Effect of Sensory Faults within Robot Swarms

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Background

Swarming

With the increased use of autonomous swarms of wheeled mobile robots in real life situations the need for robust swarming algorithms becomes apparent. It is paramount that these systems can handle faults that might occur, whether they be sensory or mechanical.

Sensory faults

Can range from range sensors failing all the way to communication breakdown, whether it be accidental or due to some malicious actor.

Research Question

- What is the effect of sensory faults on the performance of a robot swarm acting out a routing or foraging problem?
- How do we measure the effect of these faults accurately, taking into account multiple types of failures?

Algorithms and Testing

Swarming Path Algorithms

Conduct a test on a simplified version of the multiple destination routing problem using two algorithms: Vasarehelyi [1] and Olfati-Saber [2]. These algorithms use the distance to obstacles and the positions of their fellow agents to pass through the maze.

Delta Swarm

Swarm must stay in a delta formation while moving at a constant speed.

Performance Measuring

Calculate performance through a heuristic scoring function.

BW4T Collaborative AI

Robots within a swarm working in a collaborative setting to complete a task where communication is paramount.

References

[1] C. Vir´ a gh, G. V´ as´ arhelyi, N. Tarcai, T. Sz¨or´ enyi, G. Somorjai, T. Nepusz, and T. Vicsek, "Flocking algorithm for autonomous flying robots," Bioinspiration&amp Biomimetics, vol. 9, no. 2, p. 025012, may 2014. [Online]. Available: https://doi.org/10.1088%2F17483182%2F9%2F2%2F025012

[2] R. Olfati-Saber, "Flocking for multi-agent dynamic systems: algorithms and theory," IEEE Transactions on Automatic Control, vol. 51, no. 3, pp. 401–420, 2006.

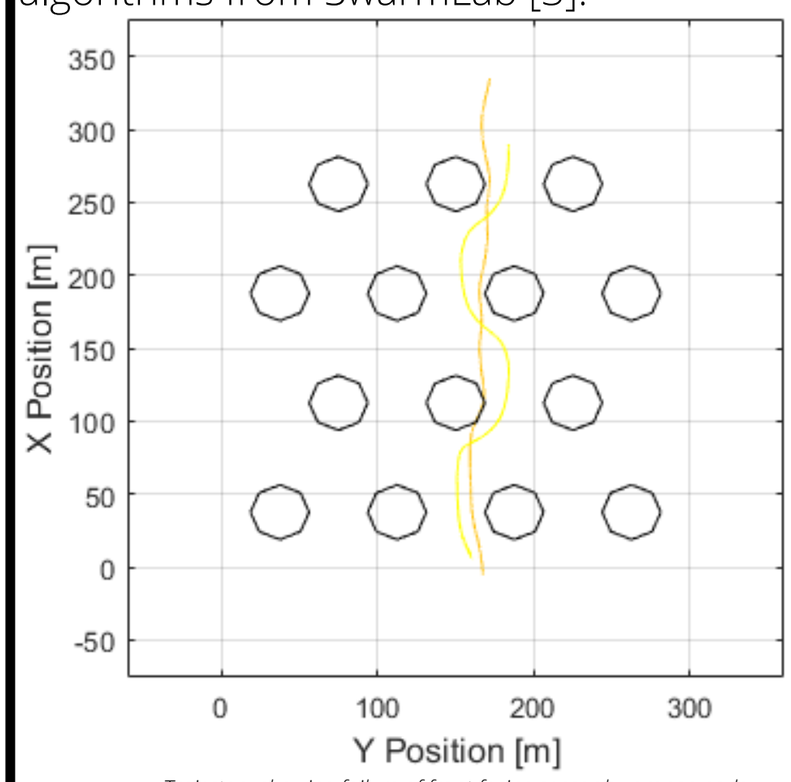
[3] E. Soria, F. Schiano, and D. Floreano, "Swarmlab: a matlab drone swarm simulator," in 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2020, pp. 8005–8011.

[4] M. Johnson, C. Jonker, M. Riemsdijk, P. J. Feltovich, and J. Bradshaw, "Joint activity testbed: Blocks world for teams (bw4t)," 11 2009, pp. 254–256.

Simulation Environment

MatLab

Simulation software that allows for realistic and repeatable runs of the 2 tested algorithms using already implemented algorithms from SwarmLab [3].



Trajectory showing failure of front facing sensor by orange node.

Delta Swarm Formation

Custom written point-mass based simulation, positions described by

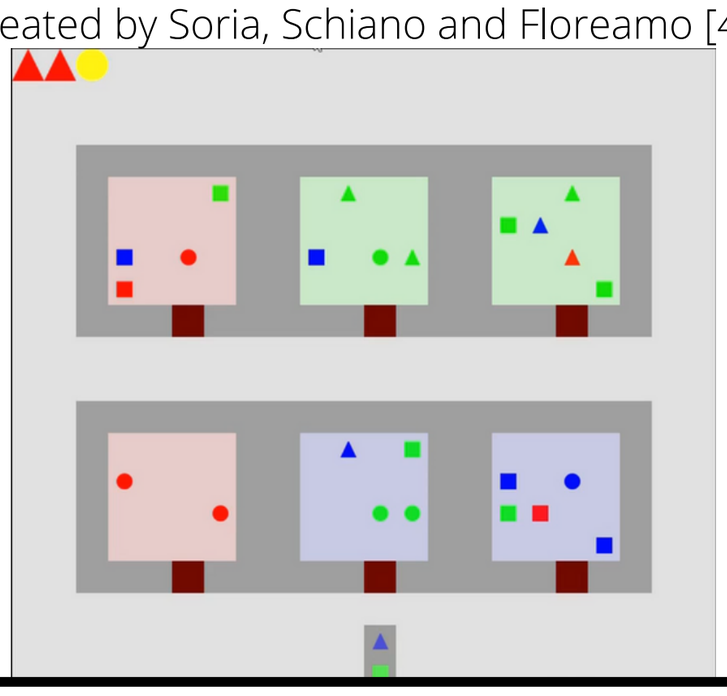
$$x_i = \begin{cases} \dot{x}^i = v^i \\ \dot{v}^i = a^i = \sum_{j \in neighbours^i} F_{ij} - k_{damp} v^i \end{cases}$$

$$F_{ij} = \frac{(x^i - x^j)}{|x^i - x^j|} - k_{spr}(d_{ij} - d_0)$$

k_{damp}	damping constant of the system
k_{spr}	spring constant of the system
d_0	spring length at rest

BW4T Simulation

Python based collaborative environment, created by Soria, Schiano and Floreamo [4].



Introduced Faults

Front Distance Sensor Fault

Measurements regarding distance to an obstacle or agent in front of robot will be skewed for one specific agent.

- Failure a percentage of time.
- Changeable failure offset.

Malicious Actor

Lying agent introduced into swarm, lies changeable percentage of time.

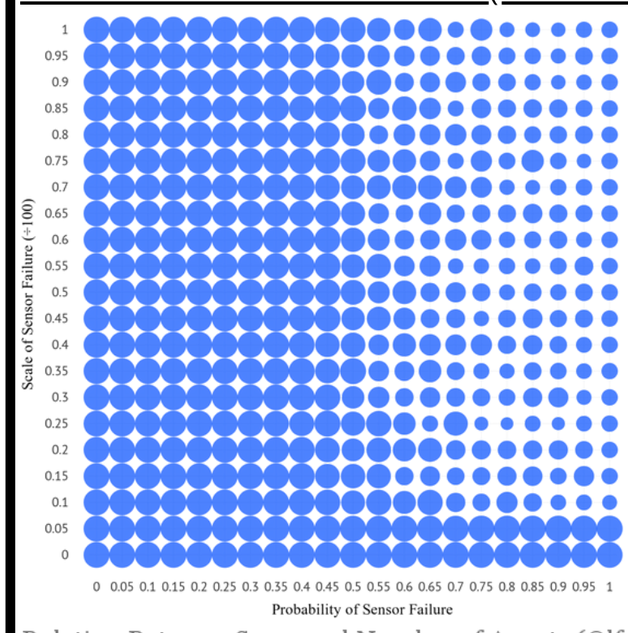
Information Delay

Measurements come in with diff. delay.

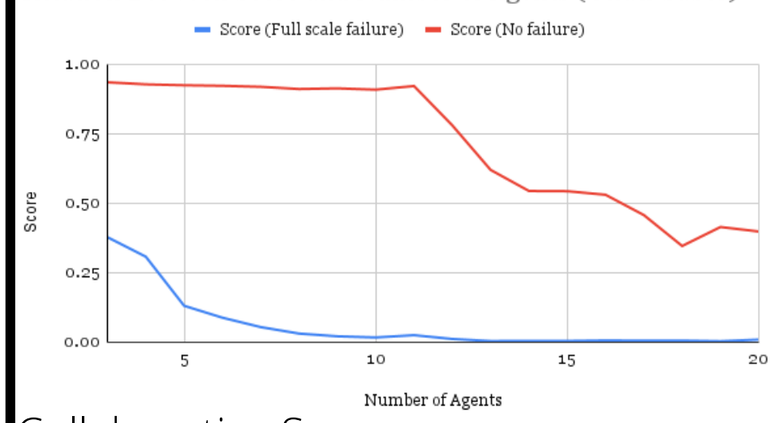
Results

Lot of data gathered, excerpt given

Distance Sensor Failure (Olfati-Saber)

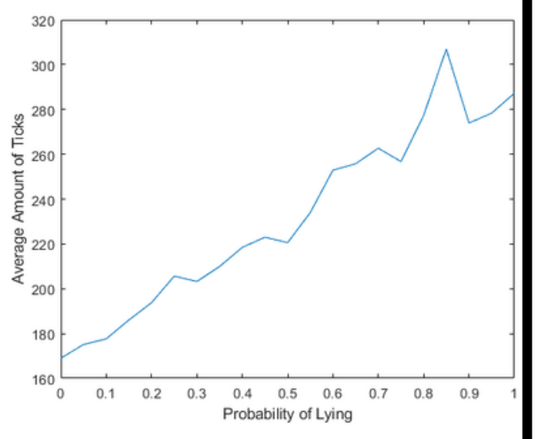


Relation Between Score and Number of Agents (Olfati-Saber)

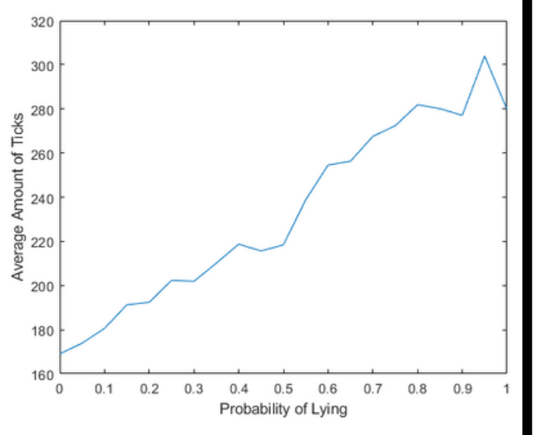


Collaborative Swarm

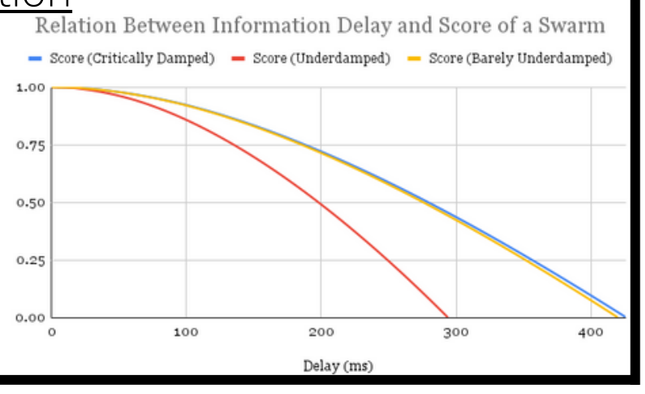
Intra-round learning



Inter-round learning



Information delay



Conclusions

This project attempted to quantify the relation between sensory faults and performance within a robotic swarm. Multiple experiments were conducted on multiple types of sensory faults within different custom written simulations. It was discovered that while usually quantifiable, it is hard to create a definitive function that describes the effect of any given type of sensory error.