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Approaches to Gas Source Tracing and Declaration by Pure Chemo-Tropotaxis

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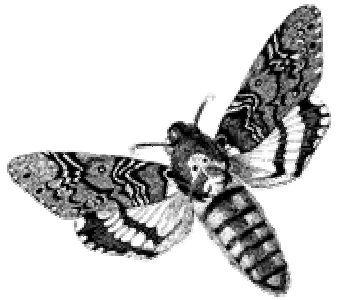
Contents

1 Motivation – Gas Source Localisation

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



- Mobile Nose - Applications
  - cover larger scale environments
  - inspection robot with smelling ability
  - use in rescue robots

2 Subtasks of Gas Source Localisation

- Gas Finding
  - detecting an increased concentration
- Source Tracing
  - following the cues towards the gas source
- Source Declaration
  - determining the certainty that a source was found

2 Subtasks of Gas Source Localisation

- Gas Finding
  - detecting an increased concentration
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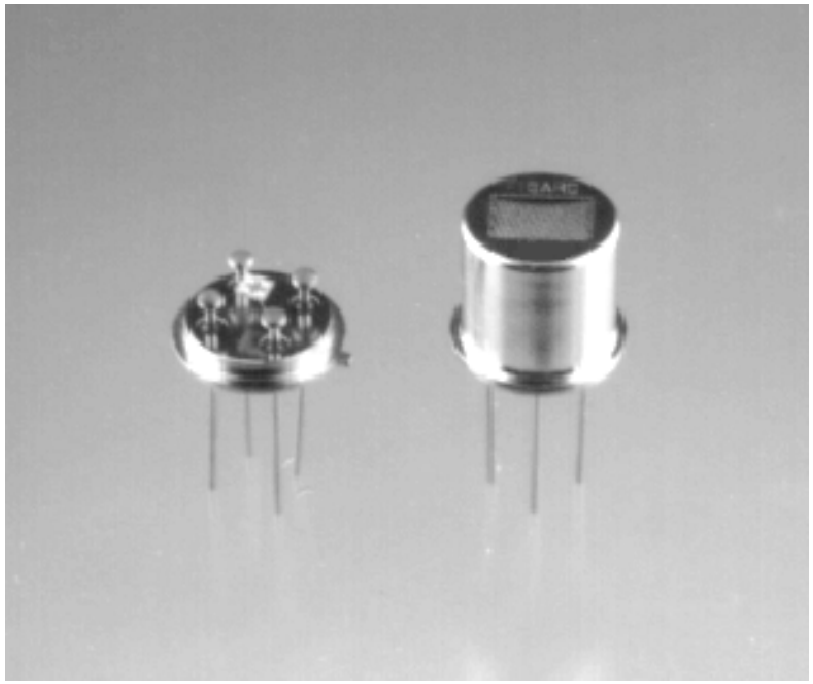
  - following the cues towards the gas source

Chemo-Tropotaxis ?

- Source Declaration
  - determining the certainty that a source was found

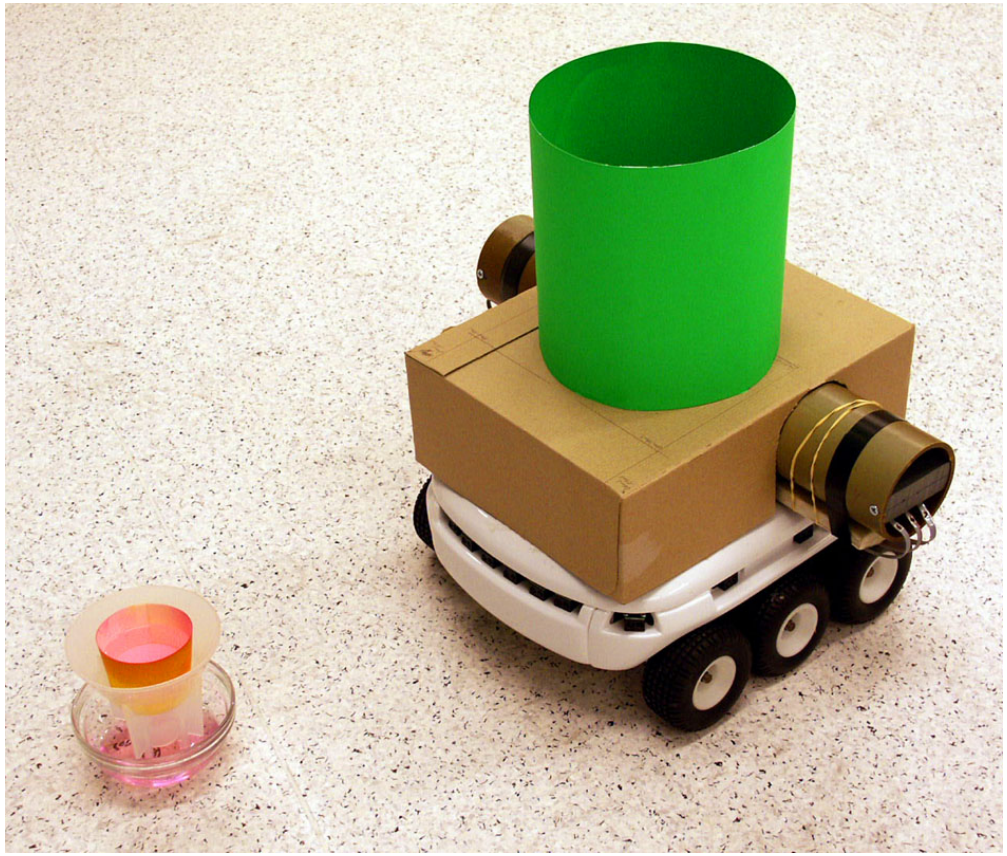
3 Main Problems: Gas Sensors

- Metal Oxide Gas Sensors (MOX)
  - doped semiconducting surface layer
  - heating element
- Pros and Cons
  - high sensivity
  - inexpensive
  - low selectivity



3 Main Problems: MOX Gas Sensors

- Delayed Response
  - $\tau_r \approx 1.8$ s
- Long Recovery
  - $\tau_d^{(fans)} \approx 11.1$ s

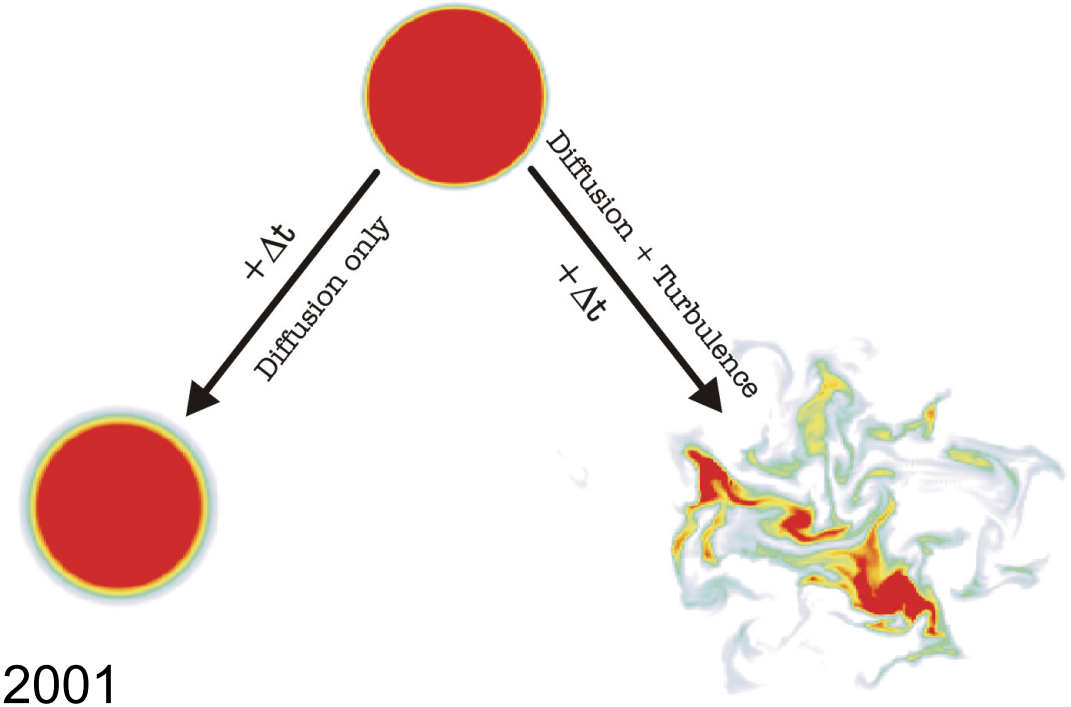


3 Environment

- Uncontrolled Indoor Environment …
  - diffusion (neglectable)
  - convective airflow
  - turbulence
- … Without a Strong Unidirectional Airflow
  - detection limit of current state-of-the-art anemometres too low

3 Main Problems: Turbulent Distribution

- Instantaneous Distribution ≠ Average Distribution



Smyth & Moum 2001

3 Main Problems: Turbulent Distribution

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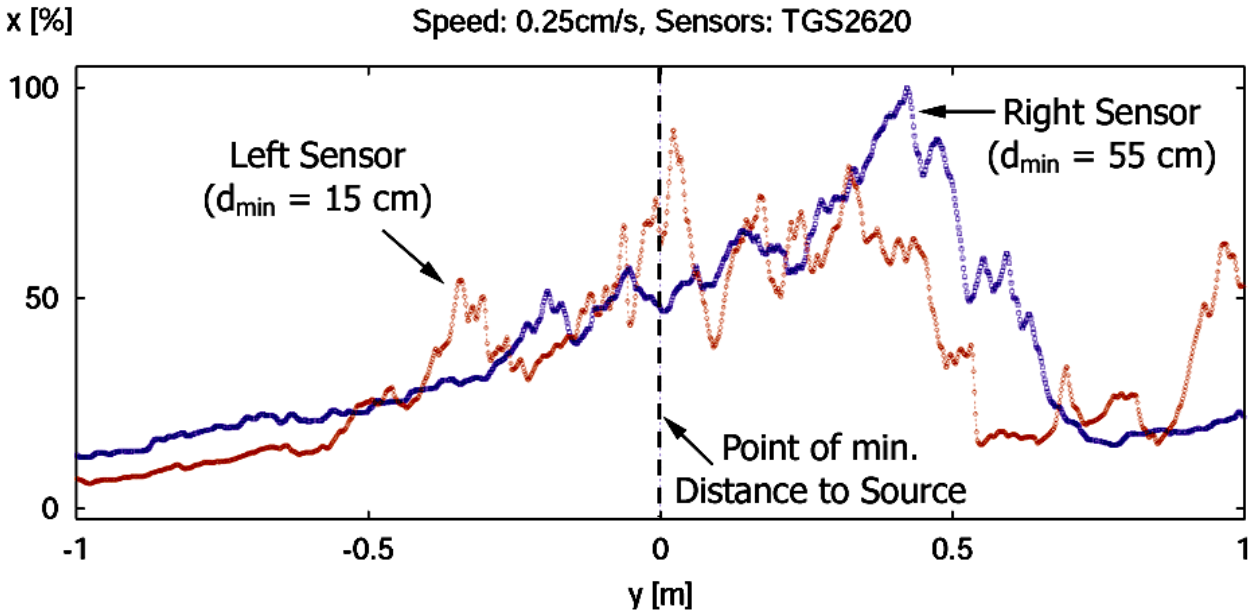
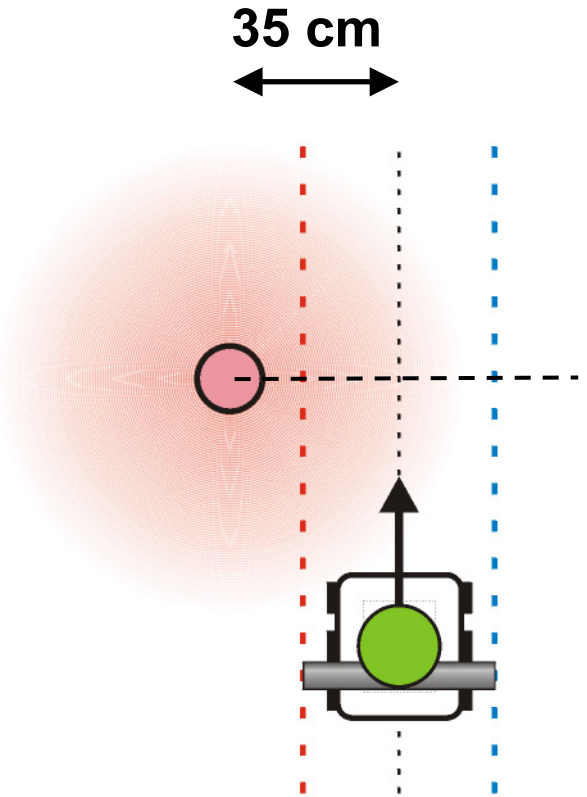
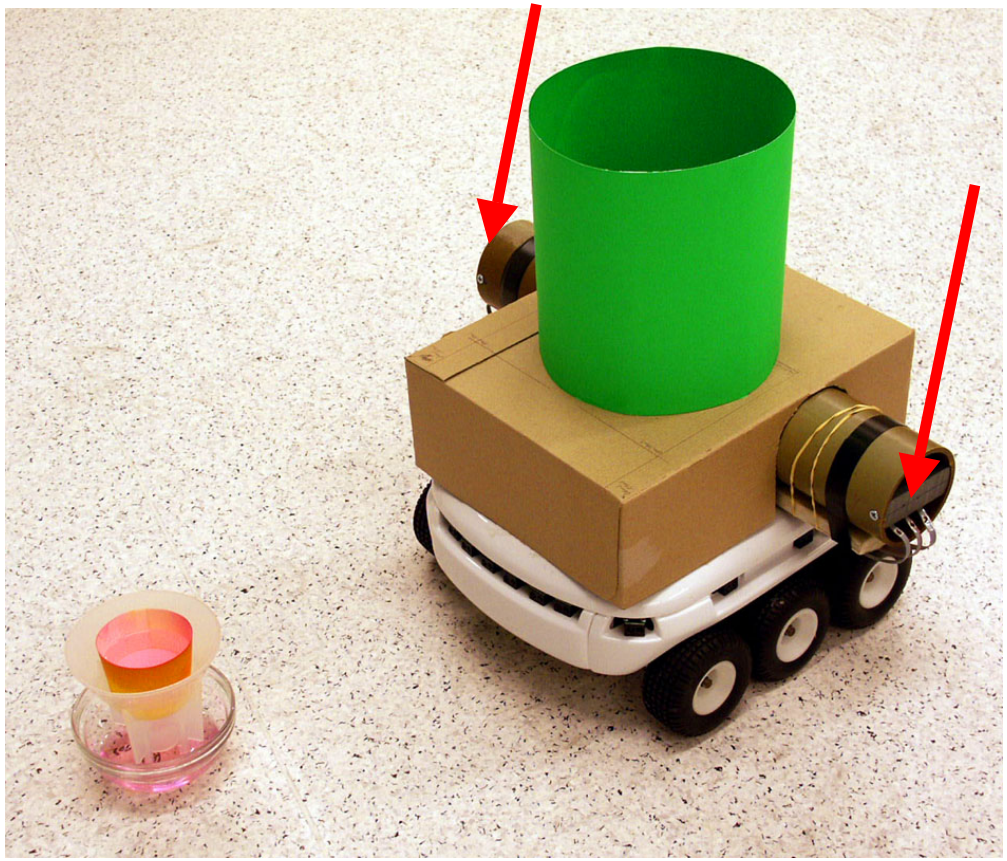




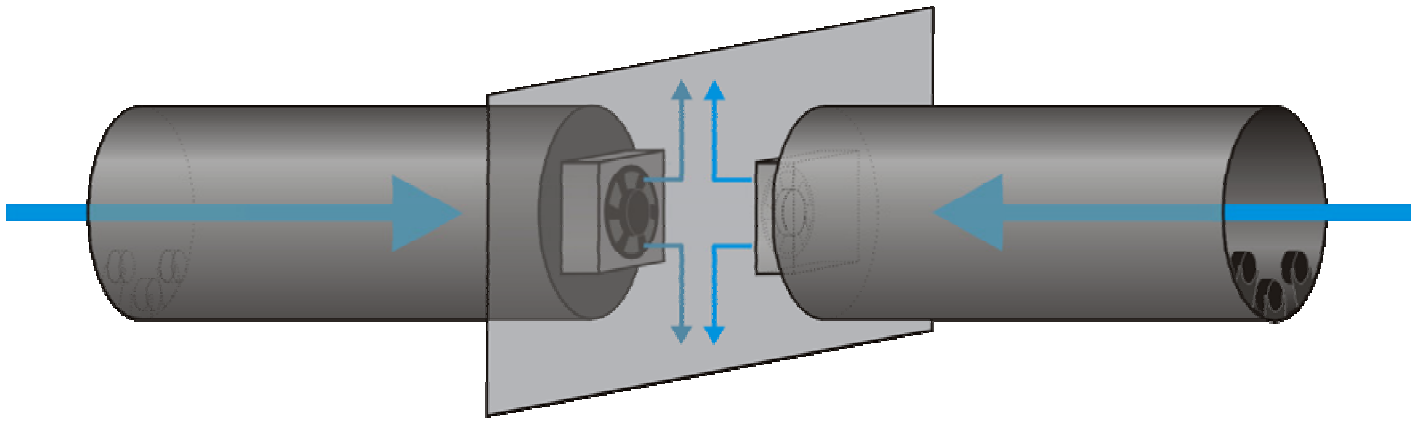
4 Exp. Setup: Mark III Mobile Nose

- Stereo Architecture
  - 2 equivalent sets
    - Figaro TGS 2600
    - Figaro TGS 2610
    - Figaro TGS 2620
  - 40 cm separation
  - suction fans



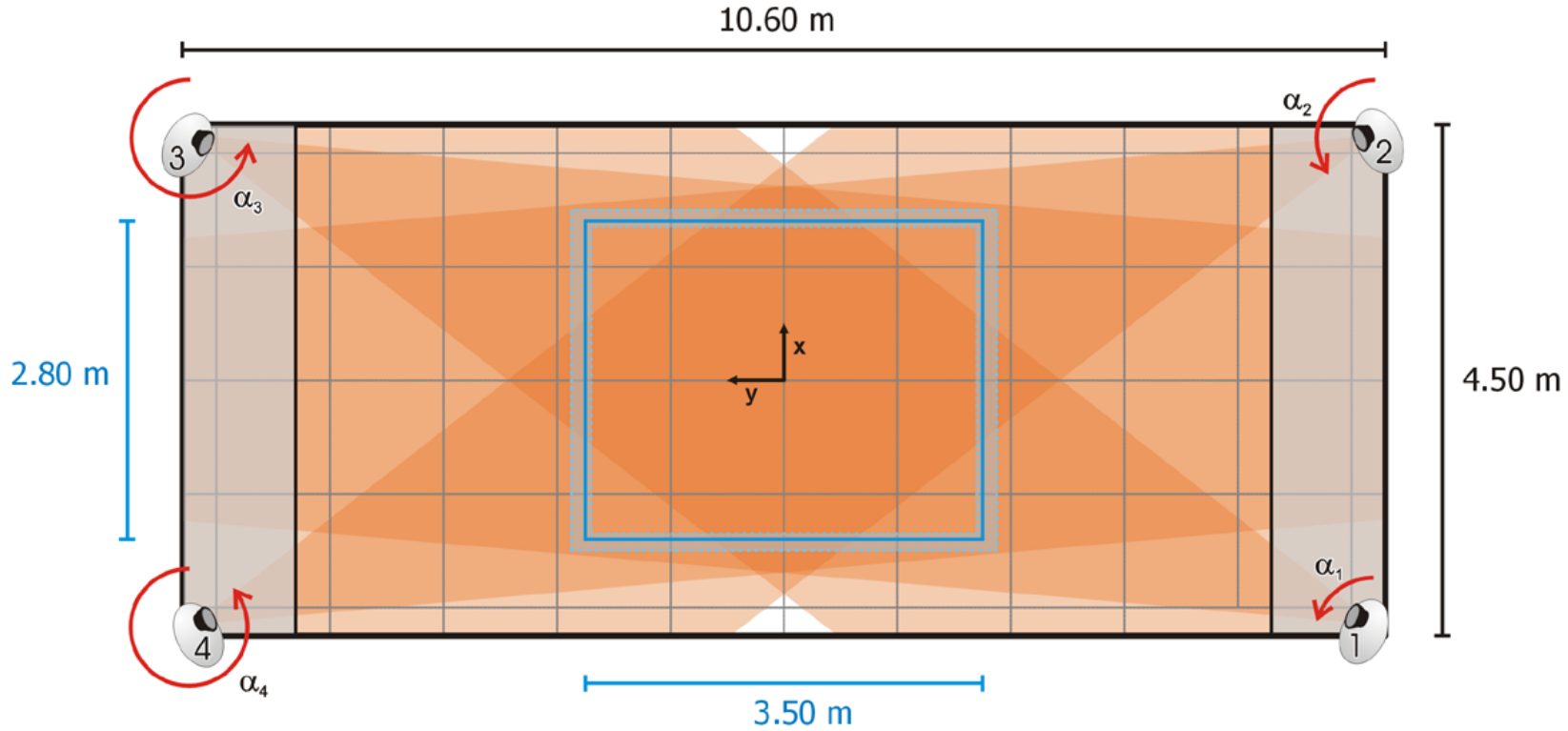
4 Exp. Setup: Mark III Mobile Nose

- Use of Suction Fans
  - Papst 405F (8 m^3/h)
  - fans directed against each other
  - use of a "septum" necessary



4 Expiremental Setup: Testbed

- A Testbed for Localisation Strategies



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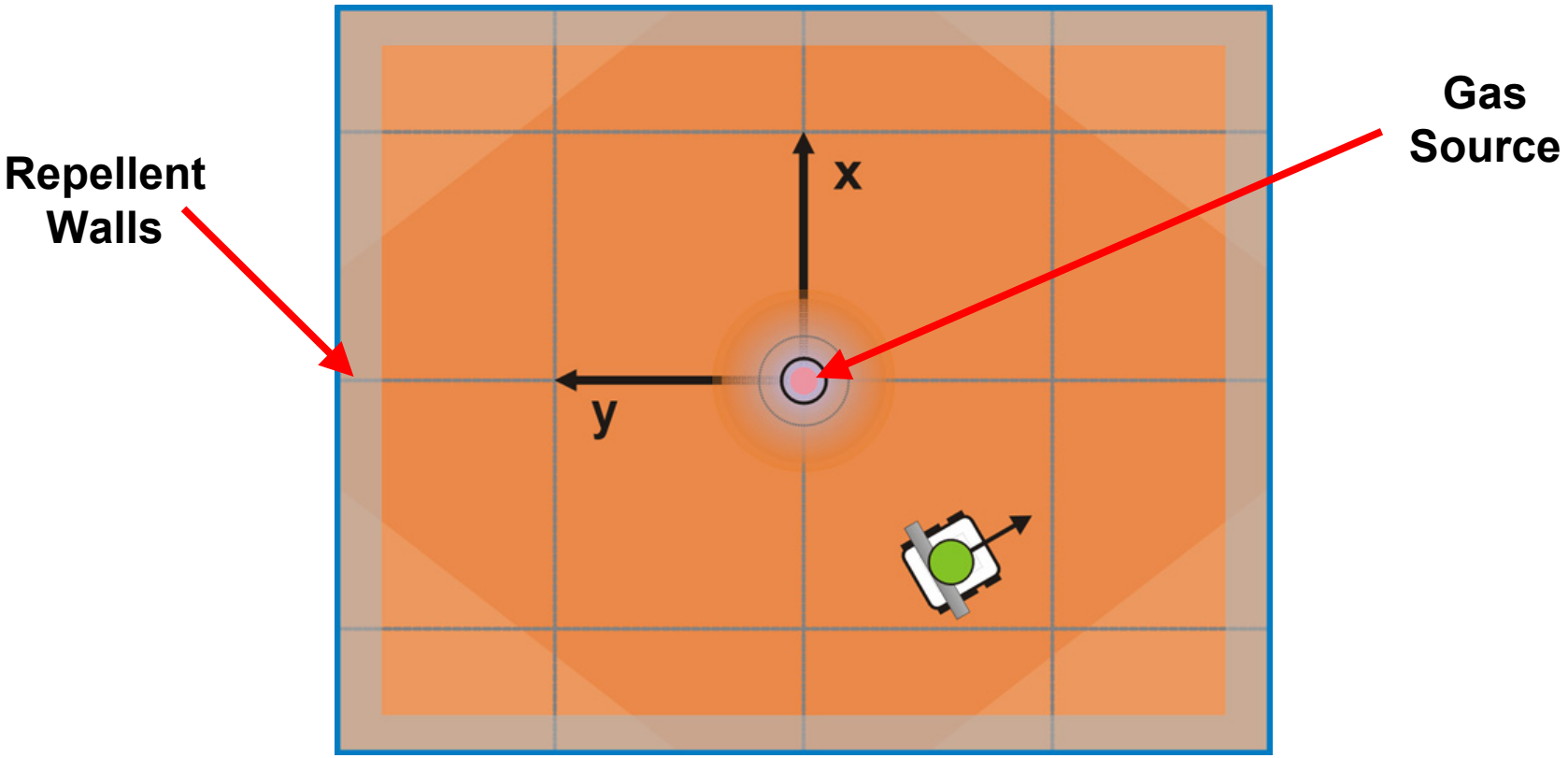
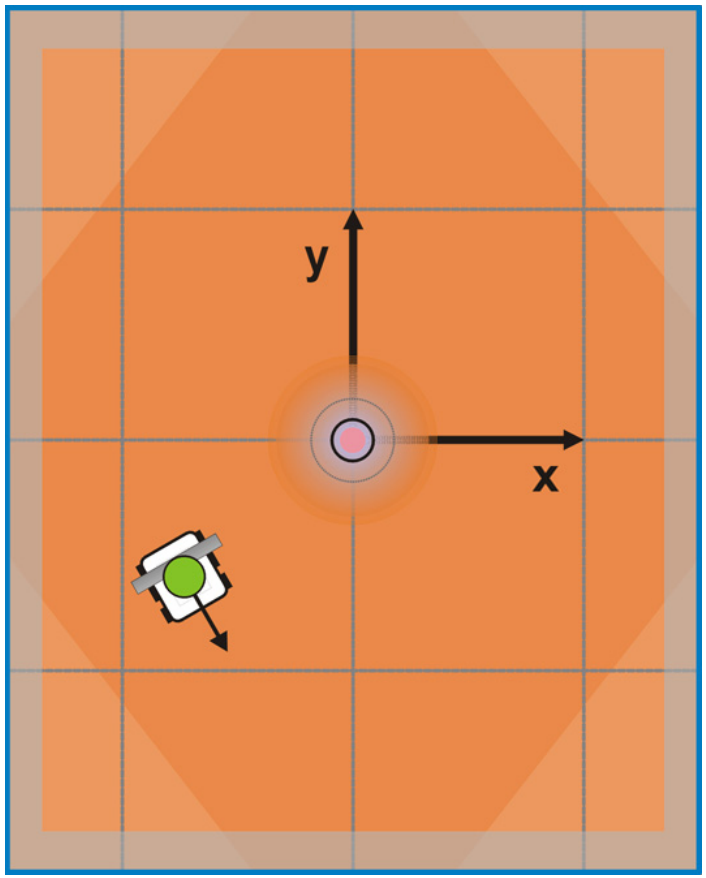


4 Expiremental Setup: Testbed

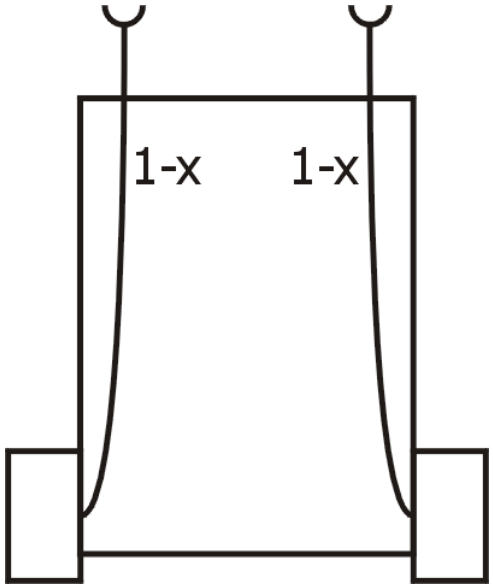
Gas Source Localisation Benchmark



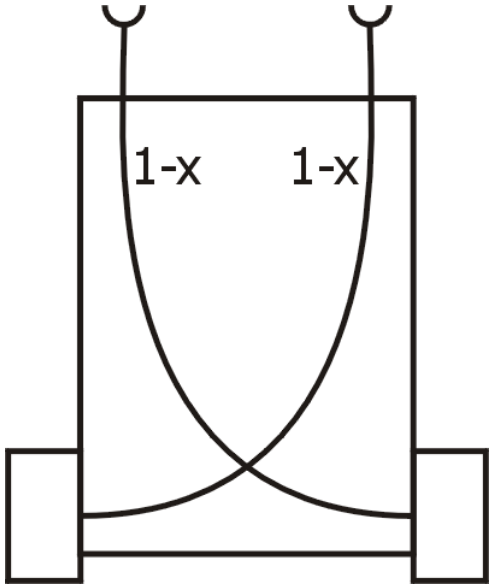
- Start
  - random starting position…
  - with min. distance of 100 cm
  - random heading
- Source is Found ...
  - … if robot would hit it
- Statistics
  - path length, wall bumps, ...

5 Chemo-Tropotaxis: Braitenberg Vehicle

- Connections: Monotonic, Inhibitory



“Permanent Love”



“Exploring Love”

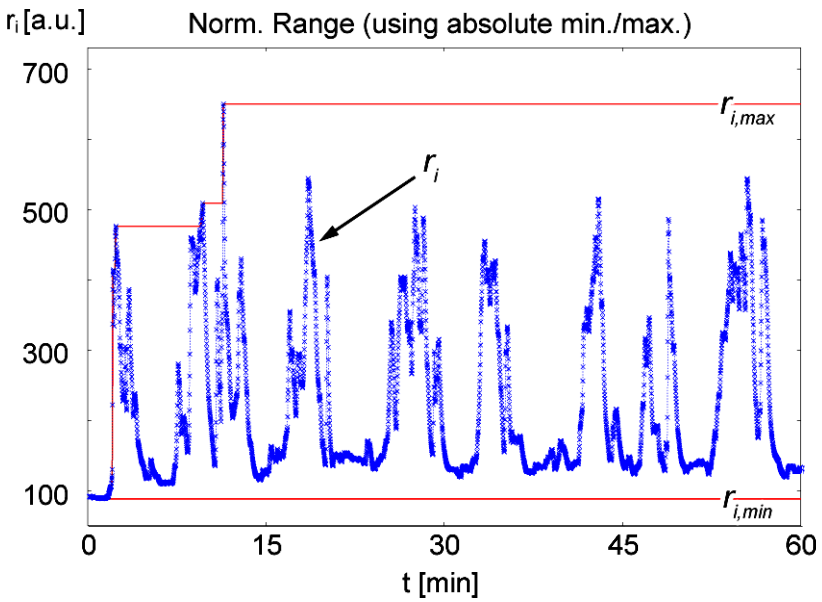
5 Data Preprocessing

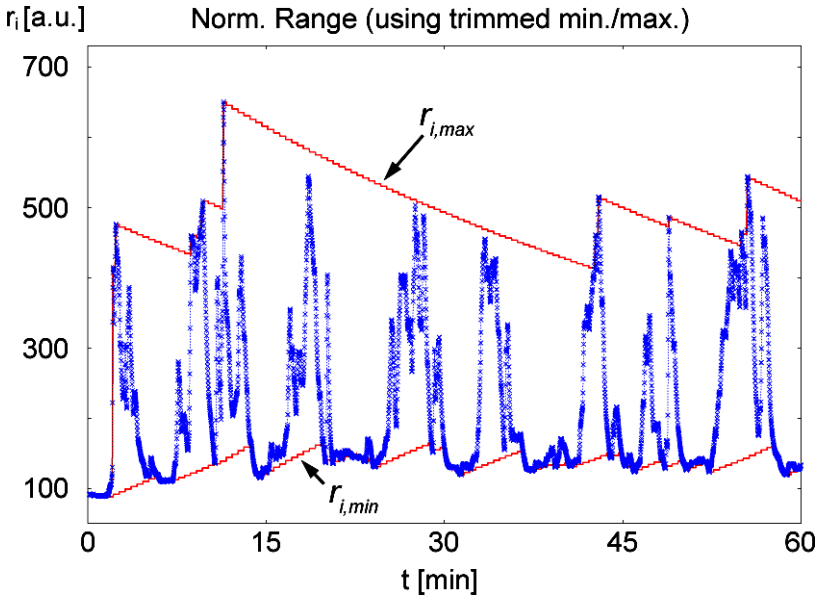
- How to Calculate x ?
  - differences between individual sensors
  - different environmental conditions
  - increasing base level of concentration

$$x_t = \frac{R_t - R_{min,t}}{R_{max,t} - R_{min,t}}$$

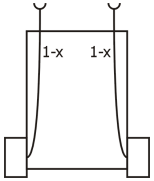
5 Data Preprocessing

- Update Minimum and Maximum Dynamically
  - trimming by 1% every 30 s





6 Results



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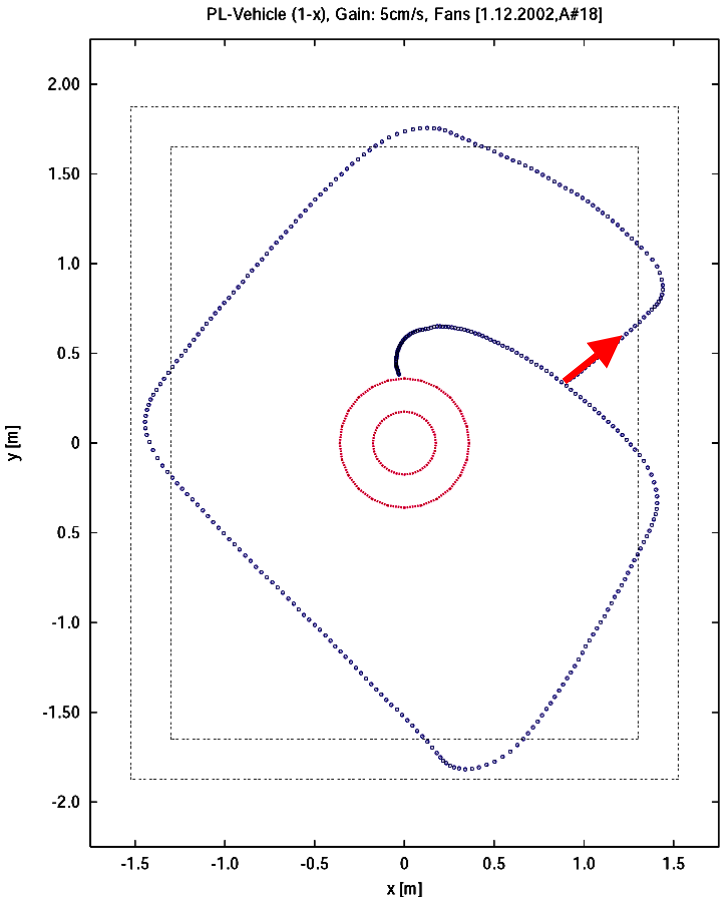

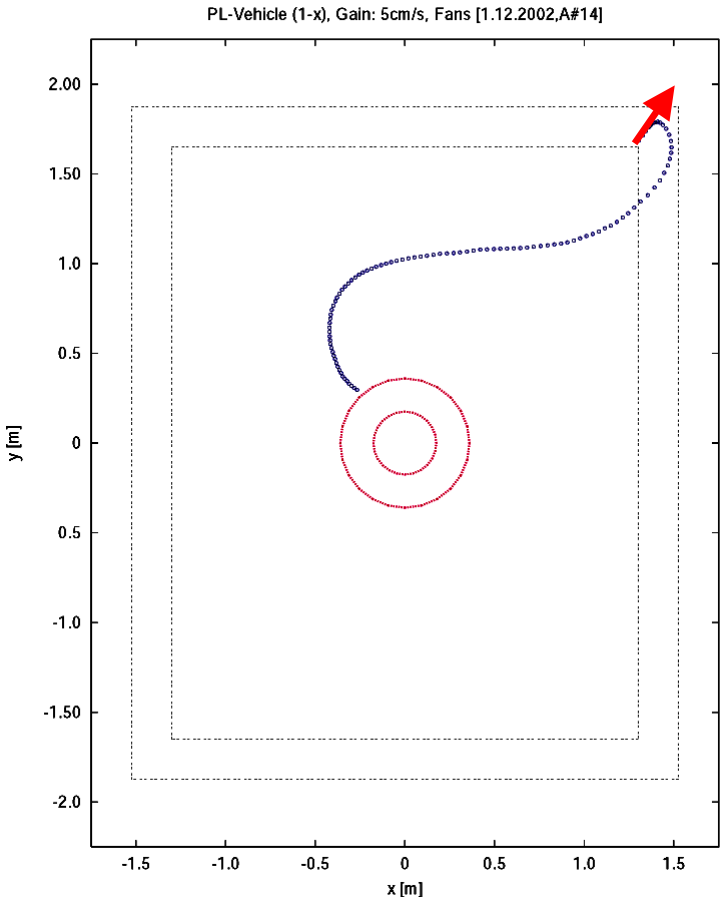

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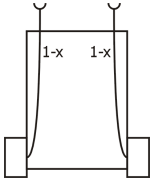

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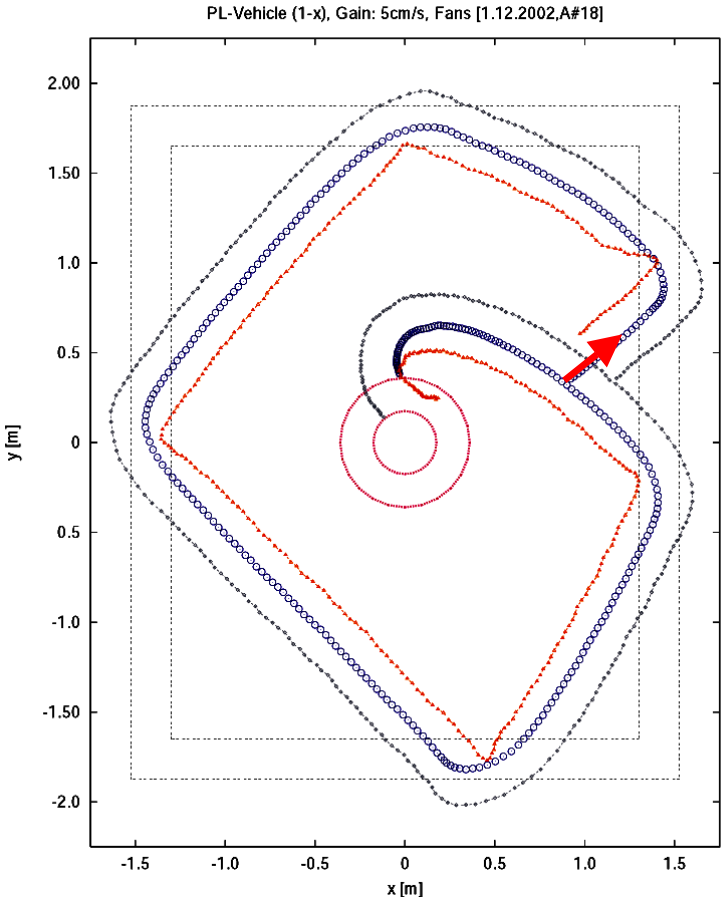

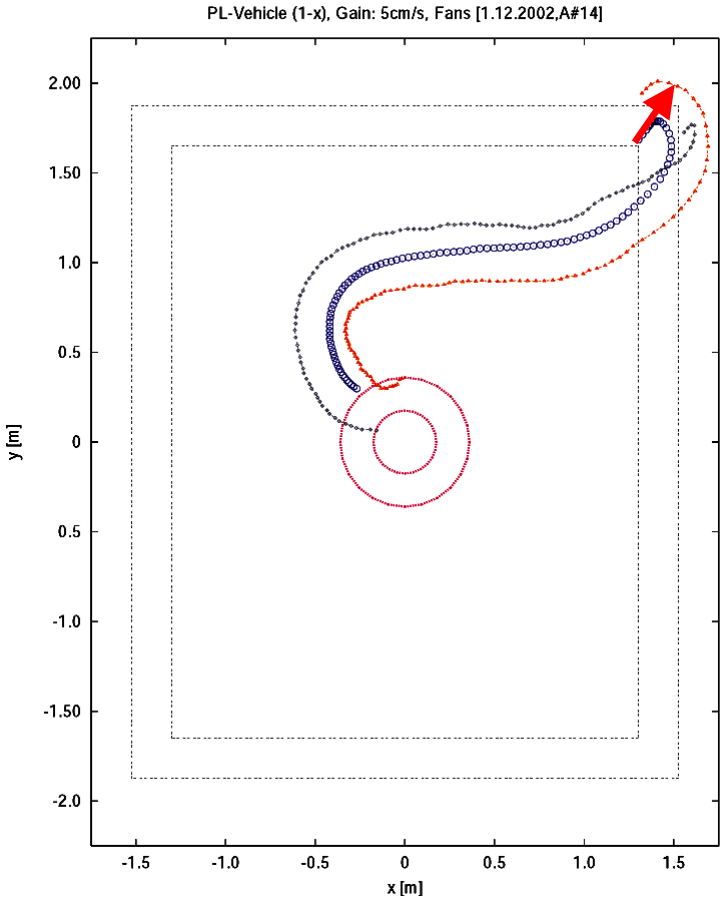

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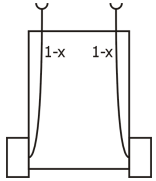

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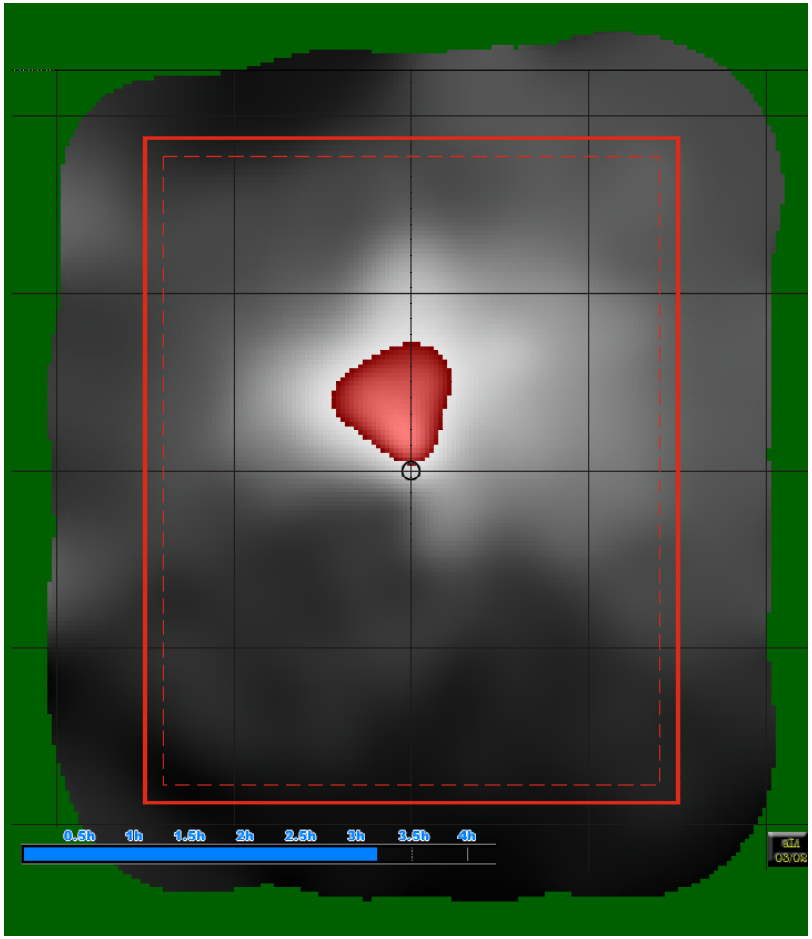

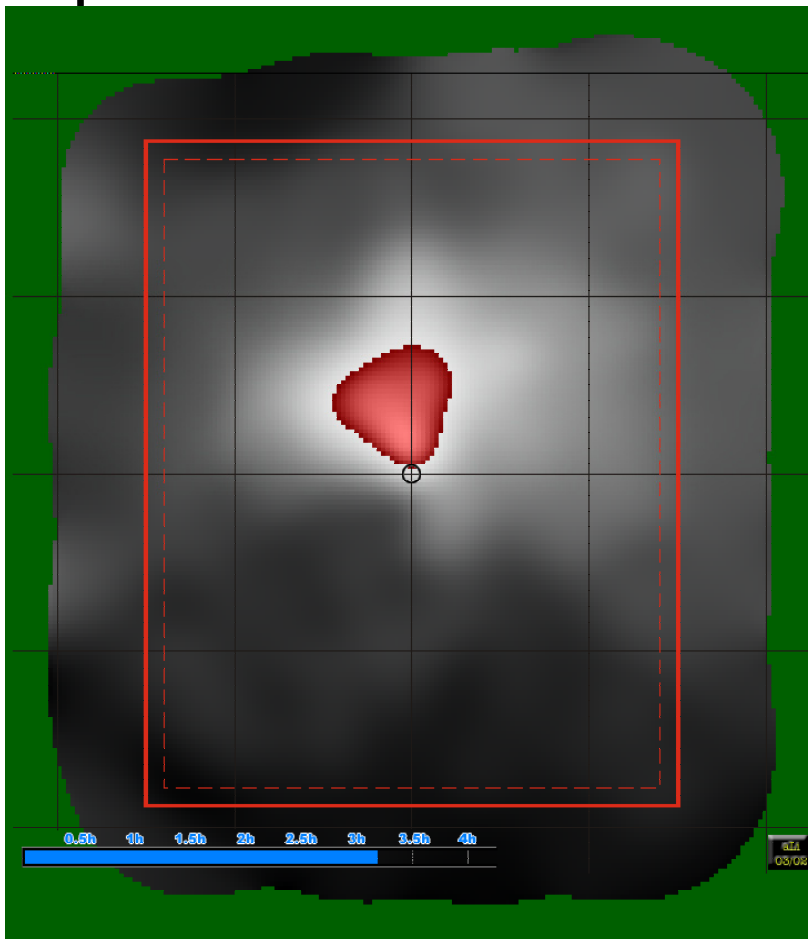

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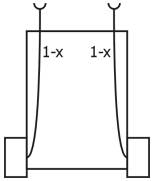

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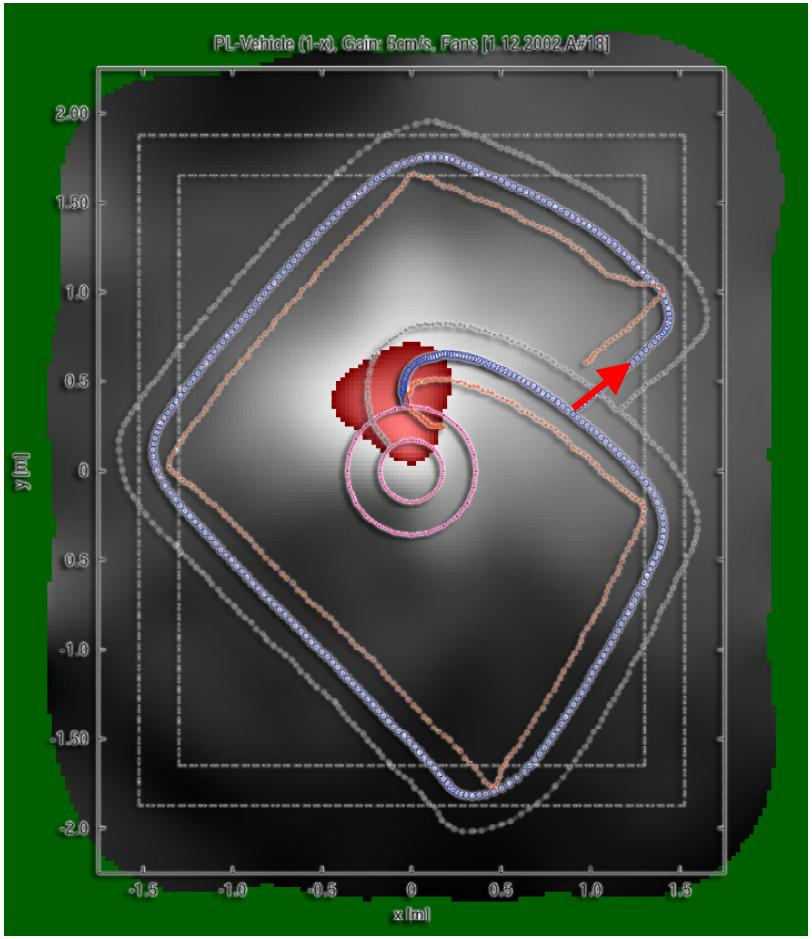

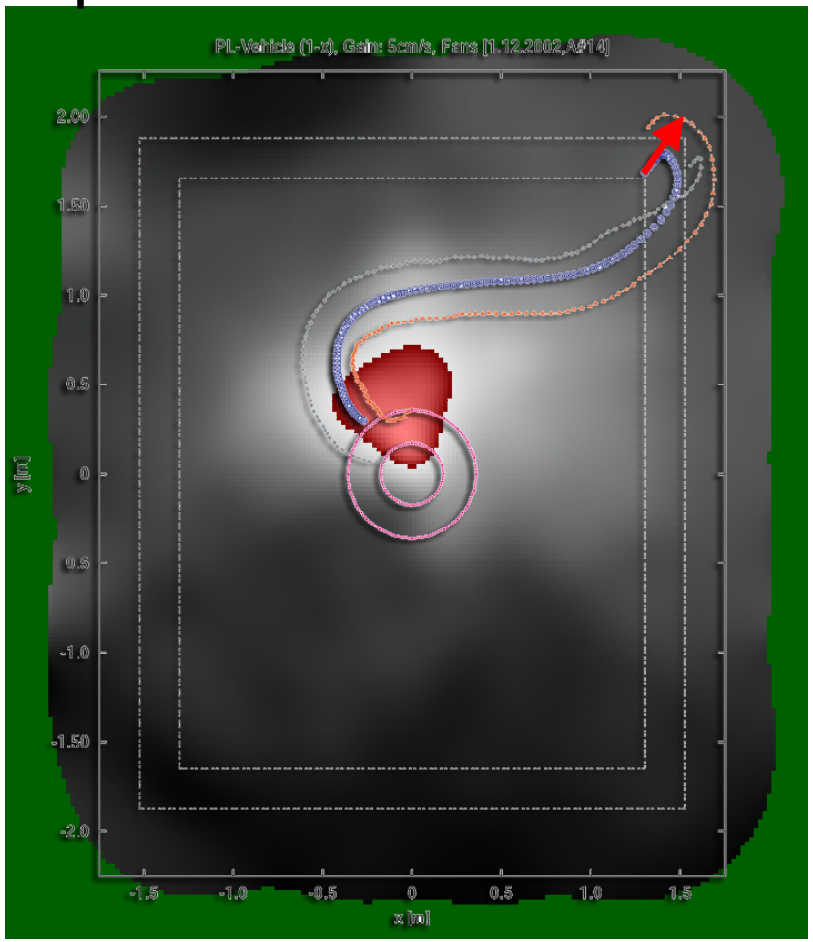

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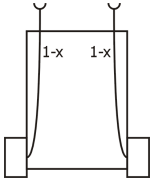
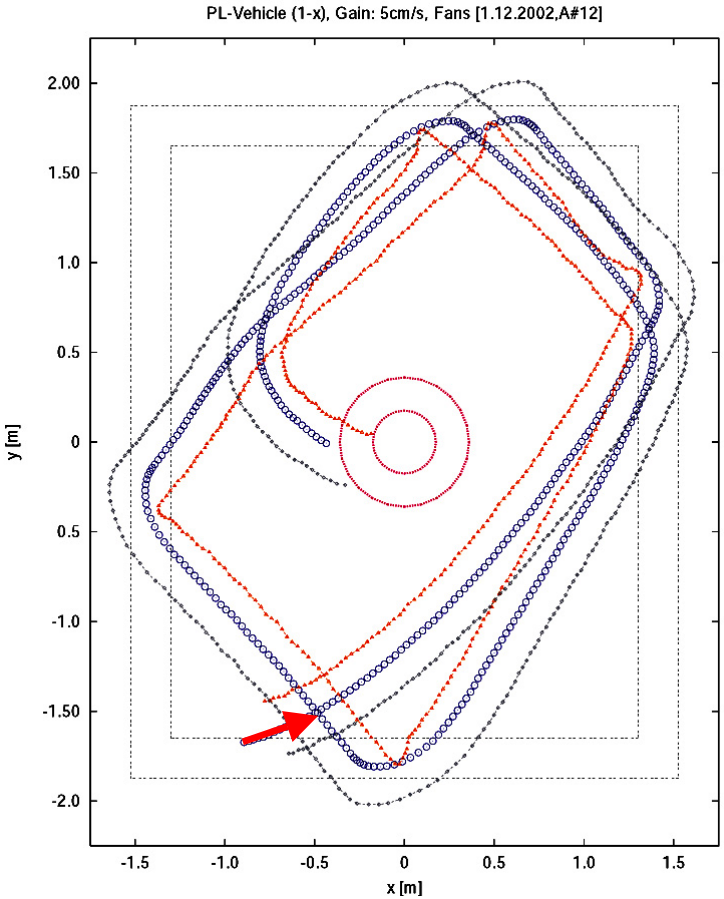
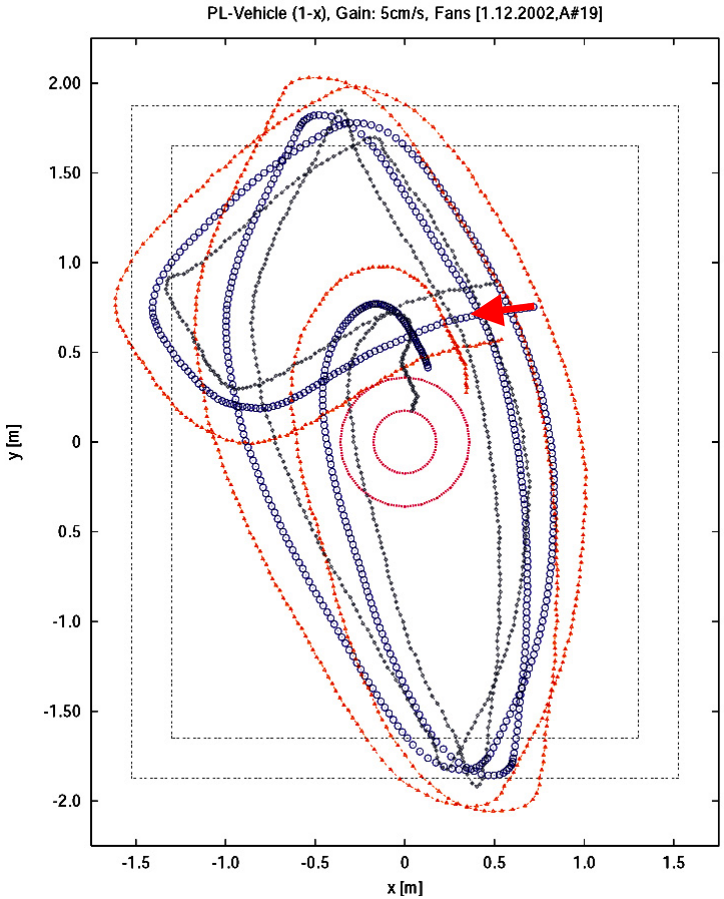


- … but sometimes changes are hard to explain





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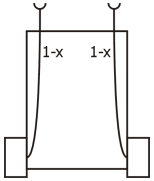

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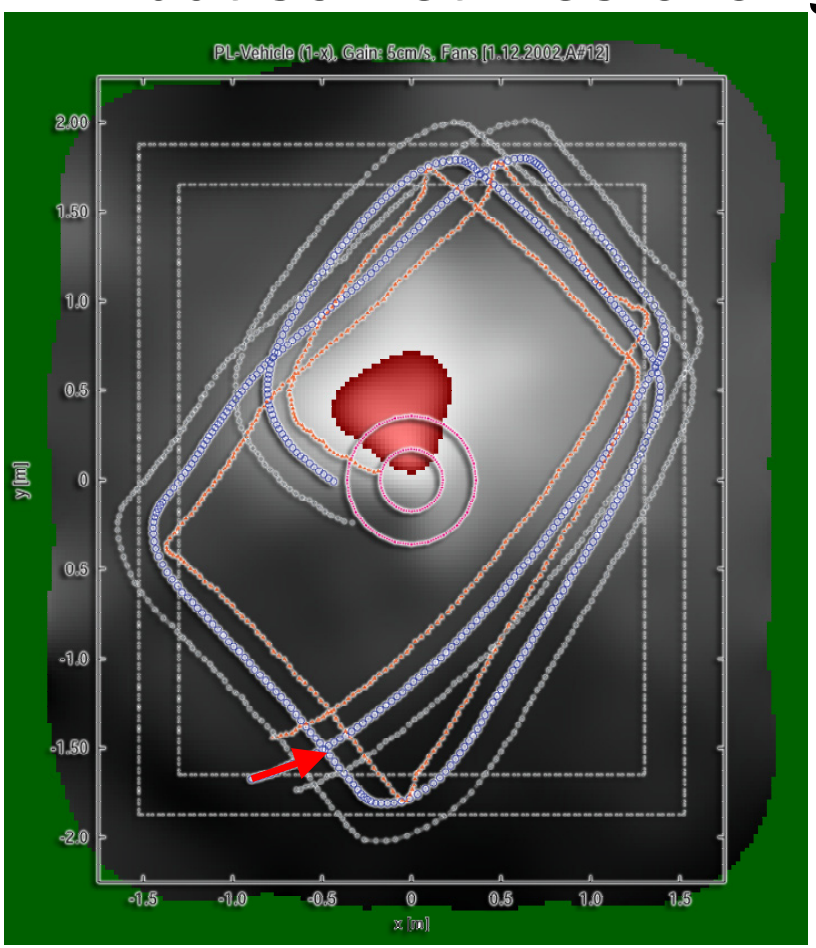

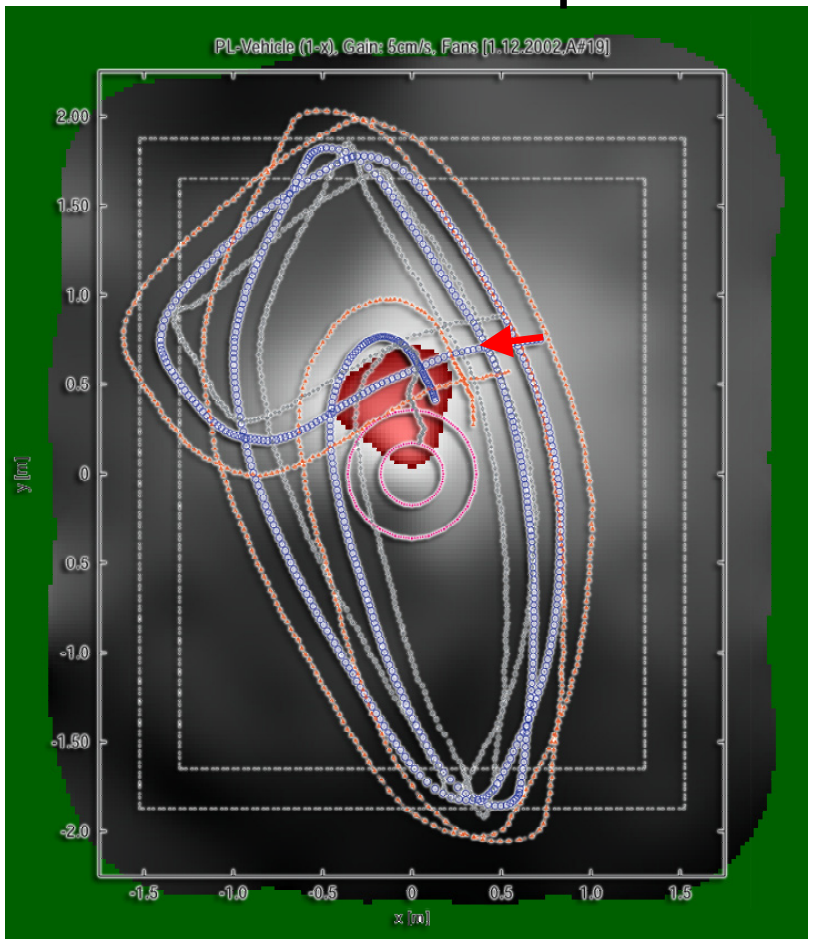

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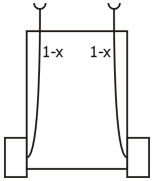
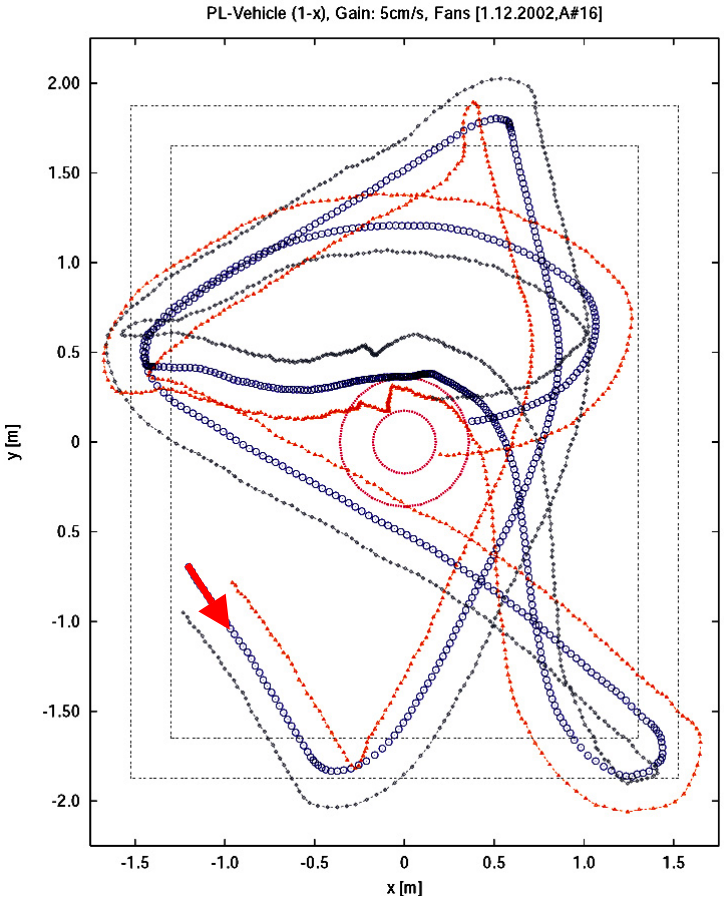


- sometimes it's just weird!



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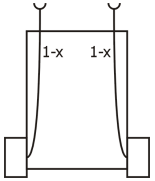

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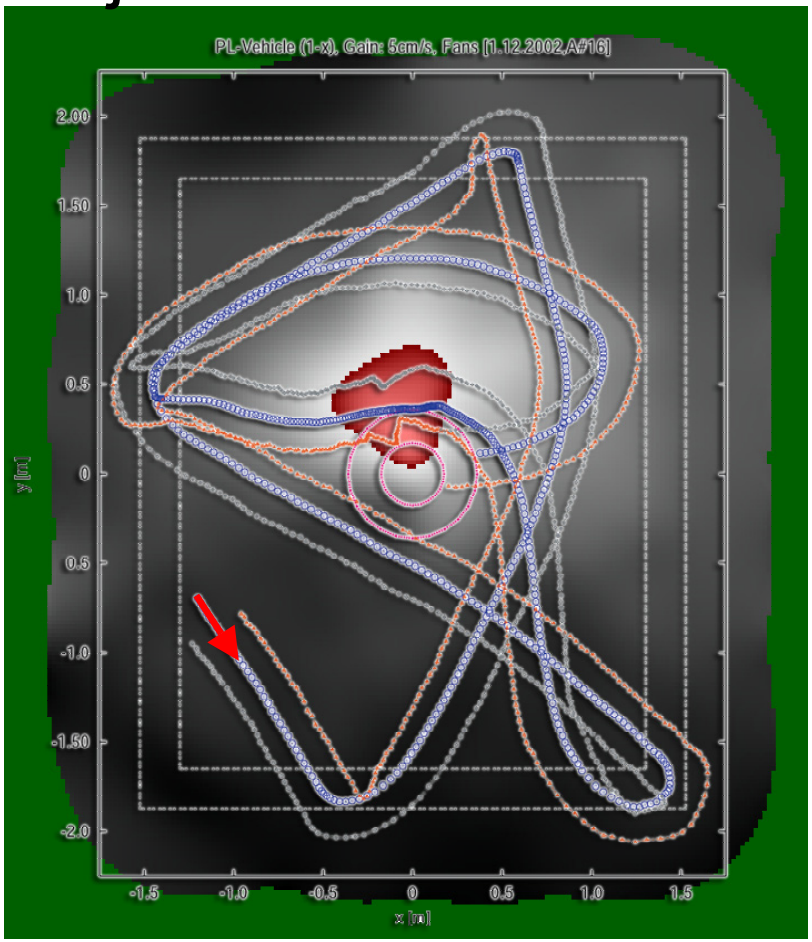

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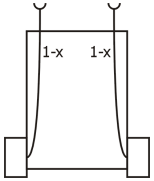
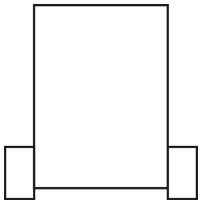
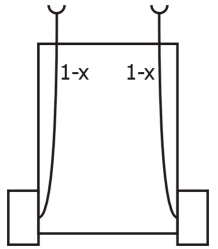


Statistics:

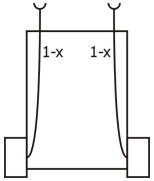
Source in the Middle





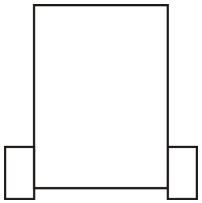
	No Odour	PL-Vehicle
average path length:	**9.67 ± 7.66 m**	**8.49 ± 7.93 m**
average distance:	136.7 ± 44.9 cm	121.9 ± 19.8 cm
number of wall hits:	3.49 ± 2.75	2.69 ± 2.59
correlation ρ_{DT}:	-24.4 ± 40.7 %	-37.9 ± 45.9 %

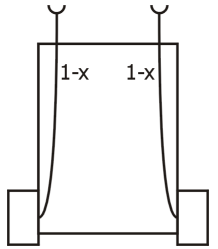
6 Results



Statistics:

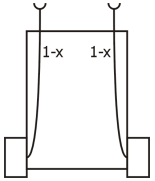
Source in a Corner



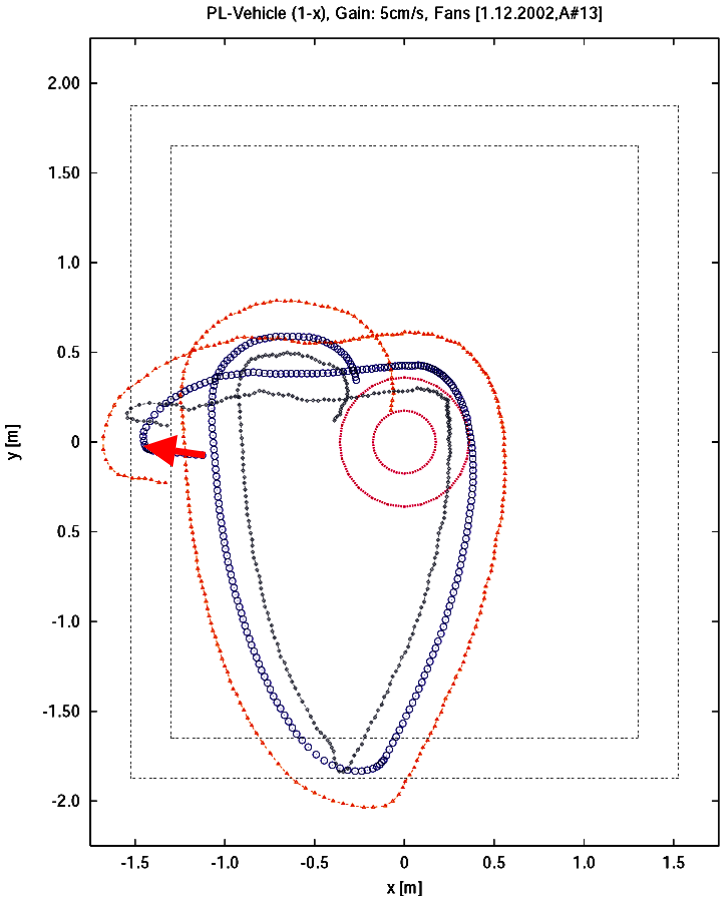


	No Odour	PL-Vehicle
average path length:	**20.46 ± 19.38 m**	**11.69 ± 11.22 m**
average distance:	218.7 ± 33.7 cm	187.6 ± 47.5 cm
number of wall hits:	7.24 ± 6.16	5.11 ± 4.49
correlation ρ_{DT}:	-22.7 ± 42.9 %	-59.7 ± 40.9 %

6 Results



- sometimes the robot is too fast



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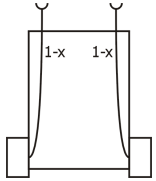

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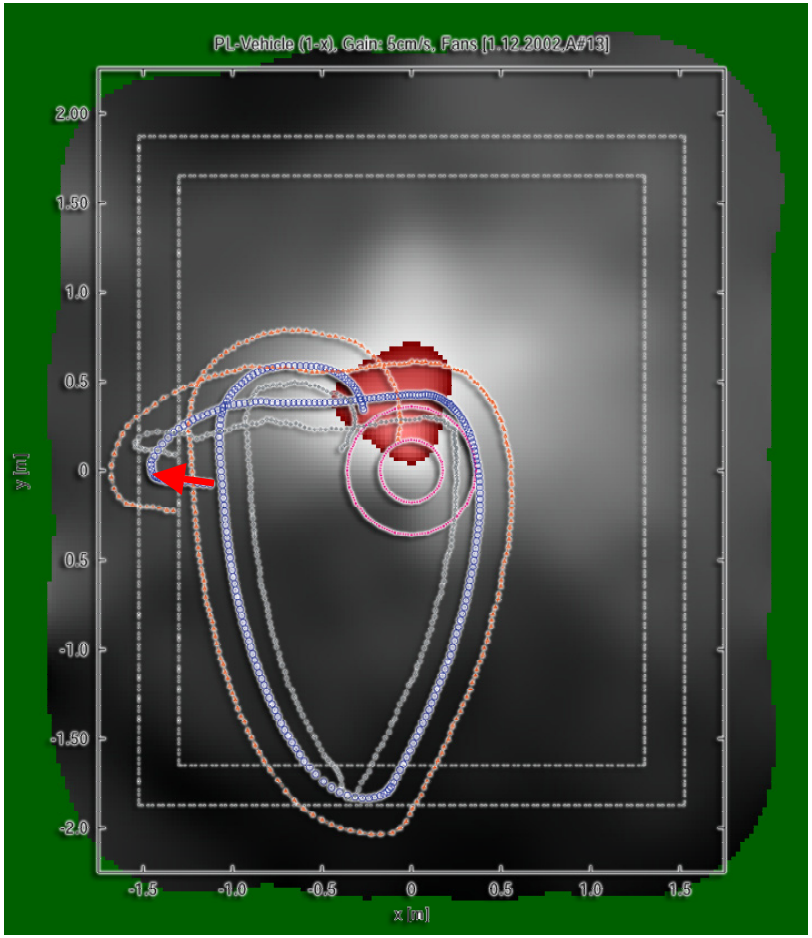

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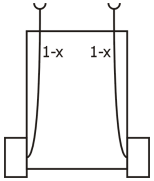

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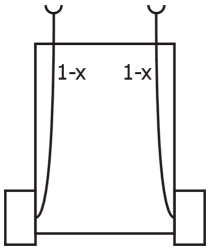
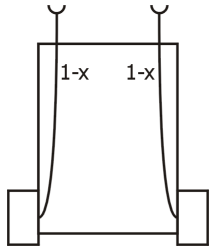
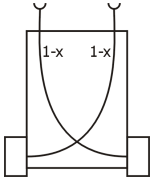




	PL, K_v = 5cm/s	PL, K_v = 3cm/s
average path length:	**14.10 ± 14.56 m**	**9.42 ± 6.91 m**
average distance:	193.4 ± 50.0 cm	180.1 ± 44.7 cm
number of wall hits:	5.69 ± 5.60	4.56 ± 3.08
correlation ρ_{DT}:	-53.3 ± 43.5 %	-65.8 ± 38.1 %

6 Results



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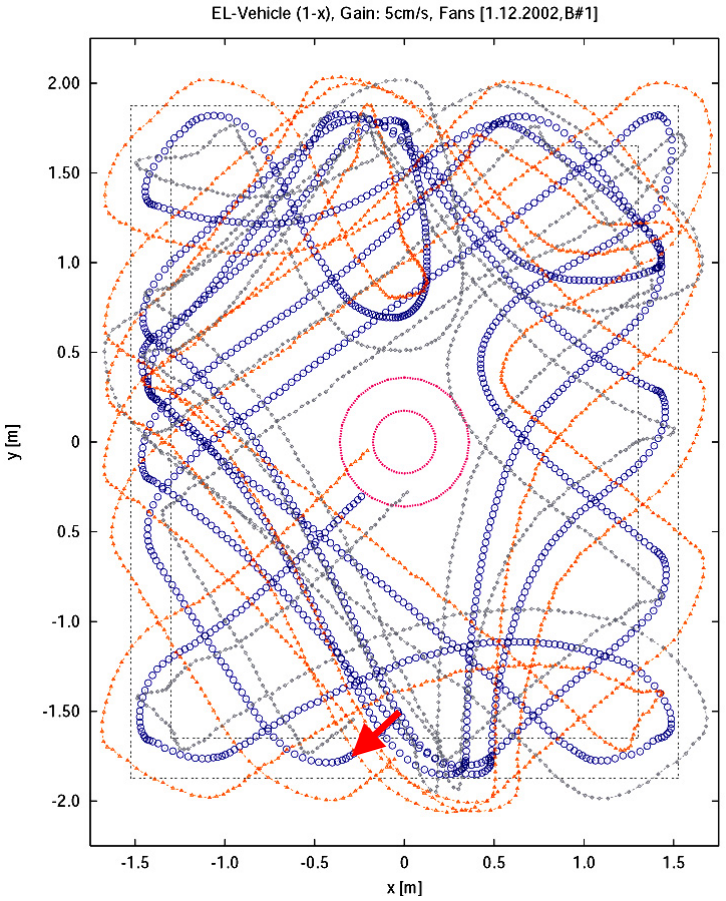
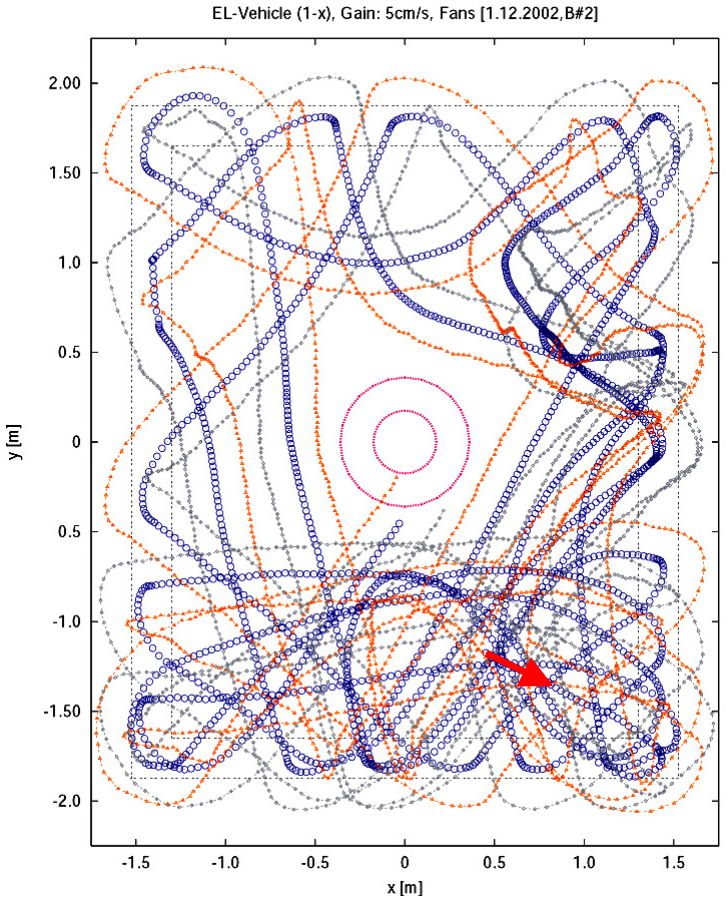
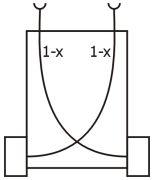
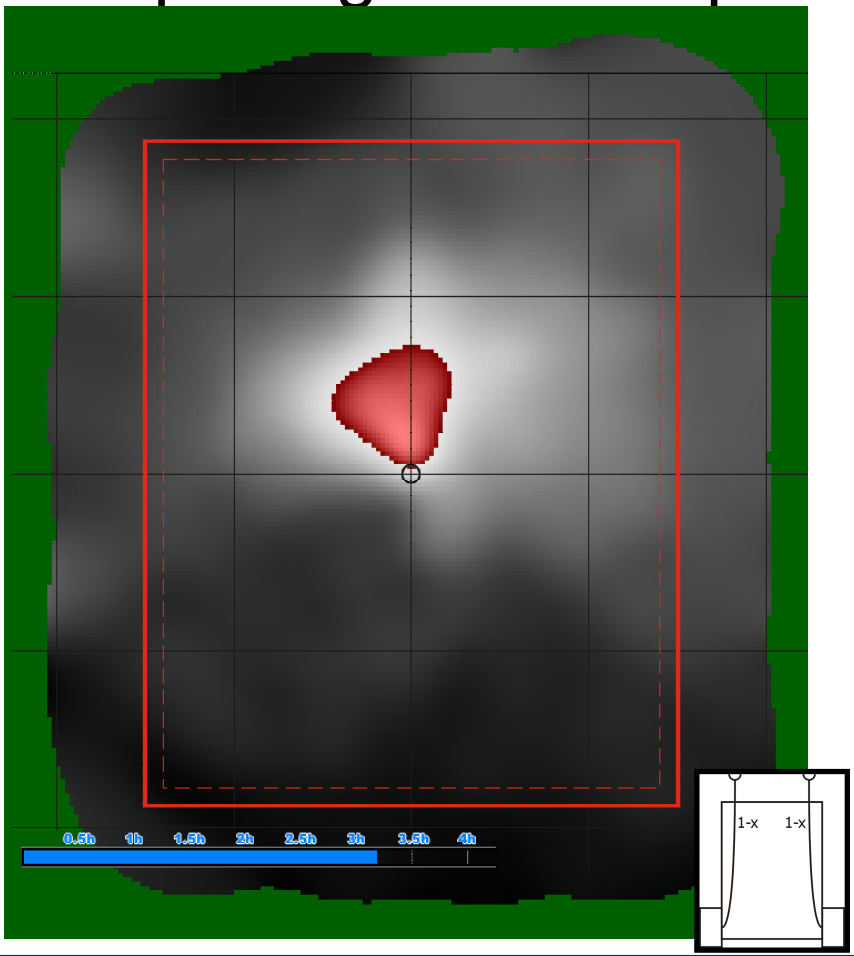


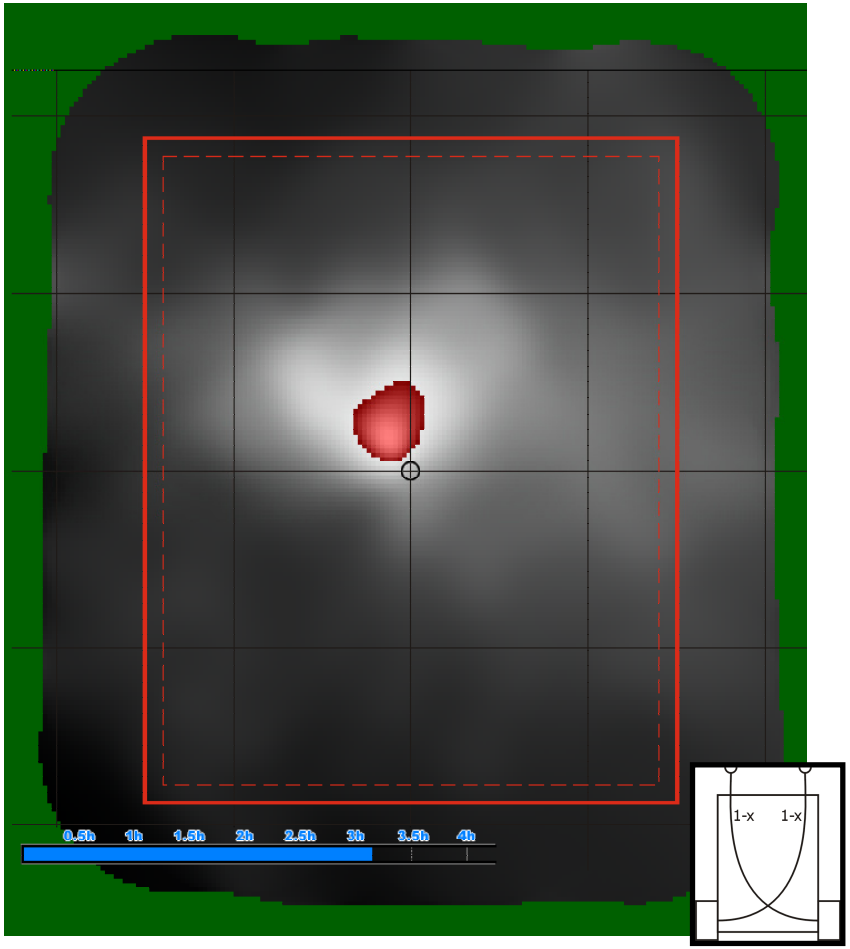


6 Results

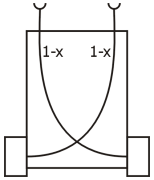


- “Exploring Love” is quite different ...





6 Results



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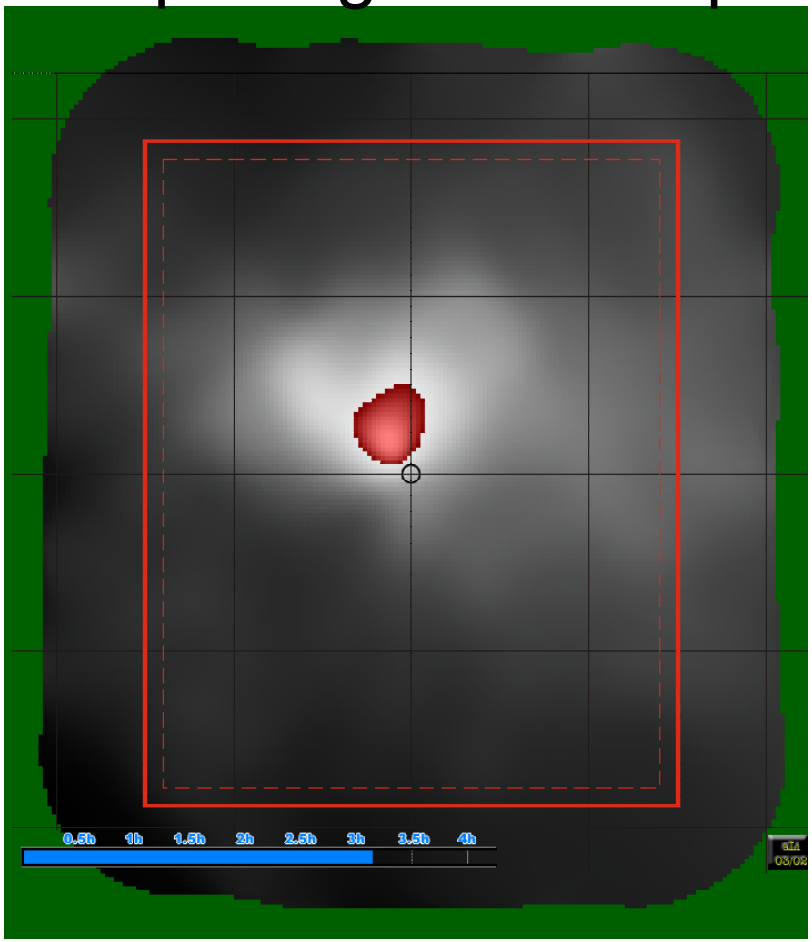

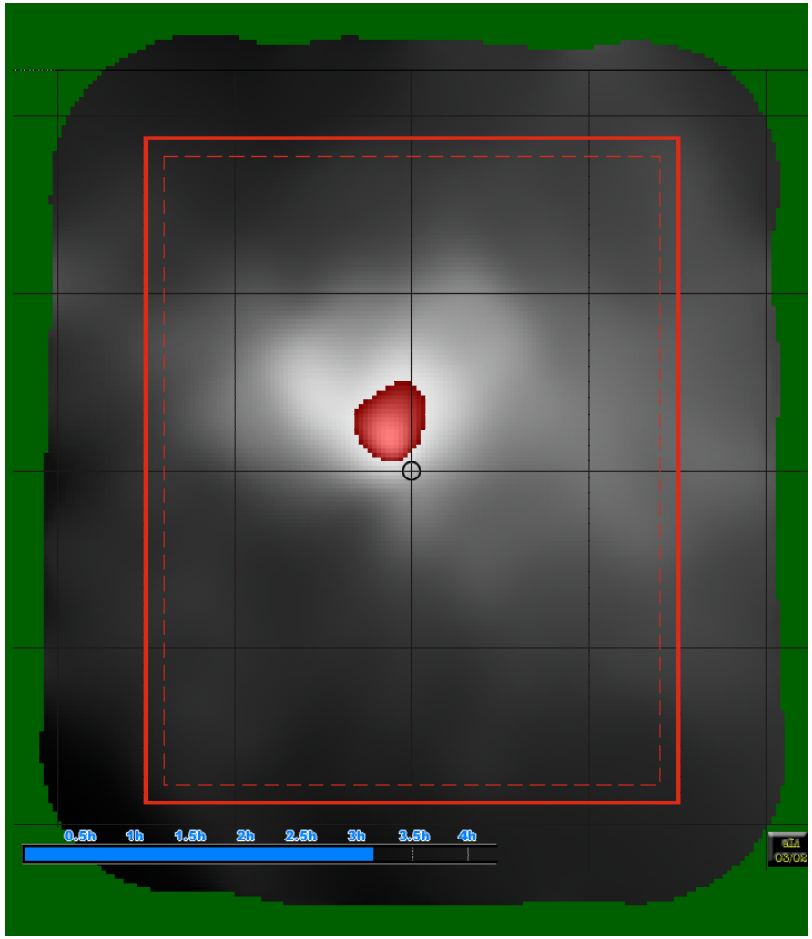

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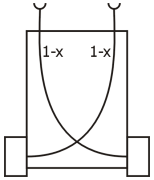

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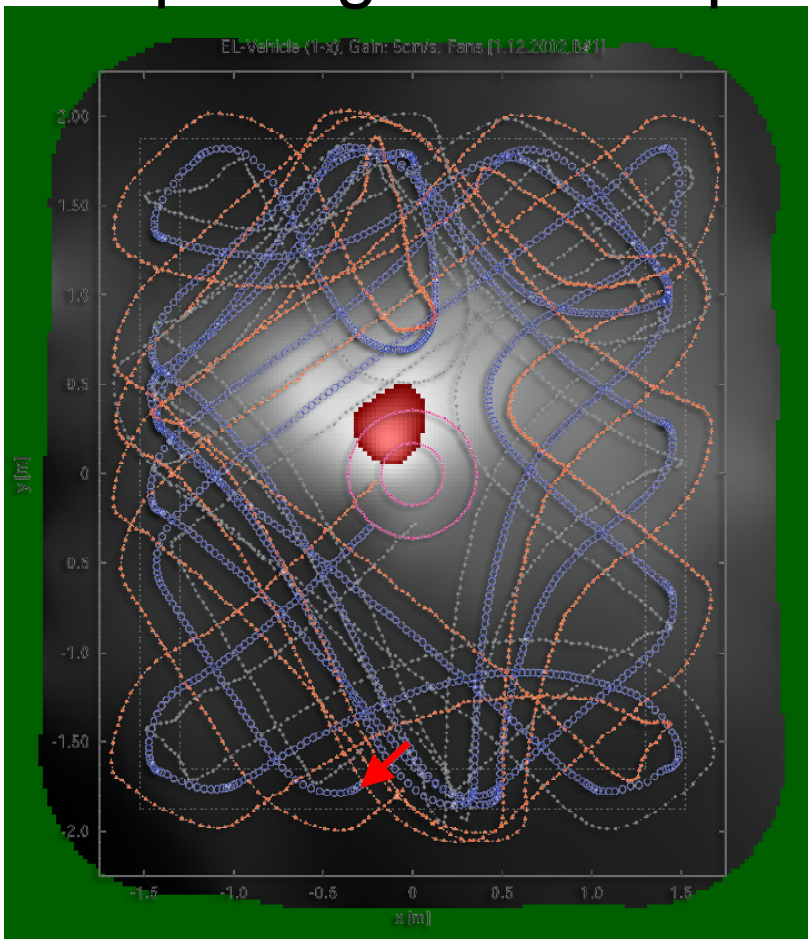

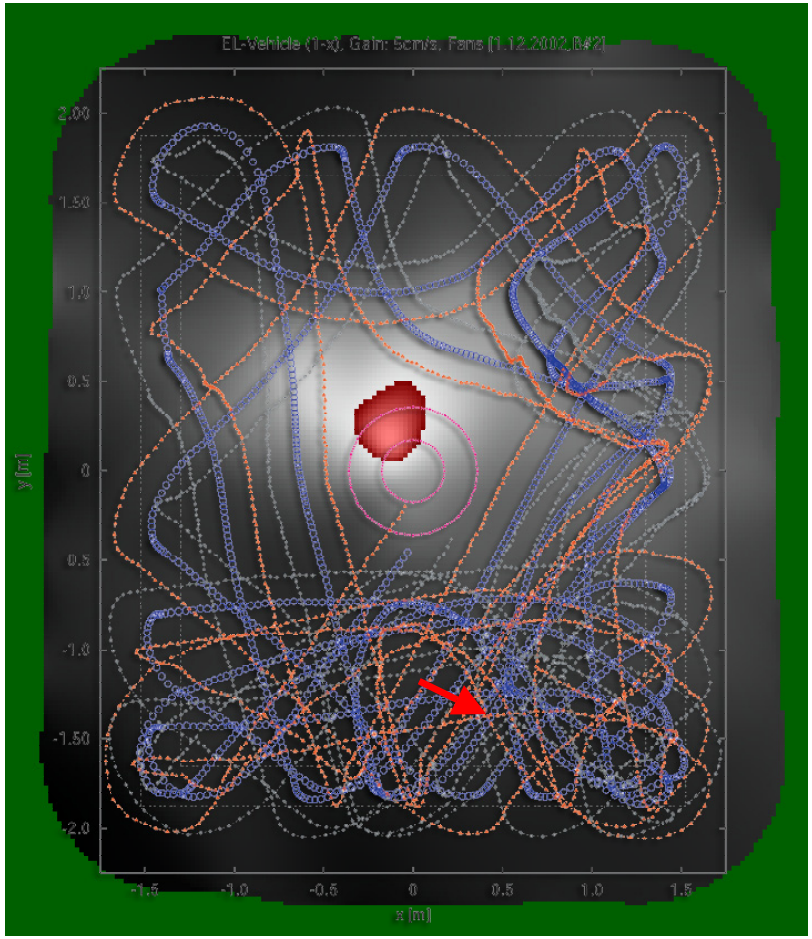

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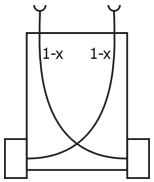

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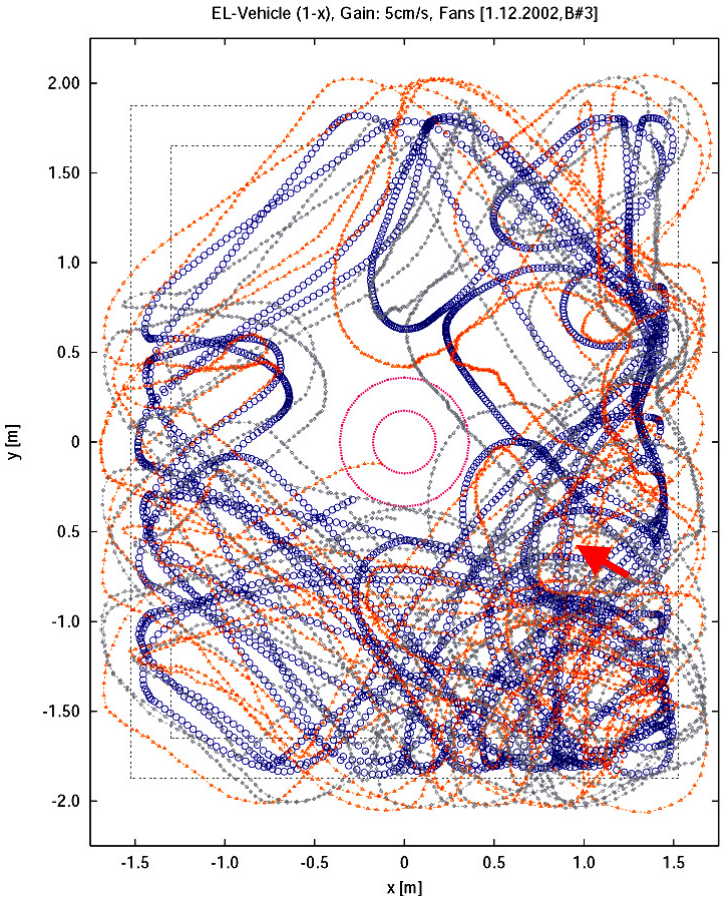

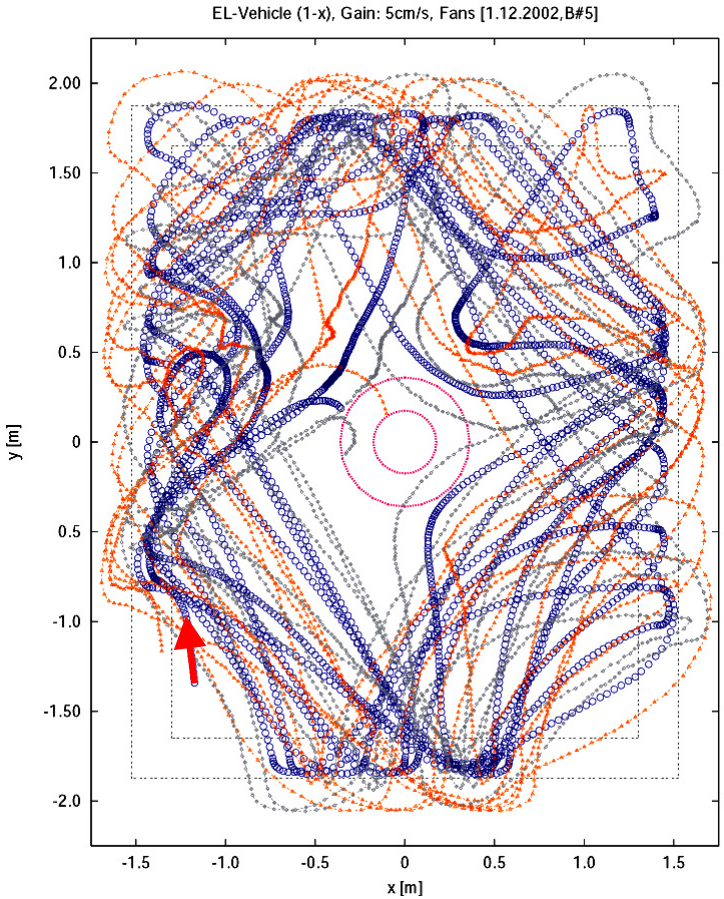

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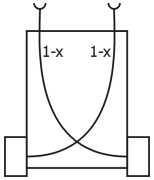

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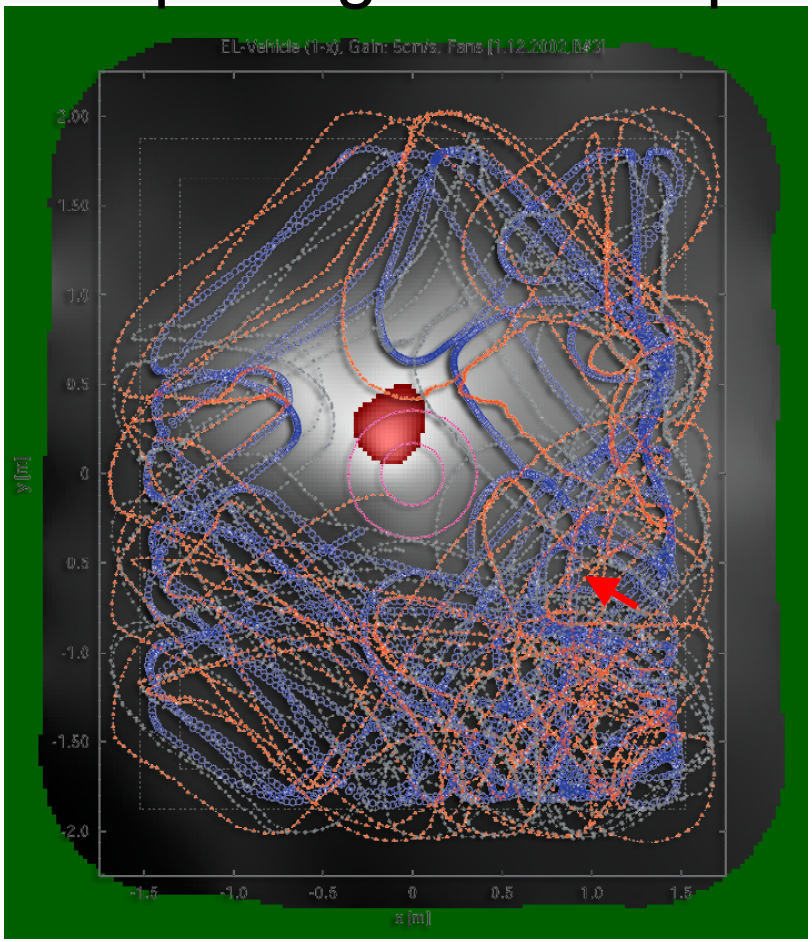
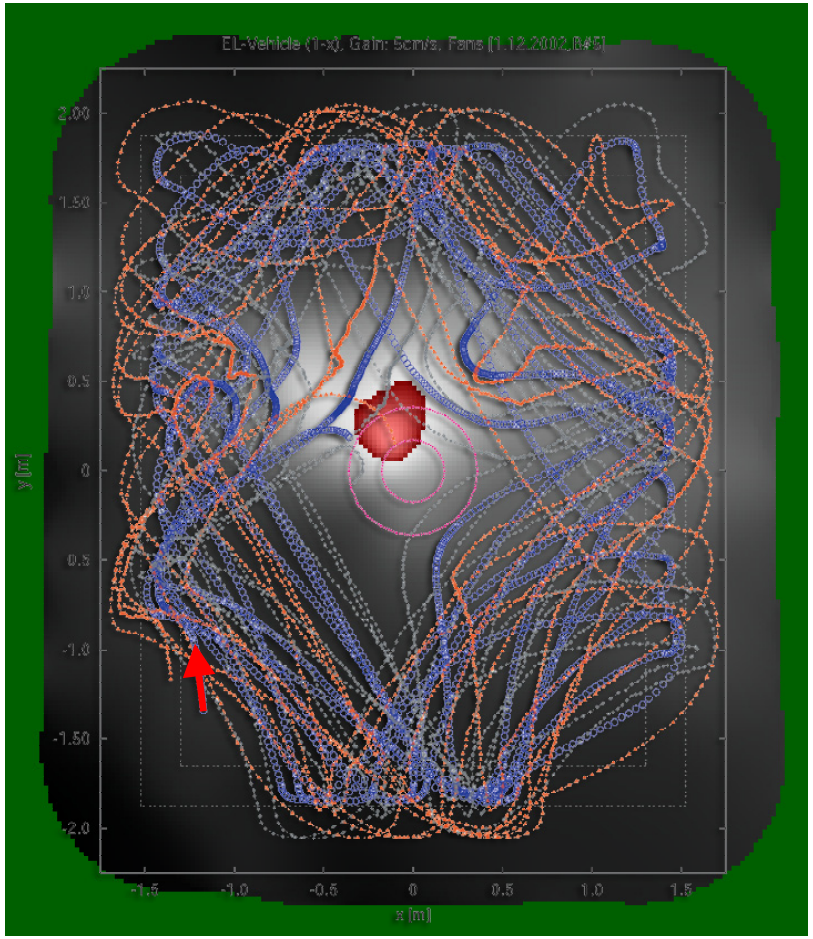
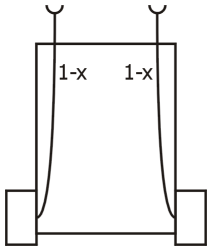


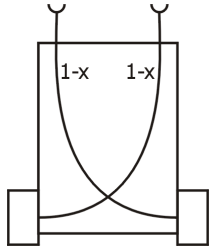


6 Results

Statistics:

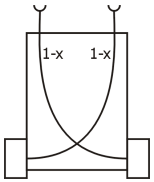
Source in the Middle



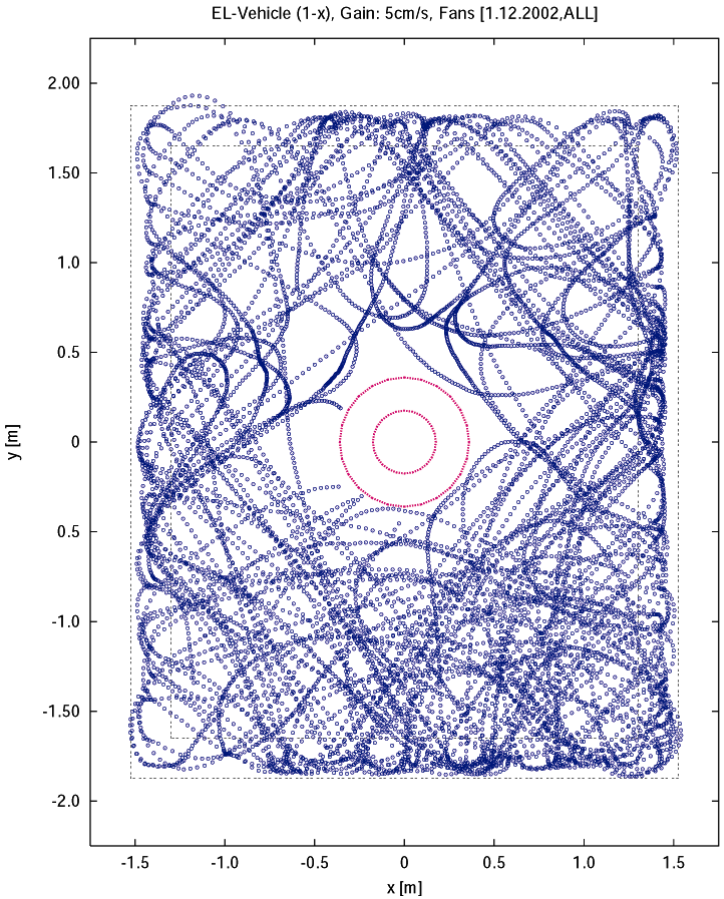


	PL-Vehicle	EL-Vehicle
average path length:	**8.49 ± 7.93 m**	**77.27 ± 42.17 m**
average distance:	121.9 ± 19.8 cm	139.8 ± 6.1 cm
number of wall hits:	2.69 ± 2.59	32.40 ± 19.55
correlation ρ_{DT}:	-37.9 ± 45.9 %	5.4 ± 3.2 %

6 Results



- Localisation by Concentration Peak Avoidance!



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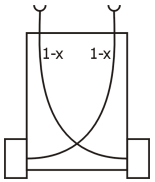
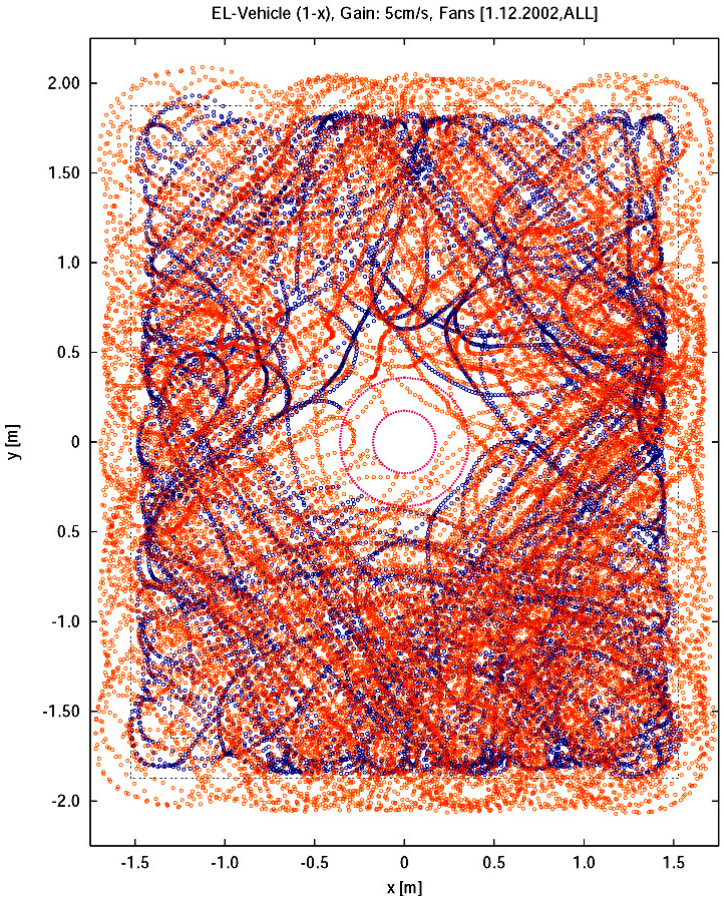


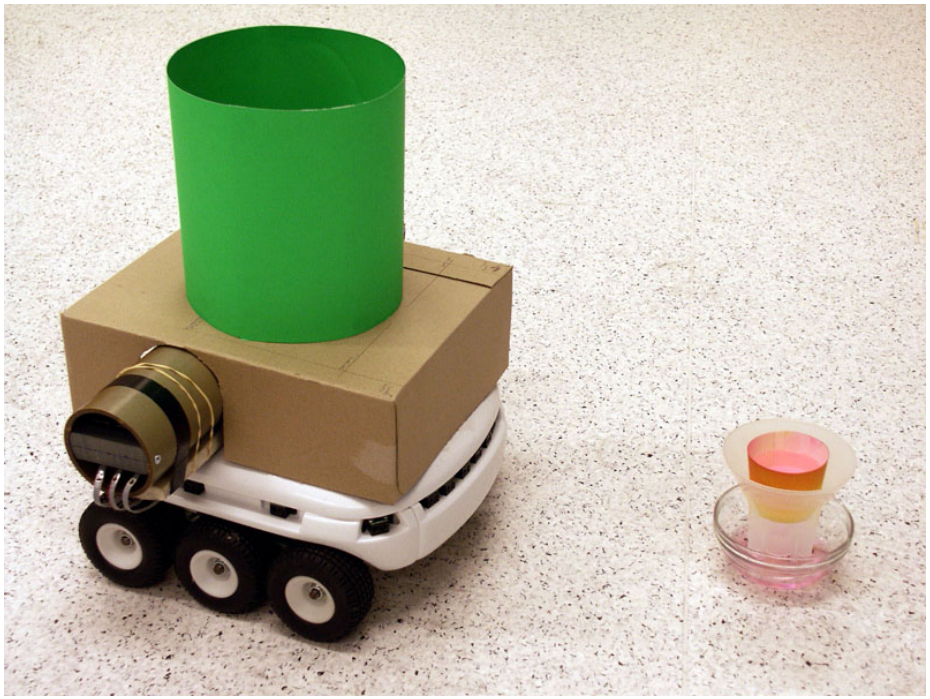
- Possible Method for Gas Source Declaration!!



6 Results

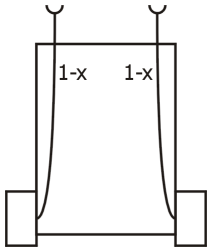
Total Run Time: **> 36 h**

Total Path Length: **~ 5 km**

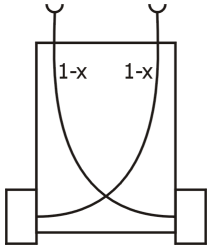


7 Summary

- Mark III Mobile Nose Architecture
- Testbed for Gas Source Localisation
- “Smelling" Braitenberg Vehicle: “Permanent Love"
  - path length to hit gas source decreased
  - ≈ ×0.5 compared to random search



- “Smelling" Braitenberg Vehicle: “Exploring Love"
  - path length to hit gas source increased (≈ ×8)
  - might be a method to declare a gas source



7 Outlook

- Speed Up ”Localisation by Conc. Peak Avoidance“
  - incorporate advanced exploration strategies
- Increase Ability to Avoid to Run Into the Source
  - investigate extended architectures
  - optimize the set of parameters used
  - investigate non-linear transfer functions
- Investigate Other Tracing Strategies …

WSI
Wilhelm-Schickard-Institute for Computer Science

Marie Curie Fellowship Association

Eberhard Karls Universität Tübingen

Approaches to Gas Source Tracing and Declaration by Pure Chemo-Tropotaxis

Achim Lilienthal, Tom Duckett

Thank you!