Emergent self-coordination in simulated swarms steered by Spiking Neural Networks

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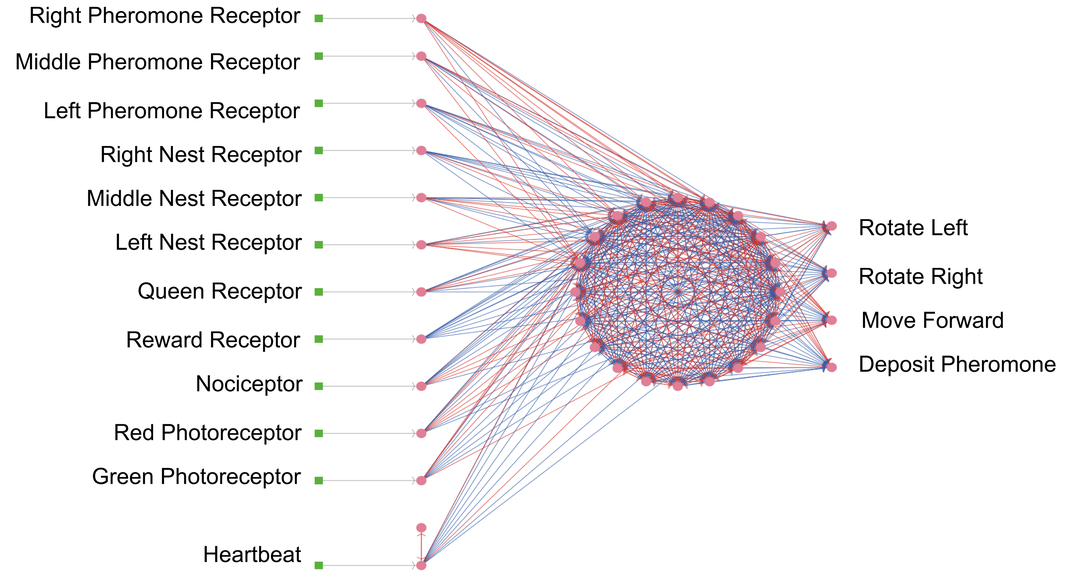
Swarm Optimization

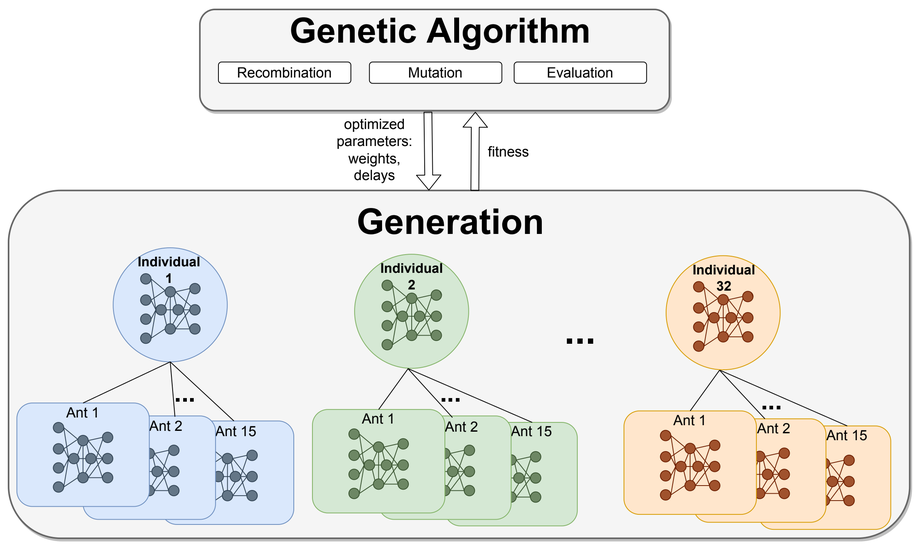
Courtesy of [1]

- Multi-agent simulation in NetLogo [2]
- Ants (red, green) explore and forage for food (green patches)
- Drop pheromones (blue, white) for communication
- Steered by a Spiking Neural Network (SNN) in NEST [3]

SNN controlling the agents

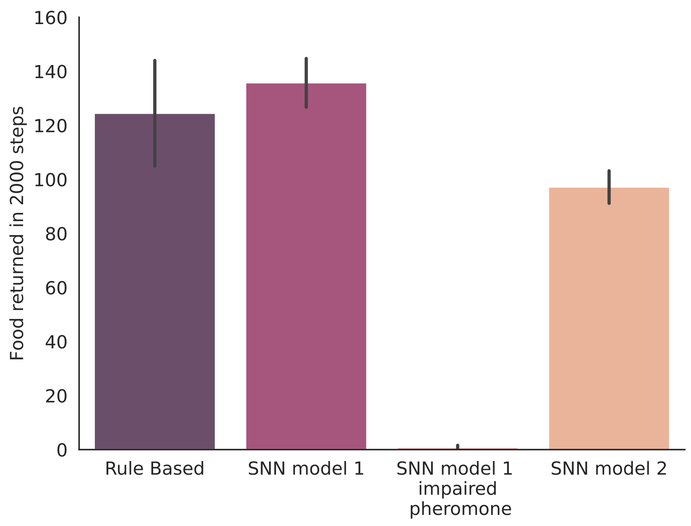


Optimization Workflow



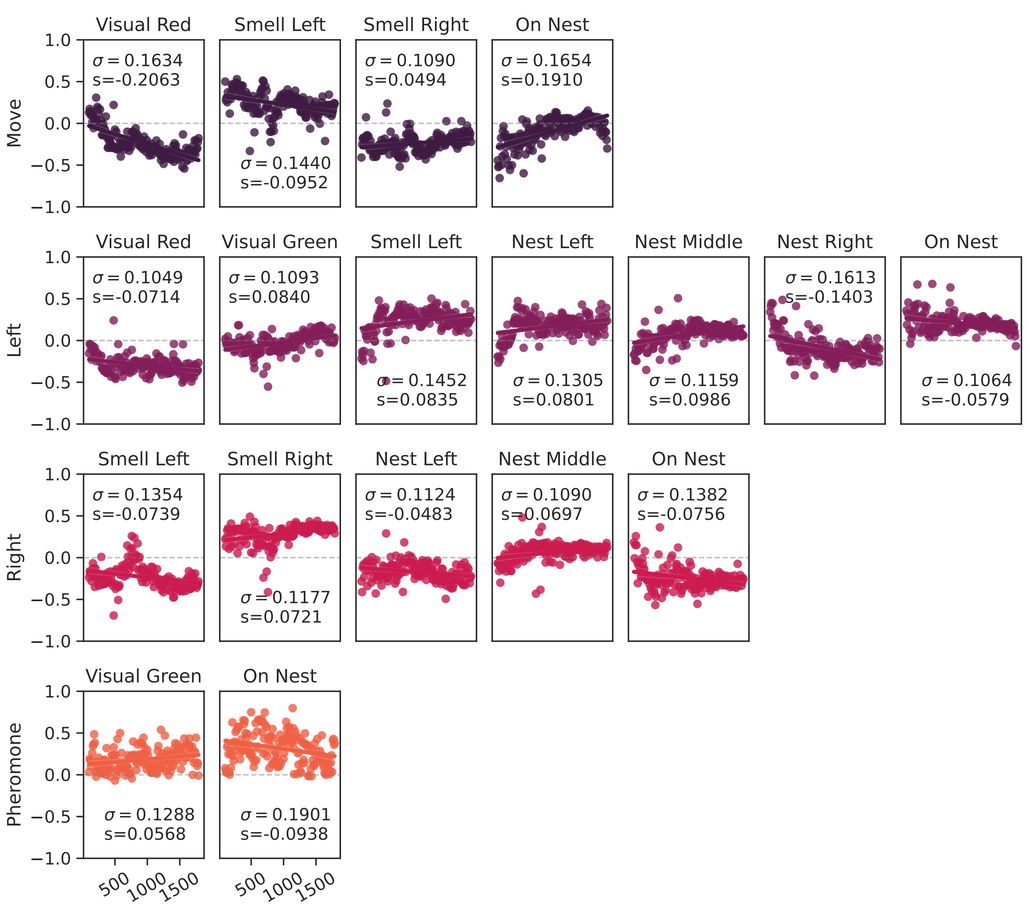
- Optimization of weights and delays with L2L [4]
- 32 individuals (colonies) optimized in parallel
- Each colony is comprised of 15 ants

Performance Comparison



- Rule-driven model: Ants follow predefined rules
- SNN-model 1: Emergent coordination via pheromones
- SNN-model 1: Same as previous model but pheromone sensing deactivated
- SNN-model 2: Colony evolved without pheromone usage

Mapping Sensing to Behaviour

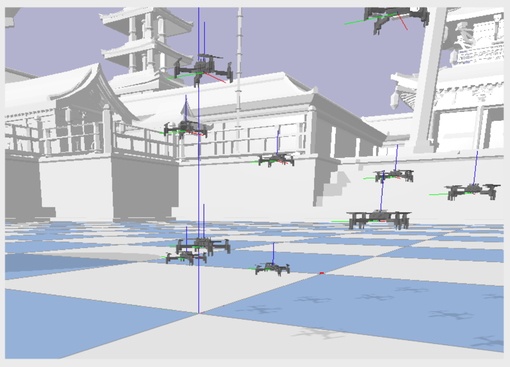


- Correlating the network input and output spike trains
- Pearson correlation coefficients of all ants from the best individual

Results

- Ants learn to collaborate by depositing pheromones close to the food and nest
- Pheromone usage not manually encoded into SNN; instead behaviour is established through optimization by exploiting physiological properties of the agents
- Pheromone-based communication increases the performance of the colony

Outlook



Modified from [5]

- Transfer strategy from simulation to actual robotics hardware
- Application to real world problems (e.g. by utilizing drones)
- Deployment in changing environments with harsh conditions
  ↳ single agents are more prone to failure
- Multiple types of pheromones to achieve complex communication within the colony

Acknowledgments

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References

[1] Deborah Gordon. *Two Lessons We Can Learn From Ant Colonies*. 2016. URL: https://www.huffpost.com/entry/two-lessons-we-can-learn_b_9039230 (visited on 12/21/2022).

[2] Seth Tisue and Uri Wilensky. "Netlogo: A simple environment for modeling complexity". In: *International conference on complex systems*. Vol. 21. Boston, MA. 2004, pp. 16–21.

[3] Jan Hahne et al. *NEST 3.0*. Version 3.0. June 2021. DOI: 10.5281/zenodo.4739103. URL: https://doi.org/10.5281/zenodo.4739103.

[4] Alper Yegenoglu et al. "Exploring Parameter and Hyper-Parameter Spaces of Neuroscience Models on High Performance Computers With Learning to Learn". In: *Frontiers in Computational Neuroscience* 16 (2022).

[5] Jacopo Panerati et al. "Learning to Fly—a Gym Environment with PyBullet Physics for Reinforcement Learning of Multi-agent Quadcopter Control". In: *2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2021.