The Impact of Robot Morphology on Evolving Co-operative Behaviour

Our research aimed to develop controllers for robotic agents that exhibit intelligent co-operative behaviour in a team. We used Evolutionary Algorithms (EAs) to design these controllers.

We were chiefly interested in how the sensor configuration (morphology) of a robot could influence the development of its controller for tasks requiring co-operation.

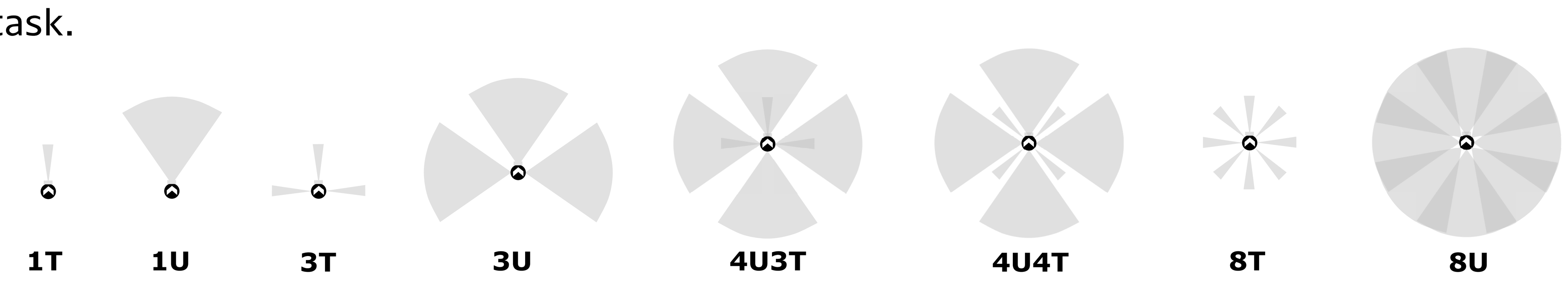
The task chosen was the collective foraging task which requires a group of robots to find resources and push them into a target area. This task could be rigged to require co-operation among agents by including larger resources that required multiple agents to push.

A popular approach to designing robot controllers is to use Machine Learning (ML) methods. EAs are a type of ML method where algorithms are refined or "evolved" using an iterative process of selection, recombination, mutation and testing. Because of time and cost constraints, it is common practice to evolve robot controllers in a virtual environment before "transplanting" the controllers into physical robots.

We built a high-performance multi-robot foraging simulator in Java to evolve the controllers. Each group member tested a different hypothesis about the morphology of the robots and its effect on the evolution of their controllers.

Experiment 1:
Minimising Morphologies Needed to Evolve Co-operation

The aim is to find the minimal agent sensor configuration (morphology) that still results in the evolution of effective co-operation. 8 morphologies were designed and tested by evolving controllers using Genetic Programming on a series of 3 variants of the foraging task.



Experiment results showed that a morphology consisting of 3 ultrasonic sensors is the simplest and most effective morphology in our test tasks, followed closely by 8 ultrasonic sensors.

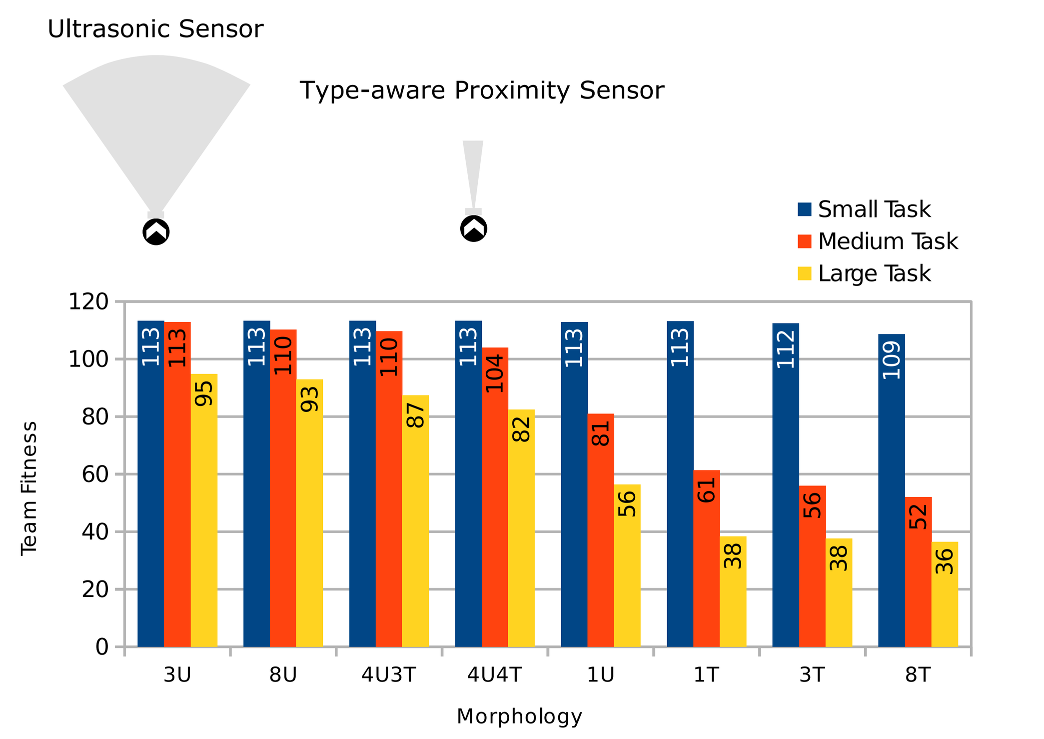


Figure 1: The maximum team fitness per morphology after 70 generations.

Experiment 2:
Distorting Sensory Input to Evolve Effective Co-operation

Each robot was equipped with 7 sensors; 4 general-purpose proximity sensors and 3 special sensors in front that could detect objects of one type only. Each special sensor was equipped with an additional linear gain parameter ∊ {0.5, 1.0. 1.5} that could make objects seem closer or further away than they actually were. Every possible 3-combination of the parameters was generated. The robot controllers were Artificial Neural Networks evolved with Neuro-Evolution of Augmenting Topologies in both genetically heterogeneous and homogeneous teams. The experiment measured the task performance of the sensory-distorted robots against a control on 3 foraging tasks, each requiring different levels of co-operation to achieve satisfactorily.

Preliminary results showed that the best performing combination of linear parameters for each task and team composition consistently performed as well or better than the control. This suggests that empirical signal amplification may be a way to improve co-operative performance in the collective foraging task.

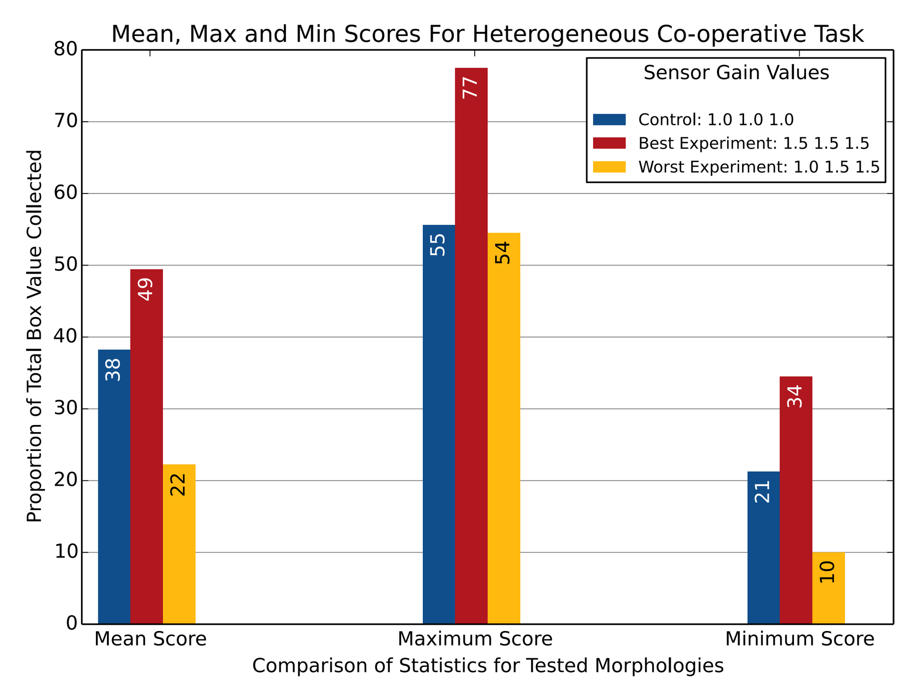


Figure 2: Sensor gain had the most effect on task performance in the heterogeneous task with mandatory co-operation. The amplification parameter listed in the legend are for the Robot Agent sensor, Resource Object sensor and Target Area sensor, respectively.

Experiment 3:
Concurrent Evolution of Controllers and Morphologies for Co-operation

A new evolutionary algorithm was developed that evolves agent controllers and morphologies concurrently. This algorithm was built on top of a popular method known as Neuro-Evolution of Augmenting Topologies (NEAT). Using the new algorithm, sensor positions are refined and new sensors are added. This has the potential to create unique morphologies that an experimenter would not have designed. The algorithm was tested against agents with a fixed morphology designed to mimic a commonly used robot, the Khepera III.

The proposed method was comparable to the fixed morphology method in cases that required a medium level of co-operation but its performance fell behind in the case where a high level of co-operation was required. Some of the evolved morphologies were retested in agents with fixed morphologies but evolving controllers. The evolved morphologies were shown to match the performance of the Khepera morphology in all levels of co-operation while featuring fewer sensors.

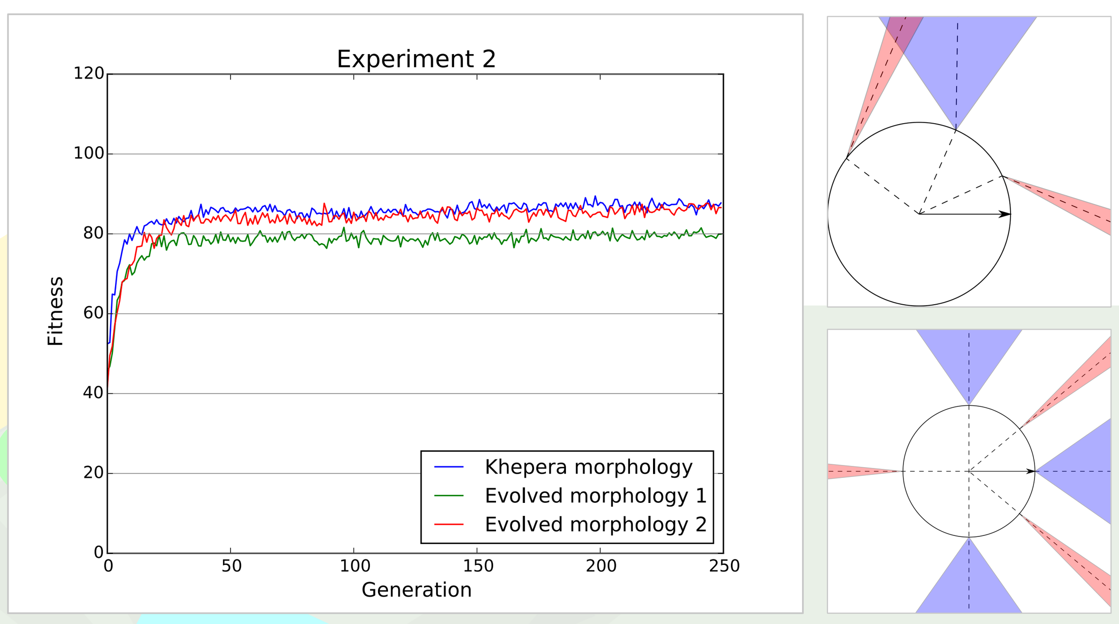


Figure 3: *Left:* A comparison of the fitness of the Khepera morphology against the fixed morphologies in the case requiring a medium level of co-operation. *Top right:* One of the evolved morphologies. *Bottom right:* The Khepera morphology used as the test case.

By Alexander Borysov, Mary Hsu and Jamie Hewland
Supervised by Dr. Geoff Nitschke
University of Cape Town Computer Science Department

Fork us on GitHub: http://git.io/sJNrig