FFI Forsvarets forskningsinstitutt

Locating a hidden Transmitter using swarm UAVs

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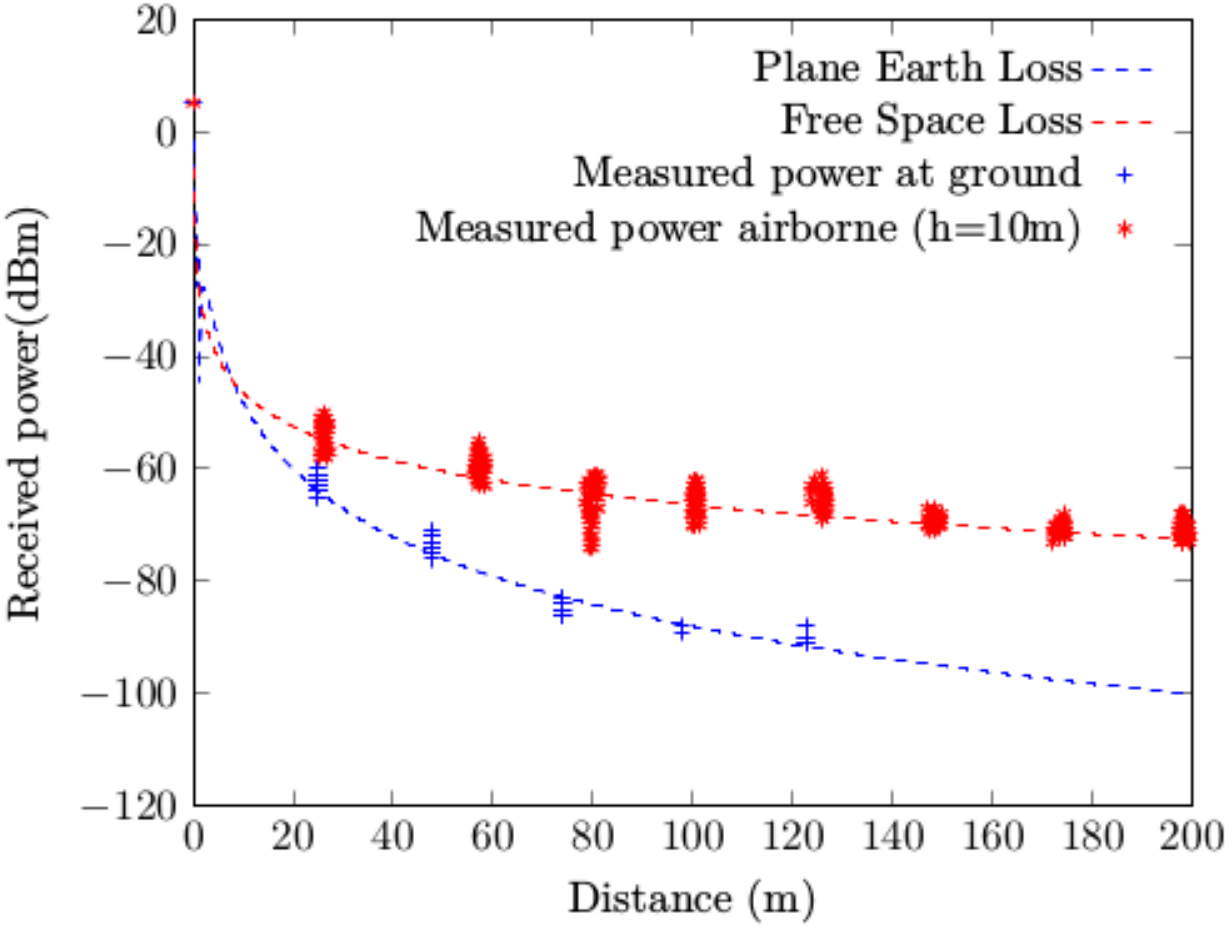
Distributed Autonomy Group @ FFI

- Research into multifunction swarms (Sensors: EO, RF, Sound)

- Research questions (TRL 2-5)
  - How can we develop sensor-based Swarm Intelligence (SI)-behaviours that optimize the collective goal of the swarm?
  - How do we distribute the computational requirements between the agents?
  - How does the amount of information sharing between the agents affect the system performance?

Why UAVs?



Frequency 2.4 GHz

Geolocation a hidden transmitter

- Angle Of Arrival (AOA)
- Time Difference Of Arrival (TDOA)
- Frequency Difference Of Arrival (FDOA)

- Power Difference Of Arrival (PDOA)*

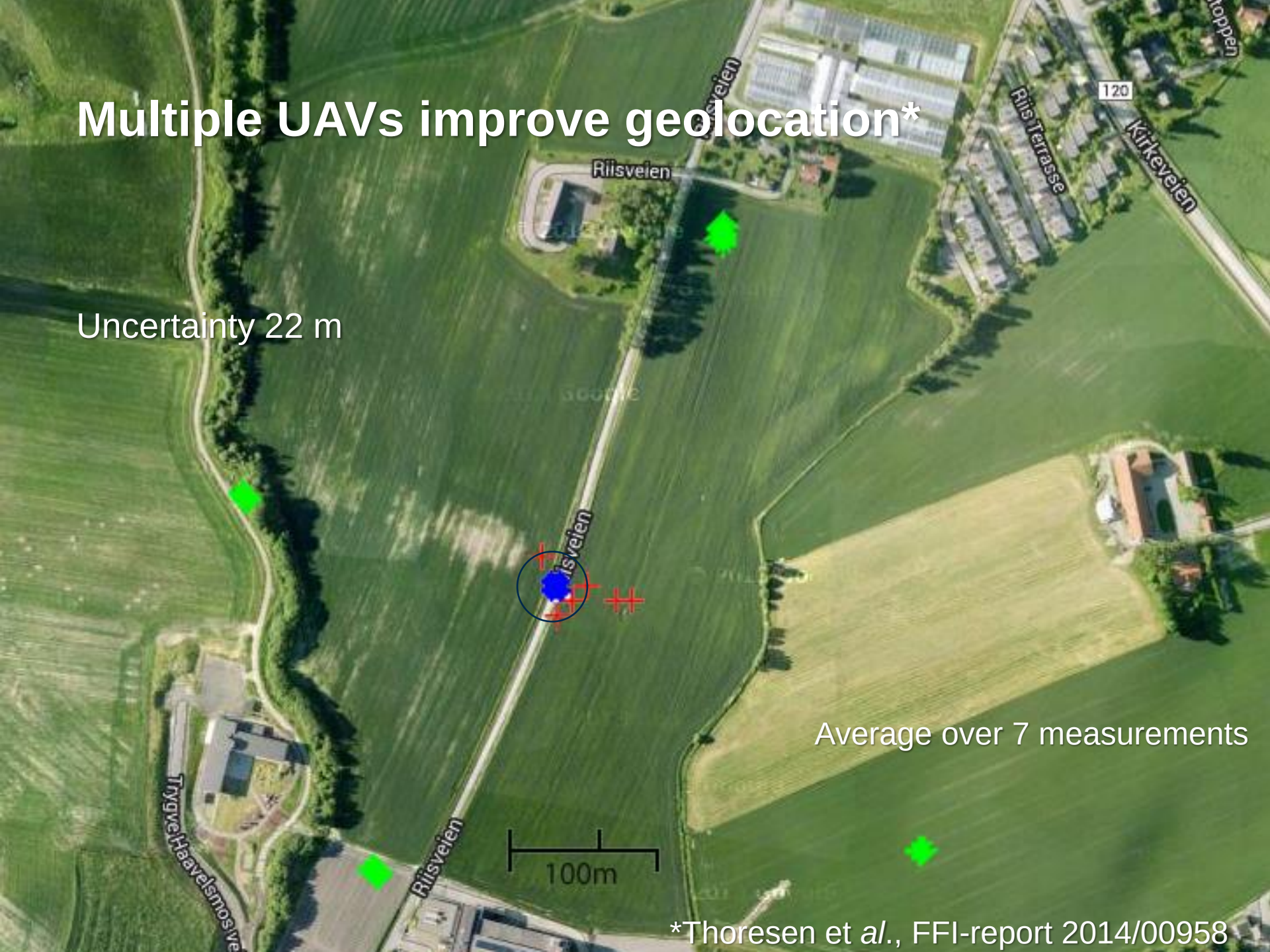
$$\overline{P_{kl}} = P_k - P_l$$

$$Q(x,y) = \sum_{k<l} [\overline{P_{kl}} - 5\alpha log_{10}\left[\frac{(x-x_l)^2+(y-y_l)^2}{(x-x_k)^2+(y-y_k)^2}\right]]^2$$

$$TransmitterPosition_{x,y} = \min_{x,y \in grid} Q(x,y)$$

*Non-Linear Least Square (NLLS)

Multiple UAVs improve geolocation*



Uncertainty 22 m

Average over 7 measurements

*Thoresen et *al.*, FFI-report 2014/00958

Swarm strategies simulated

- PDOA-strategy
- Chemotaxis-strategy*

$$direction_t = \begin{cases} direction_{t-1} \pm random(5^o), & C_t \geq C_{t-1} \\ direction_{t-1} \pm random(180^o), & C_t < C_{t-1} \end{cases}$$

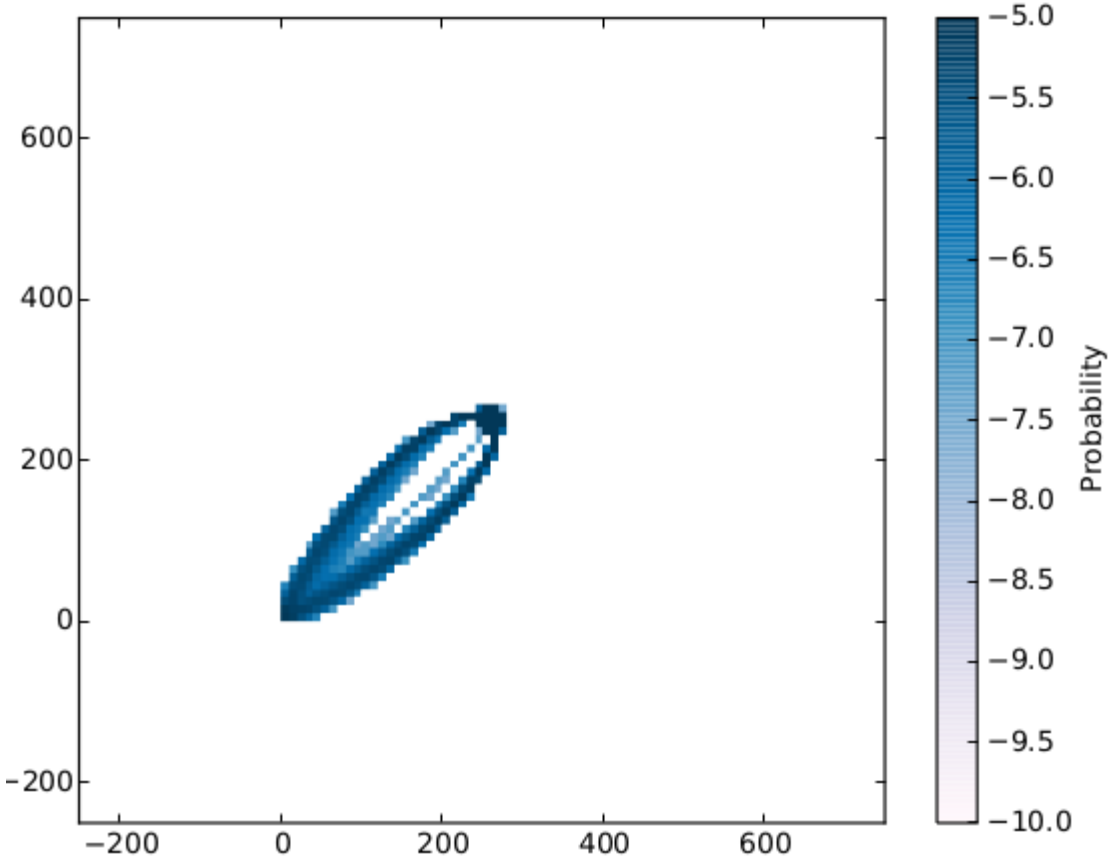
- Random direction as benchmark non-communication strategy

*Ishida, et al. 1996

Simulations

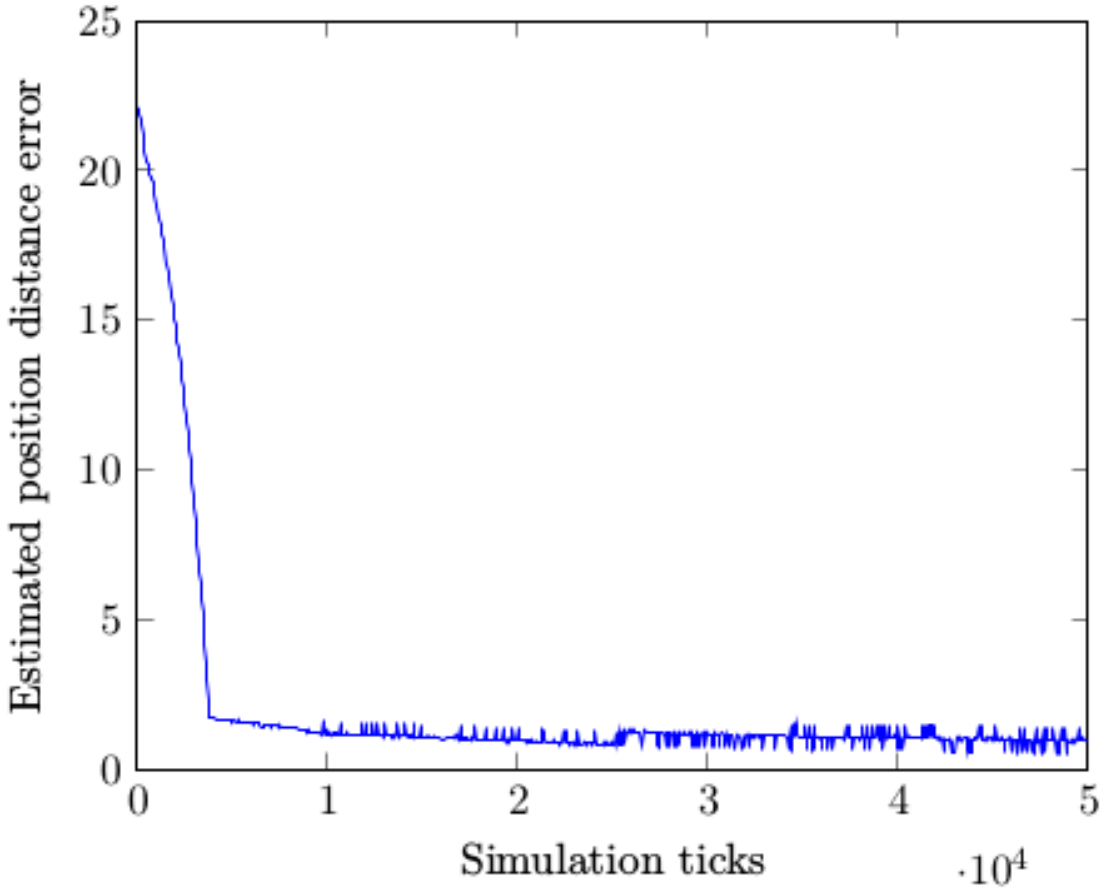
Parameter	Value
Repetitions	50
Simulation seconds	5000
Simulation steps	50 000 (10 steps per simulated second)
Transmitter threshold range	Radius 250
Transmitter position	(250, 250)
Agent starting location	Randomly placed between (0, 0) and (10, 10)
Number of agents	3, 4, 5, 6, 7, 8
Speed	1 distance unit per simulated second
Probability of False Alarms	1e-6

Simulation using PDOA-strategy



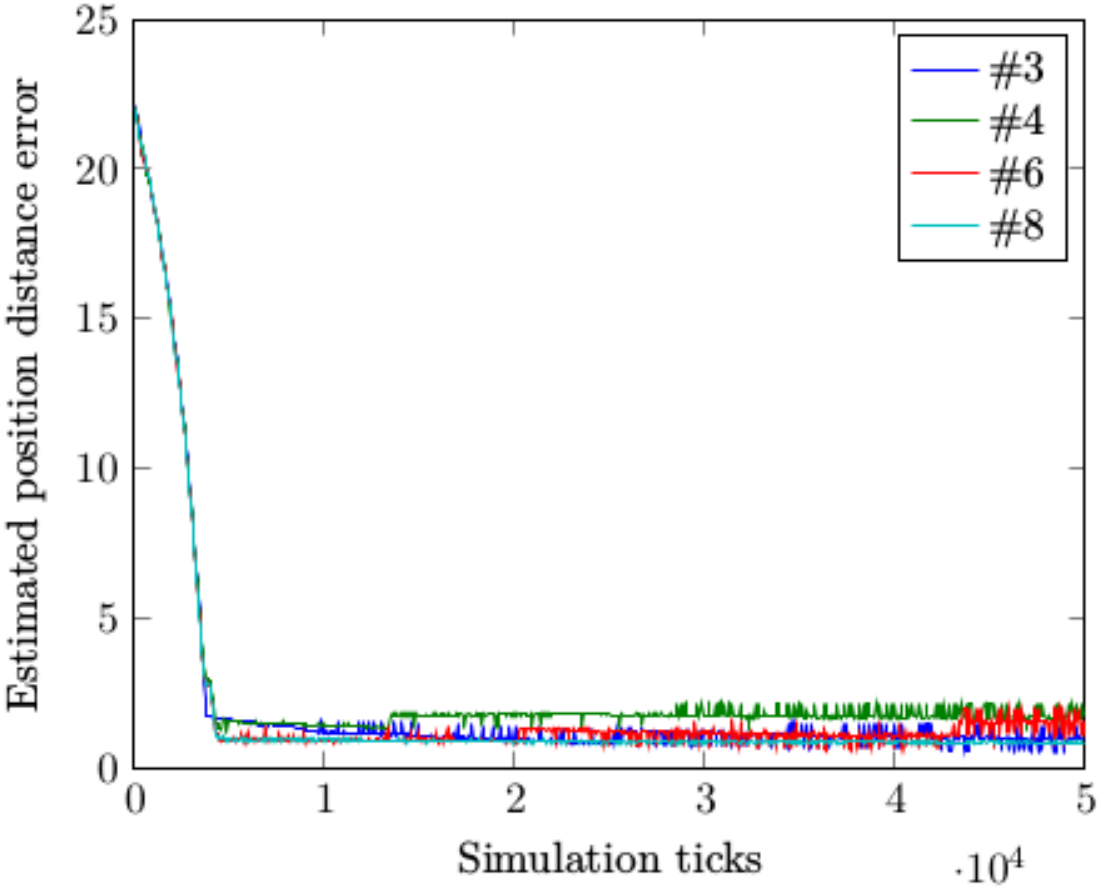
3 agents, 50 runs

Simulation using PDOA-strategy



3 agents, average of 50 runs

Simulation using PDOA-strategy

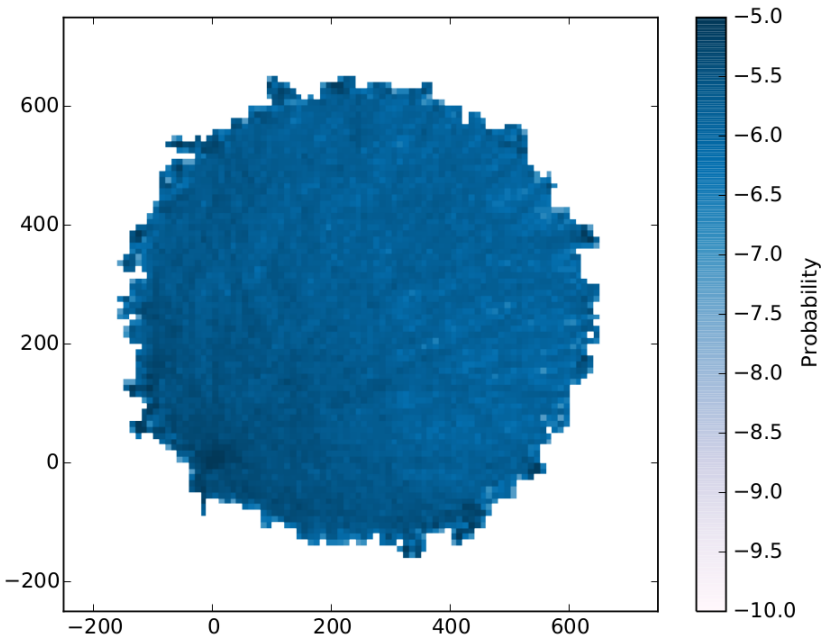


3, 4, 6 and 8 agents, average of 50 runs

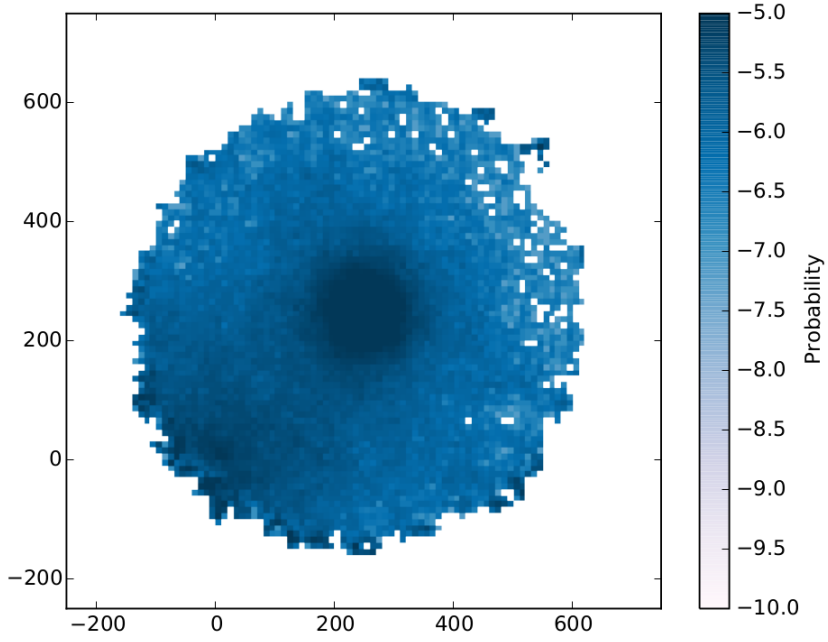
is 3 for both strategies.

Simulations using other strategies

Random

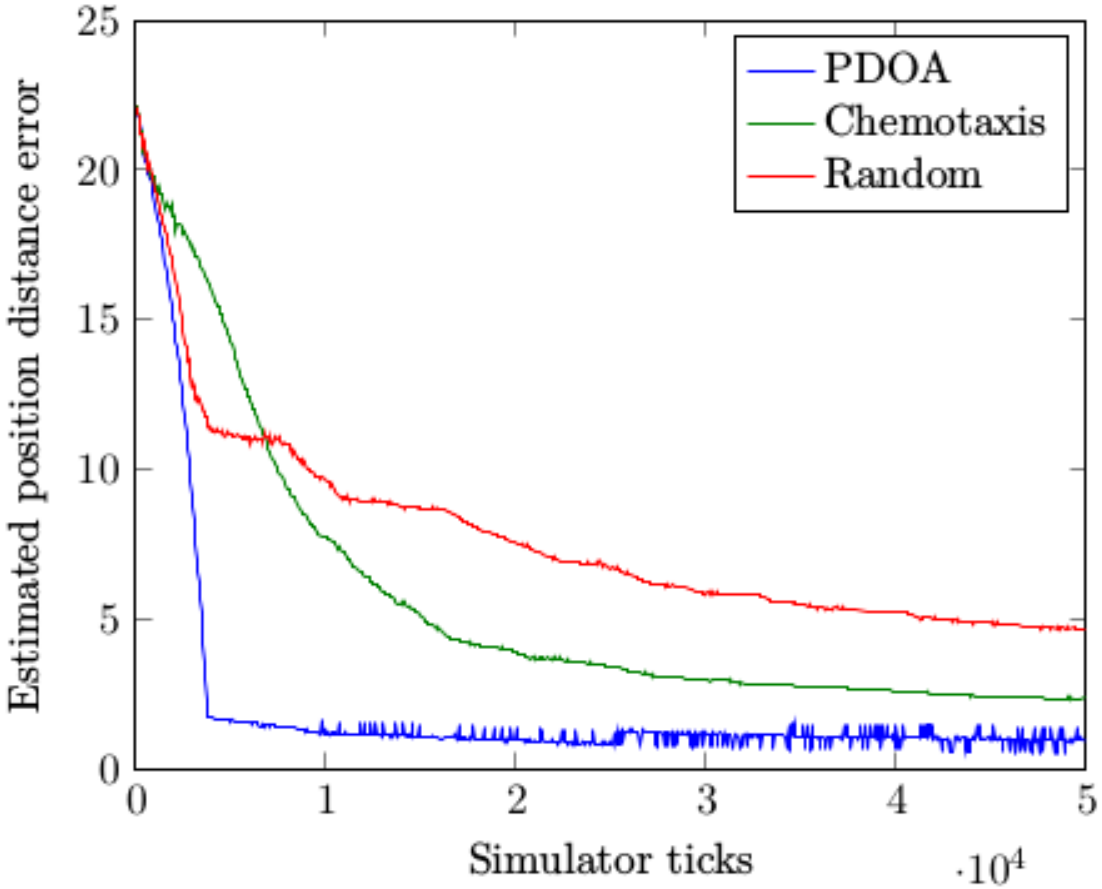


Chemotaxis



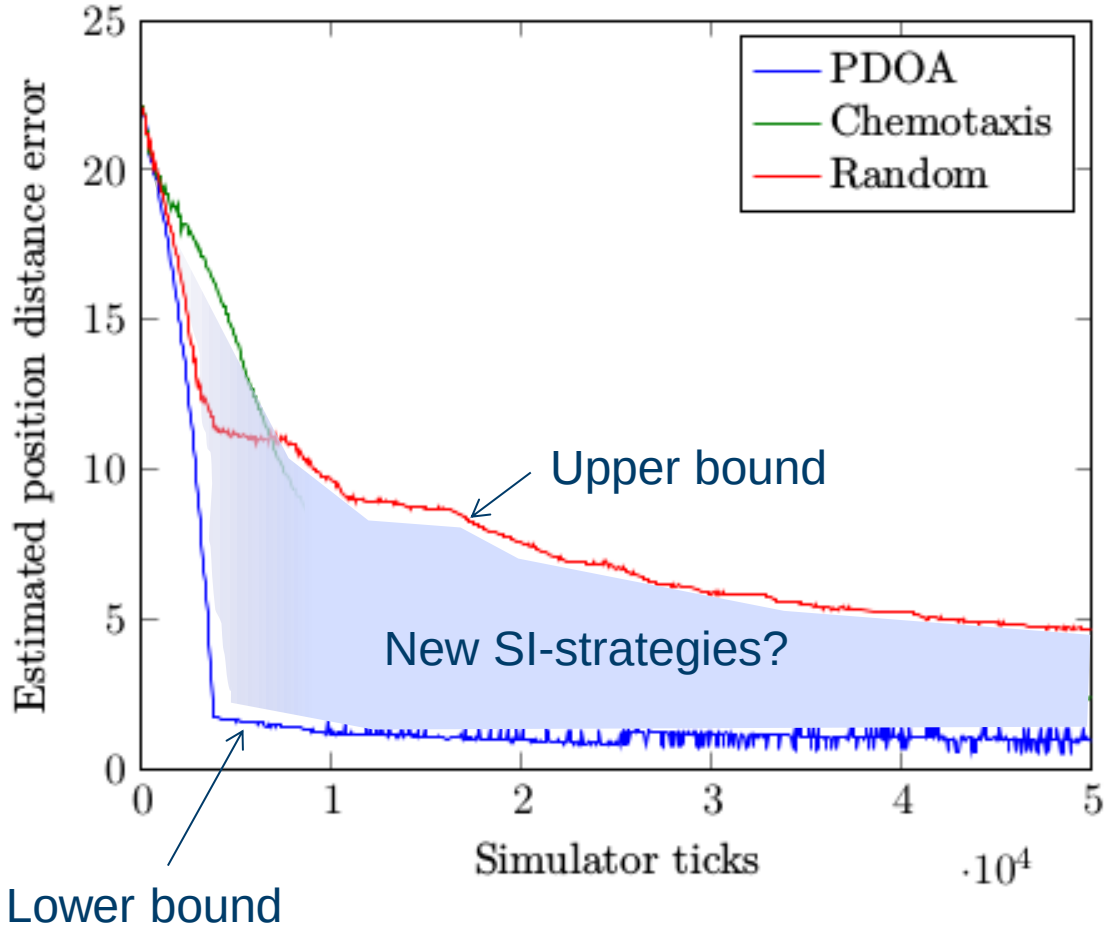
3 agents, 50 runs

Simulations comparing strategies



3 agents, 50 runs

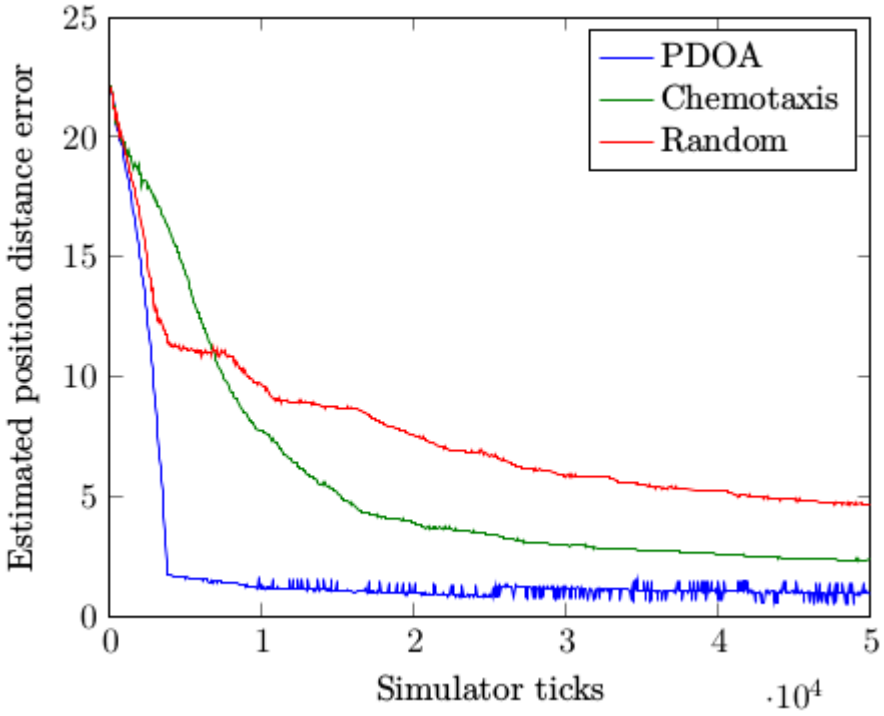
Simulations comparing strategies



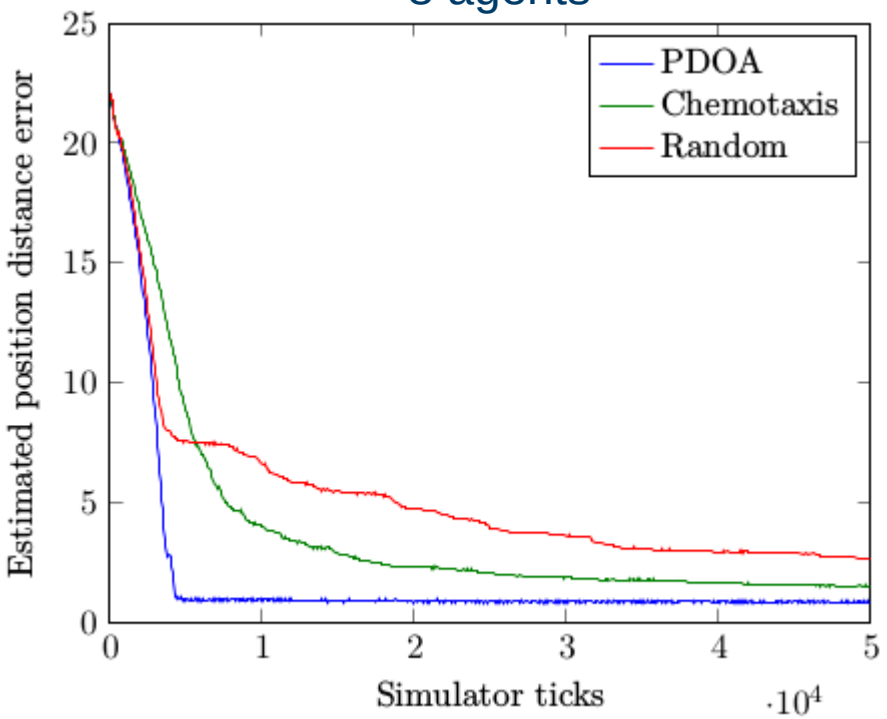
3 agents, 50 runs

Simulations comparing strategies

3 agents



8 agents



50 runs, $p<0.05$

Summary

- 3 agents are sufficient for practical real-world geolocation experiments, possibly validating simulation hypothesis

- We found upper and lower bounds in terms of information sharing for the geolocation task

- These bounds can be used in future studies as benchmark for comparing new SI geolocation behaviours

Questions?