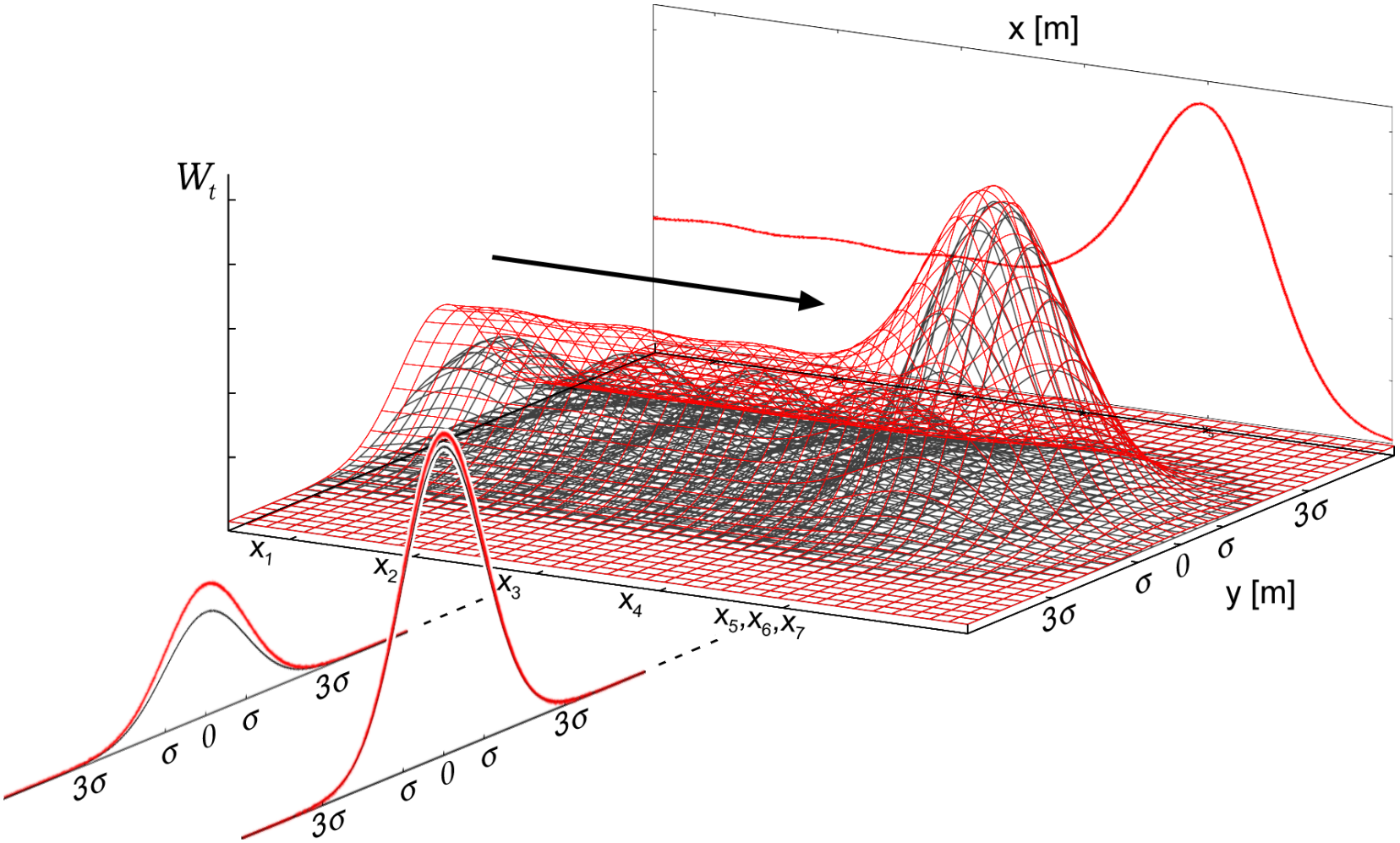
3 Creating Concentration Gridmaps

- Low Velocity → Higher Weight



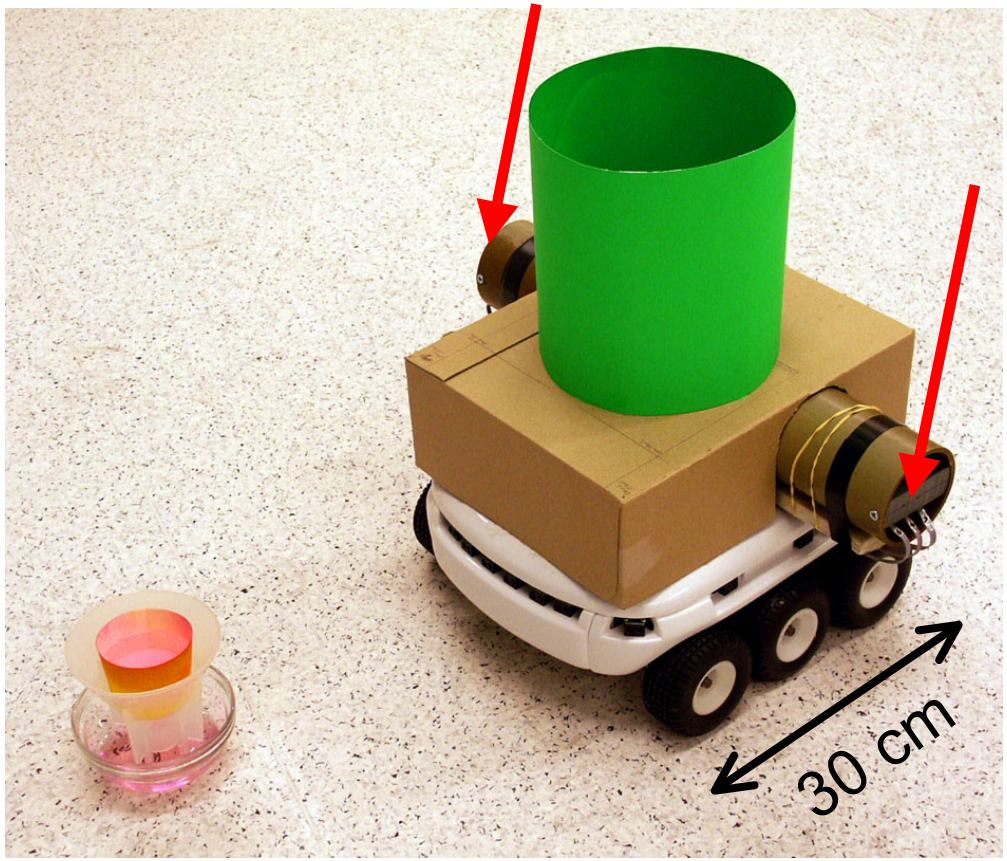
3 Creating Concentration Gridmaps

- Extrapolation on Sequential Readings



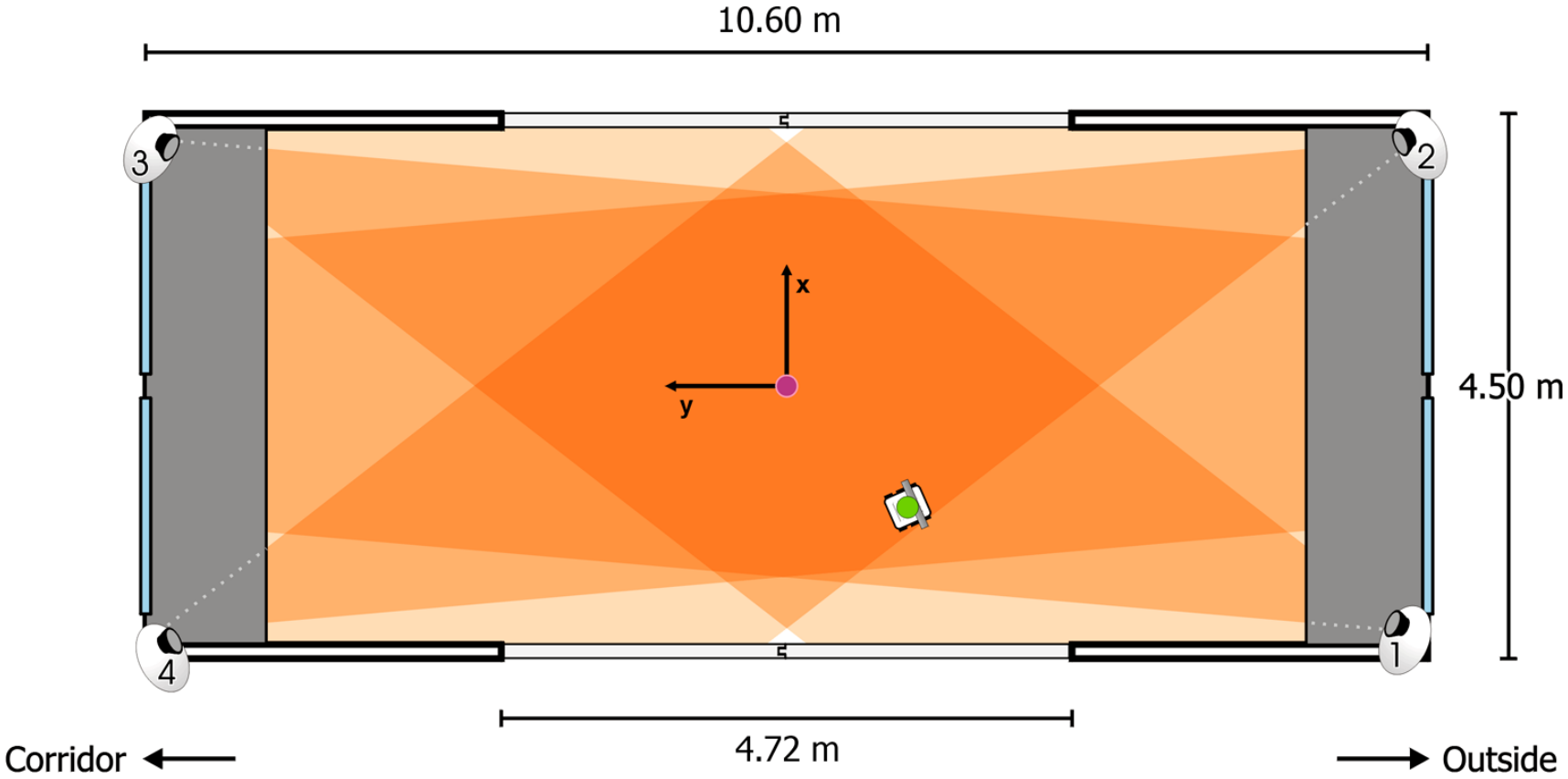
4 Experimental Setup – Mark III Mobile Nose

- 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

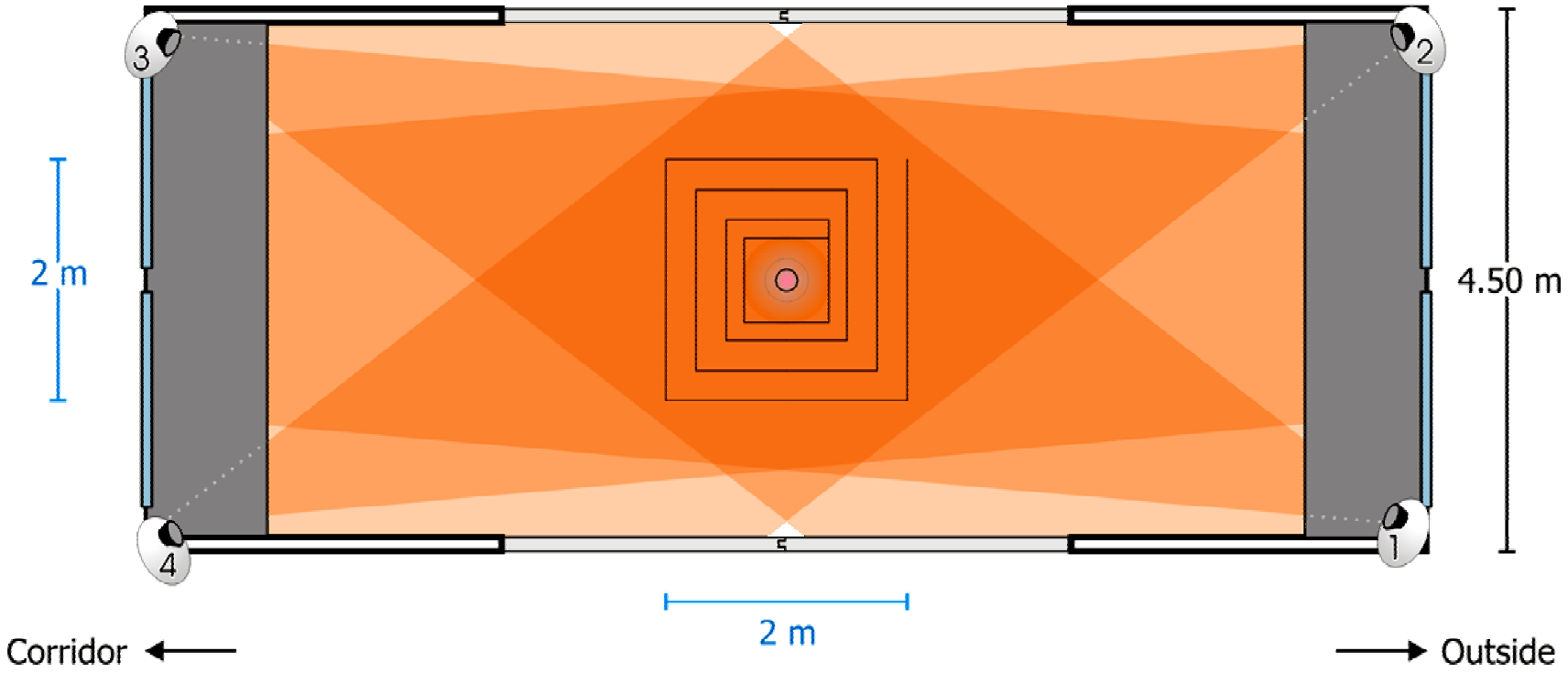


4 Experimental Setup – Data Acquisition

- 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

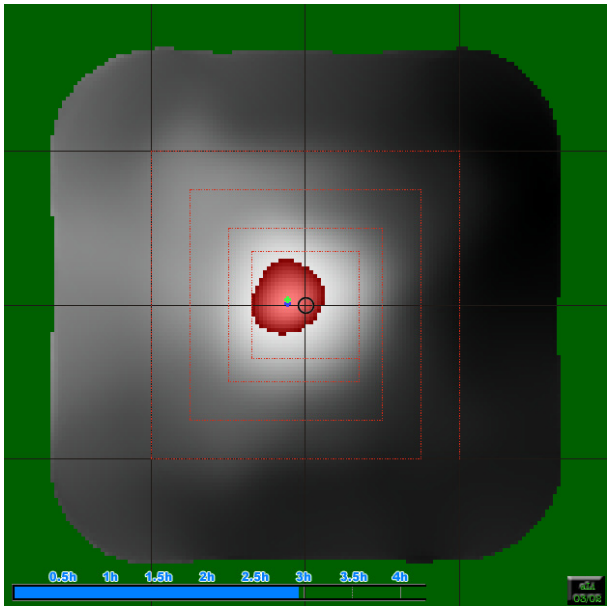
4 Experimental Setup – Data Acquisition

- Predefinded Path – Rectangular Spiral

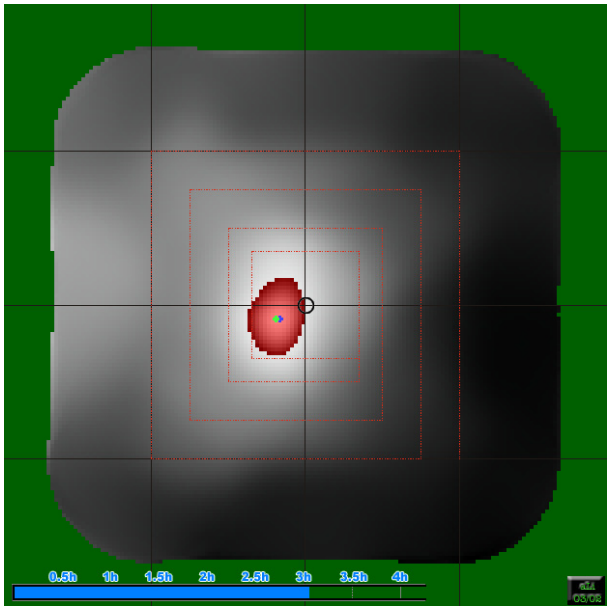


5 Results

Predefinded Path – Rectangular Spiral



2003 / 06 / 02



2003 / 06 / 03

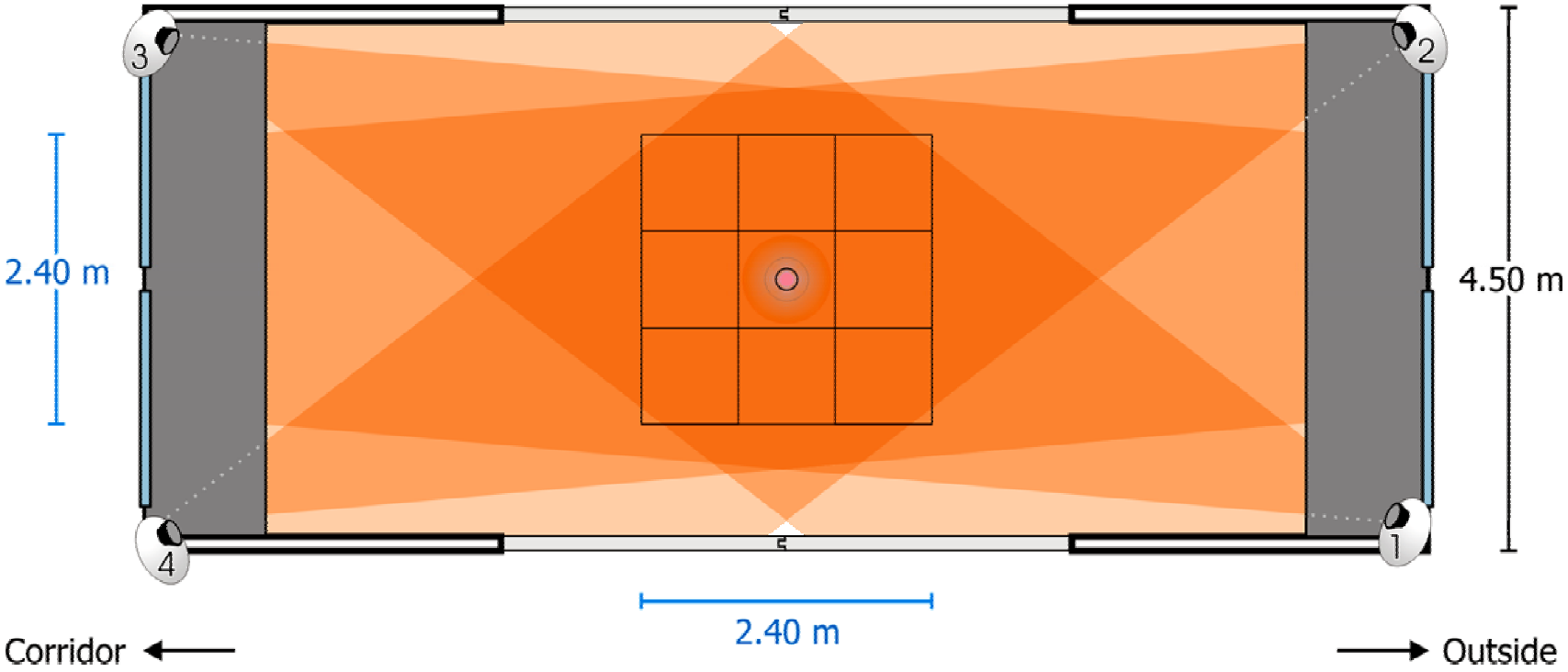
2003 / 06 / 04

5 Results

- Predefinded Path – Rectangular Spiral

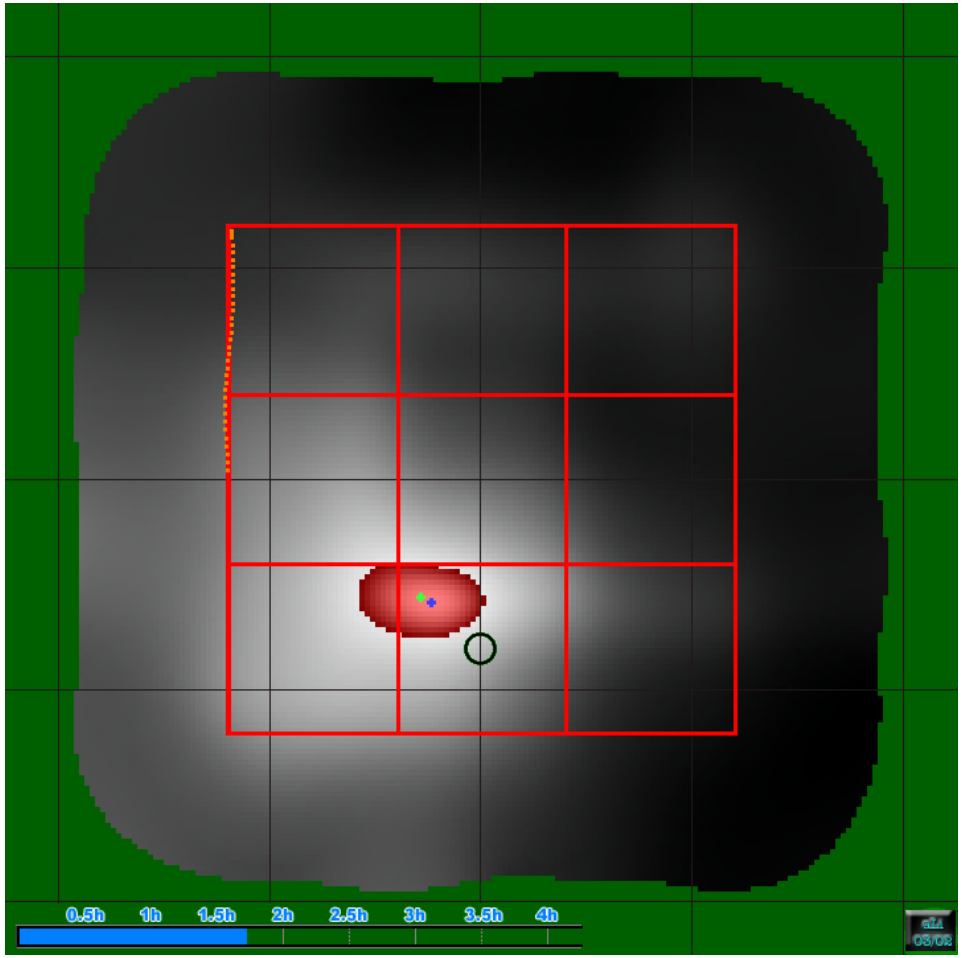
9 Gas Source Localisation

- Predefinded Path – Sweeping – w = 80 cm



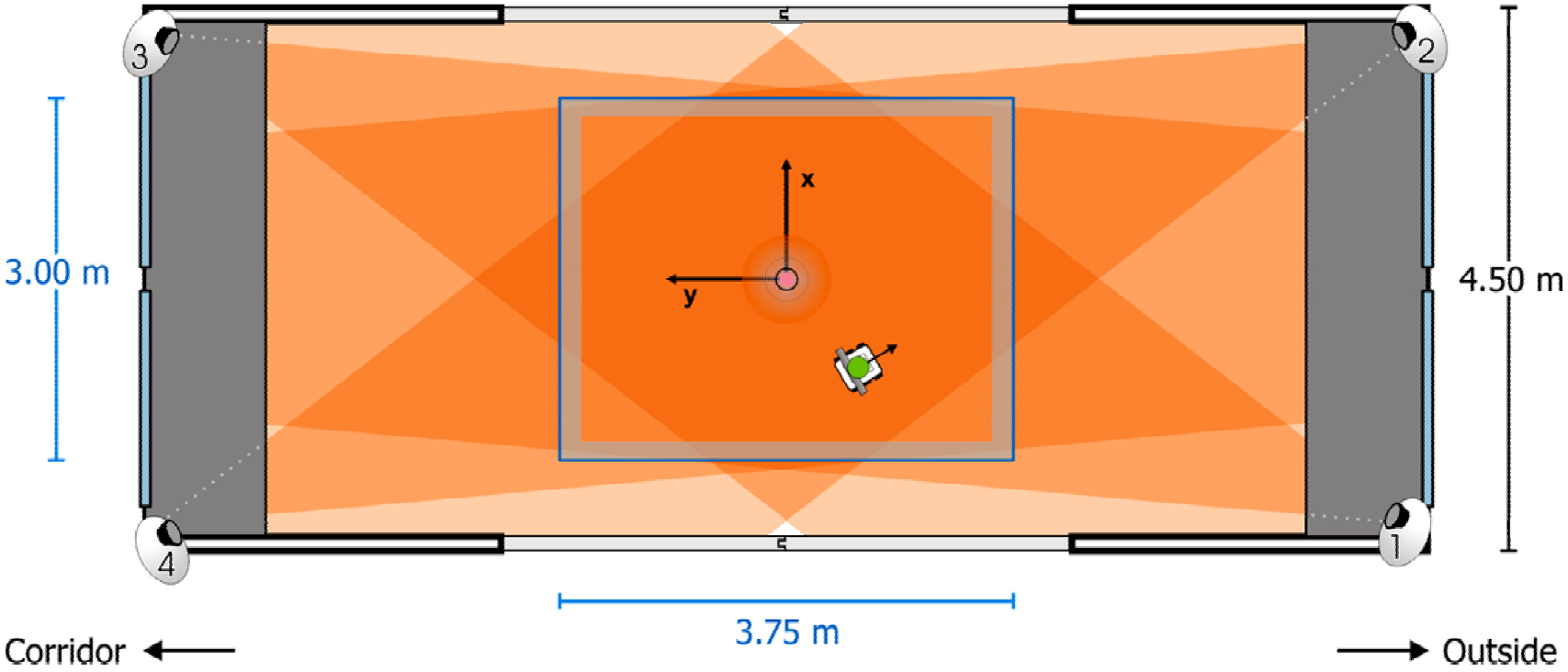
5 Results

- Predefinded Path – Sweeping Movement

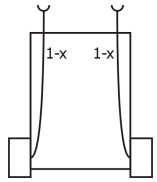


5 Results

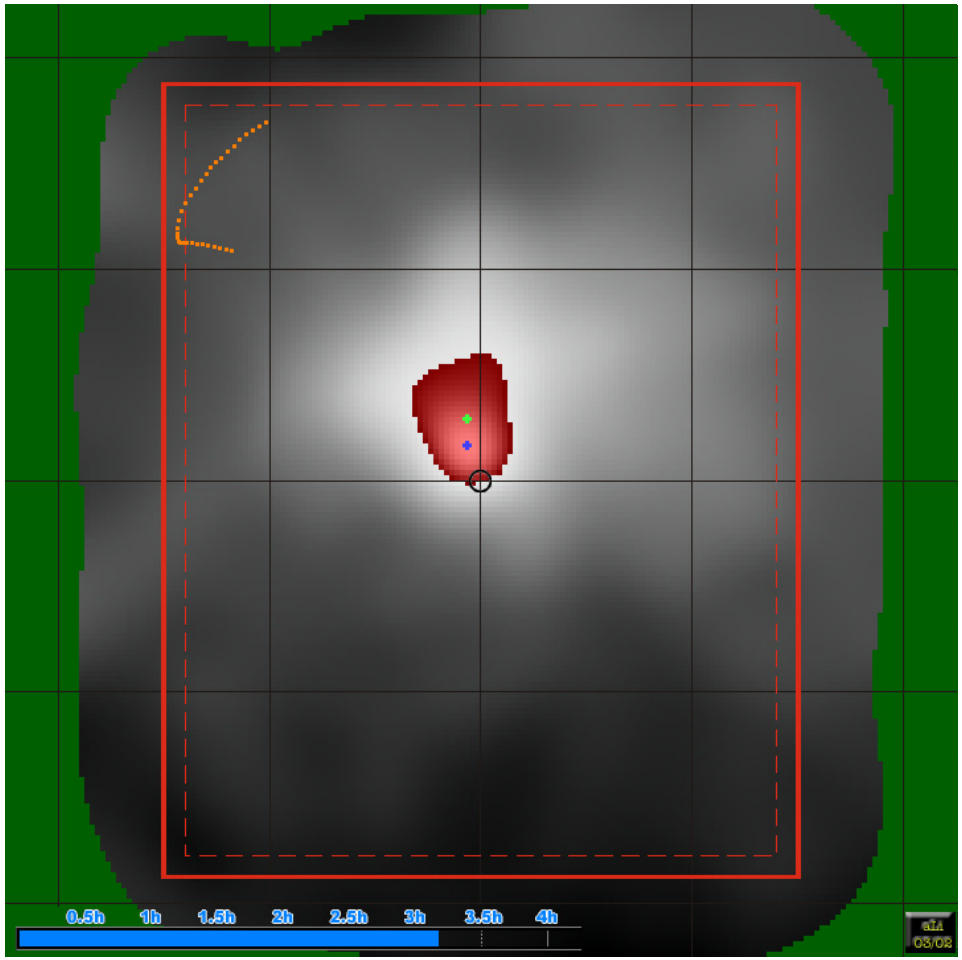
Reactive Strategy – Braitenberg Vehicle



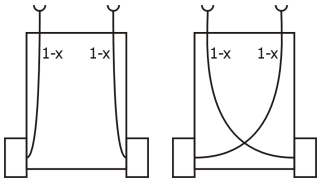
5 Results



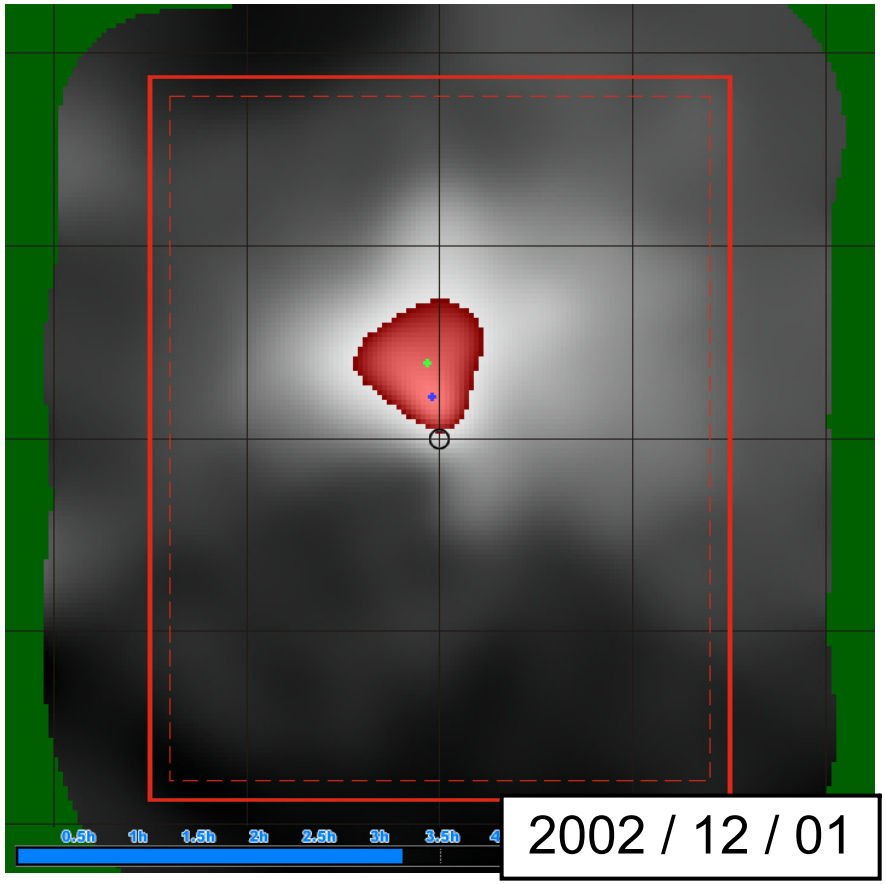
- Reactive Strategy – Braitenberg Vehicle

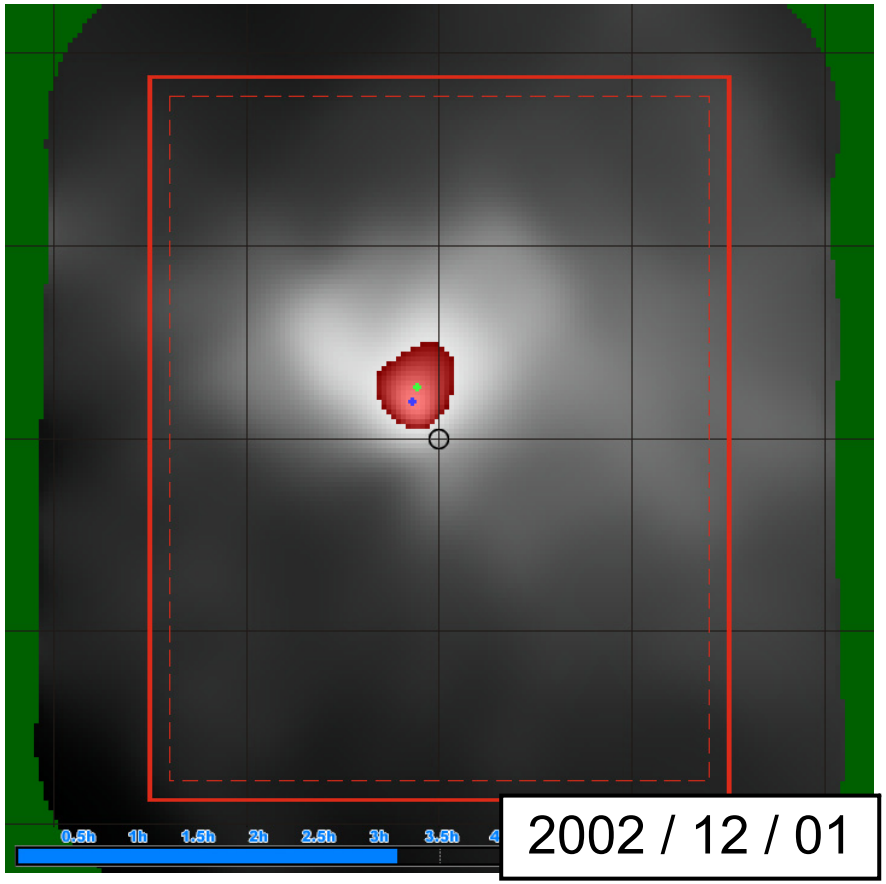


5 Gas Source Localisation

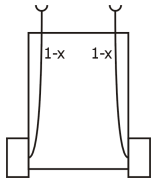


Reactive Strategy – Braitenberg Vehicle

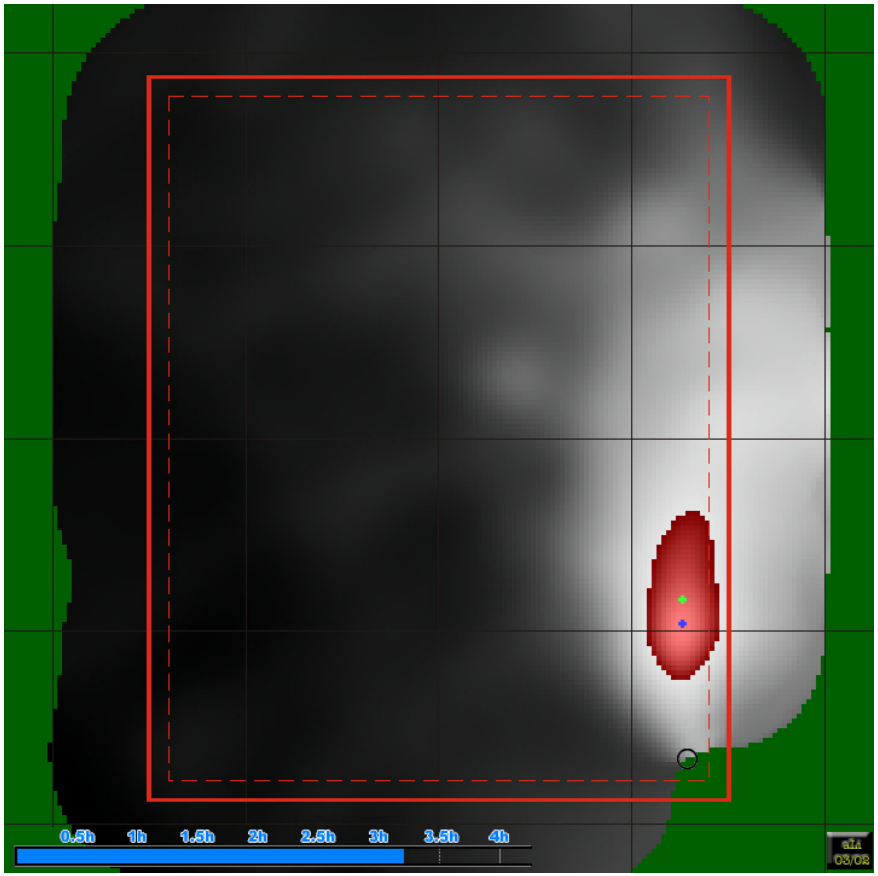




5 Gas Source Localisation



- Reactive Strategy – Braitenberg Vehicle



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!