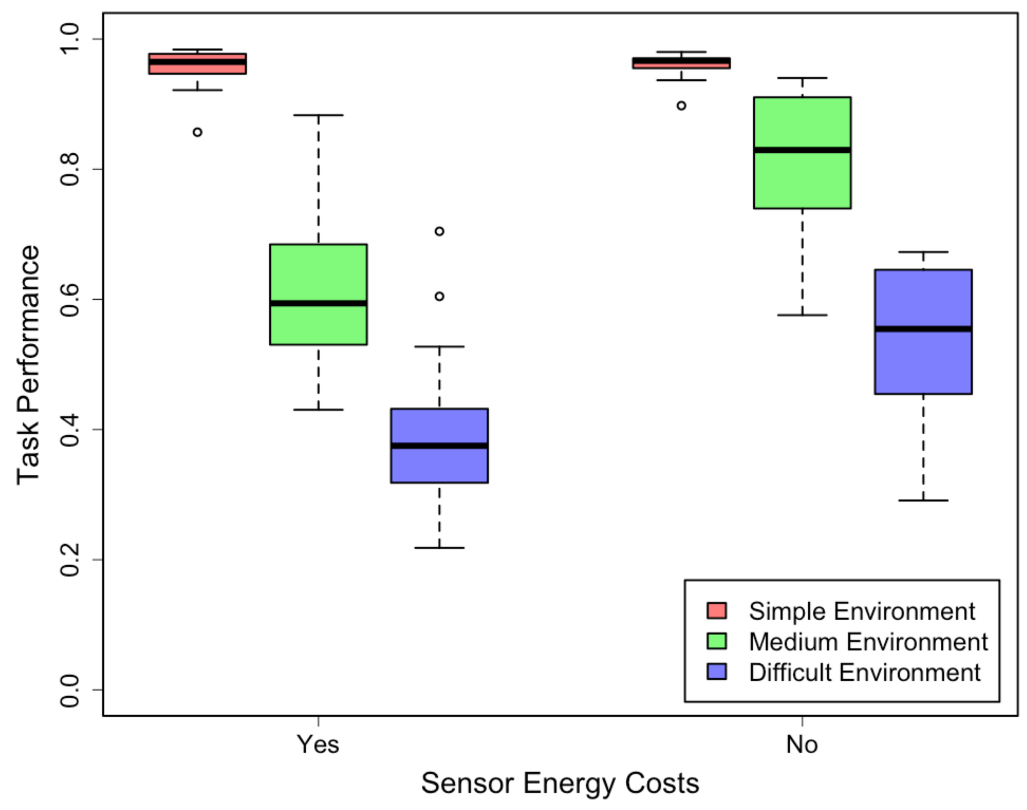
The Cost of Complexity in Robot Bodies

Overview

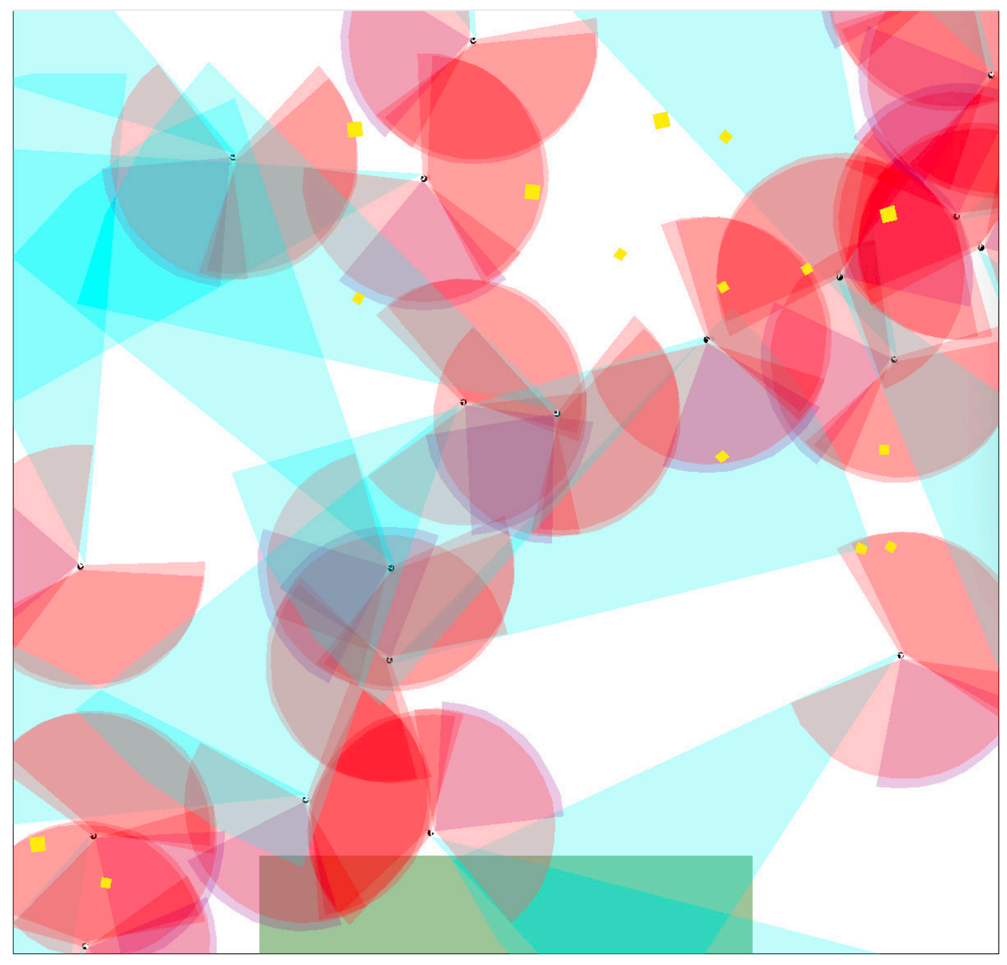
The field of Evolutionary Swarm Robotics seeks to simulate natural evolution in evolving robot morphologies (or bodies) and controllers (or brains) for collaborative task environments. This project aims to further investigate the relationship between robot complexity and task performance in a collective gathering task, while extending previously defined approaches to imposing an evolutionary cost on complexity. Single-objective evolutionary algorithms (NEAT-M and HyperNEAT-M) were implemented, constrained by the energy cost associated with draining a simulated battery in proportion to some measure of robot complexity (morphological or neural). One of the goals of using this approach is to address criticism of previous work, which embraced multi-objective methods, and was not considered to be representative of true natural evolution. Results indicate that costs on complexity are associated with evolved robots exhibiting increasingly degraded task performance in more difficult environments. It is surmised that higher complexity is required for group coordination behaviour.

Morphological Cost (NEAT-M)

- Morphological complexity was measured as the sum of the energy costs for all sensors (see bottom-right key) on a robot's body.
- Sensor configuration was free to evolve between generations.
- In medium and difficult environments (requiring increasing collaboration), robots evolved with energy costs displayed significantly degraded task performance (see adjacent figure).
- In all cases, robots evolved with energy costs exhibited significantly lower morphological complexity.

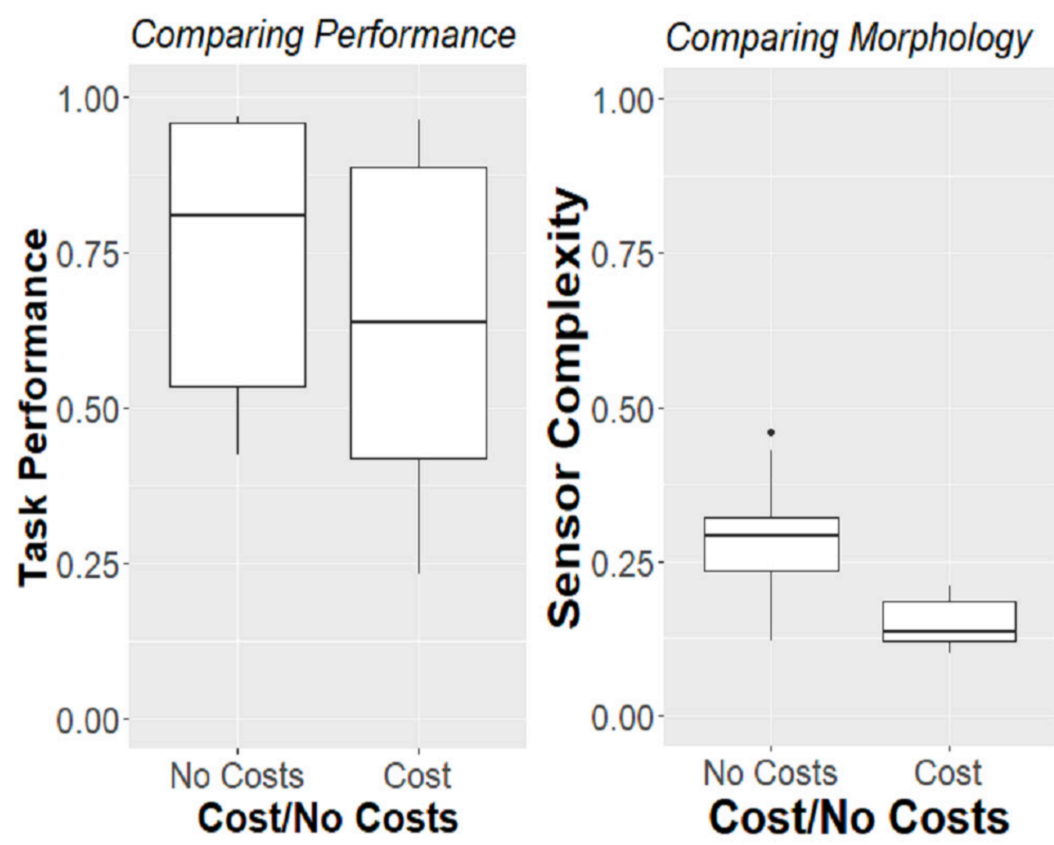


Simulated Environment

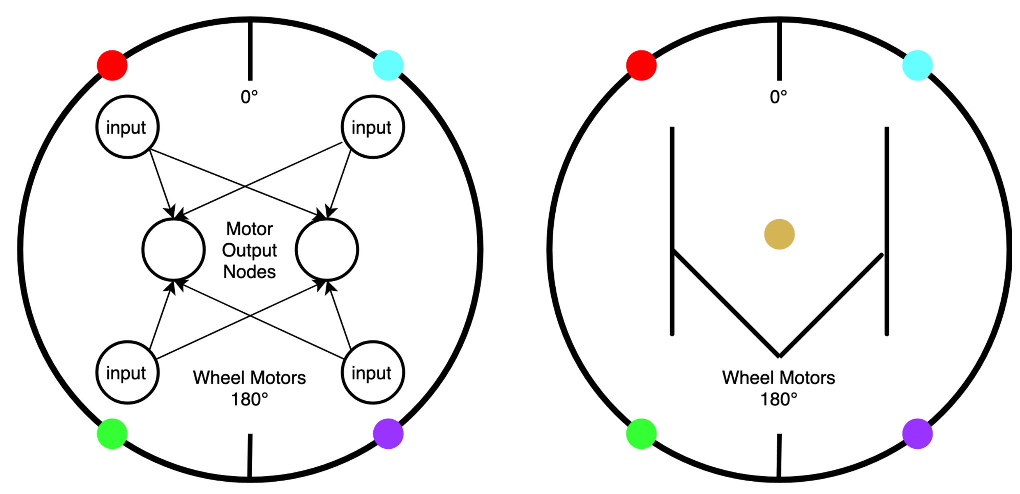


Morphological Cost (HyperNEAT-M)

- Morphological complexity was measured as above.
- HyperNEAT-M was used as the evolutionary algorithm and it was found that this did not impact results.
- In all cases, robots evolved with sensor costs had significantly lower morphological complexity (see adjacent figure).
- In all environments, robots evolved with morphological energy costs displayed significantly degraded task performance (see adjacent figure).
- The tradeoff between fitness and morphological complexity is not linear when a cost is imposed on complexity, but less than that.



Robot Artificial Neural Network Controller

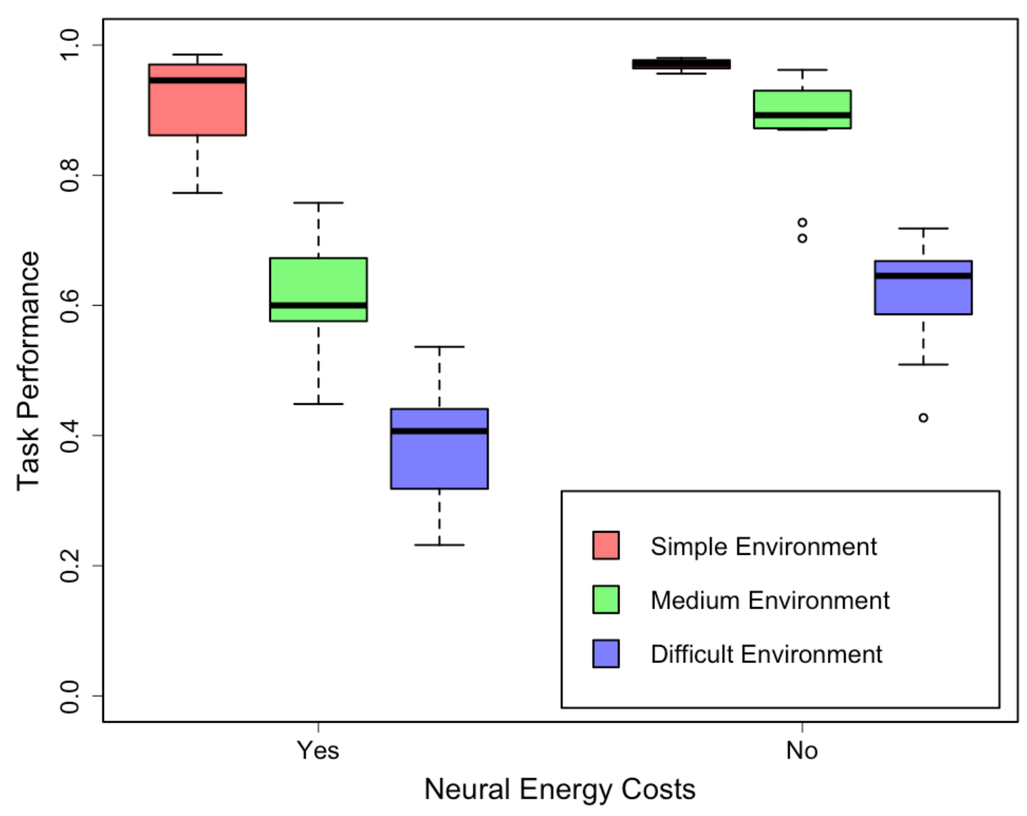


Key

- Ultrasonic Sensor (5 energy units/time step)
- Infrared Proximity Sensor (1 energy unit/time step)
- Colour Sensor (2 energy units/time step)
- Low Res Camera (10 energy units/time step)
- Bottom Proimity Sensor (1 energy unit/time step)

Neural Cost (NEAT-M)

- Neural complexity was measured as the sum of all nodes (and connections between them) in the artificial neural network associated with a robot's controller.
- Network layers and nodes evolved between generations but were constrained by a selection pressure from the imposed cost.
- In all environments, robots evolved with neural energy costs displayed significantly degraded task performance (see adjacent figure).
- Robots evolved with a neural energy cost produced simpler morphologies.



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