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Balancing Selection Pressures, Multiple Objectives, and Neural Modularity to Coevolve Cooperative Agent Behavior

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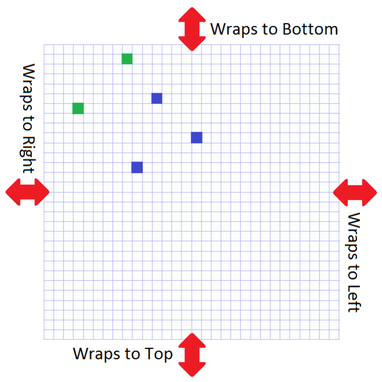
Abstract

Previous research using evolutionary computation in Multi-Agent Systems indicates that assigning fitness based on team vs. individual behavior has a strong impact on the ability of evolved teams of artificial agents to exhibit teamwork in challenging tasks. However, such research only made use of single-objective evolution. In contrast, when a multiobjective evolutionary algorithm is used, populations can be subject to individual-level objectives, team-level objectives, or combinations of the two. This poster explores the performance of cooperatively coevolved teams of agents controlled by artificial neural networks subject to these types of objectives. Specifically, predator agents are evolved to capture scripted prey agents in a torus-shaped grid world. Because of the tension between individual and team behaviors, multiple modes of behavior can be useful, and thus the effect of modular neural networks is also explored. Results demonstrate that fitness rewarding individual behavior is superior to fitness rewarding team behavior, despite being applied to a cooperative task. However, the use of networks with multiple modules allows predators to discover intelligent behavior, regardless of which type of objectives are used.

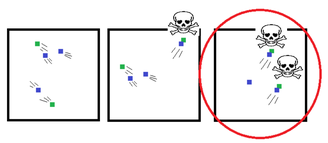
Predator-Prey Domain

- Three predators and two prey in a torus-shaped grid world [2]
- Torus-shaped grid world: agents can exit on one side of the grid world and wrap around to the opposite side
- Predators attempt to catch prey (occupy same location)
- Predators evolved against robotic/scripted prey
- Predator performance depends on different combinations of multiple fitness functions (multiobjective optimization via NSGA-II [3]):
  - o Minimize Distance from Prey
  - o Maximize Number of Prey Caught
- Predators with higher fitness scores move on to breed in the next generation while predators with lower fitness scores die out

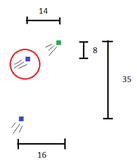
Torus Grid World



Maximize Number of Prey Caught

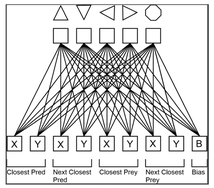


Minimize Distance from Prey

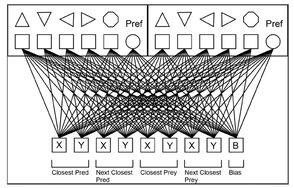


Multi-Modal Networks and Levels of Selection

One Module Network



Two Module Network

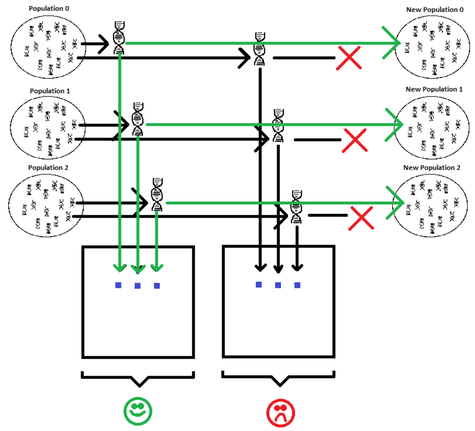


Objectives for Each Sub-Population

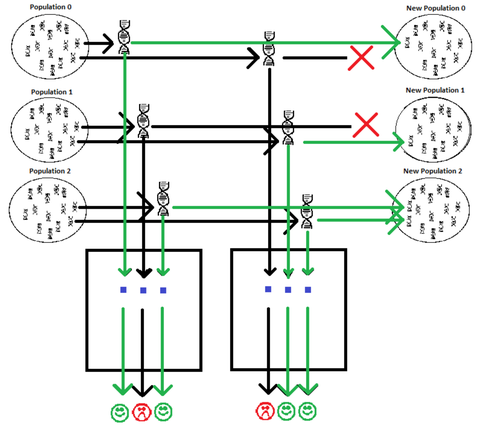
	IndCatch	IndDist	TeamCatch	TeamDist
Individual Selection	1	2	0	0
Team Selection	0	0	1	2
Both Selection	1	2	1	2

This table shows the number of fitness functions for each individual sub-population in each type of experiment. These numbers are the same for experiments where networks have either one or two modules. Ind stands for Individual Selection, and Team stands for Team Selection. Catch indicates the maximization of the number of prey caught. Dist indicates the minimization of distances between predators and prey (two distinct fitness functions of this type measure distances to the two distinct prey agents).

Team Selection



Individual Selection



Neural Modularity

A network takes numeric sensor inputs and generates numeric outputs. The output with the maximal value defines the action. This research implements networks with either one or two modules. A module is a set of outputs, corresponding to up, down, left, right, and stay still actions in this domain. Each module also has a preference neuron, and the preference neuron with the maximal output determines which module is currently being used. Experiments with one module test how agents perform with a single mode of behavior. Experiments with two modules allow agents to learn two modes of behaviors, as well as how and when to utilize each mode of behavior.

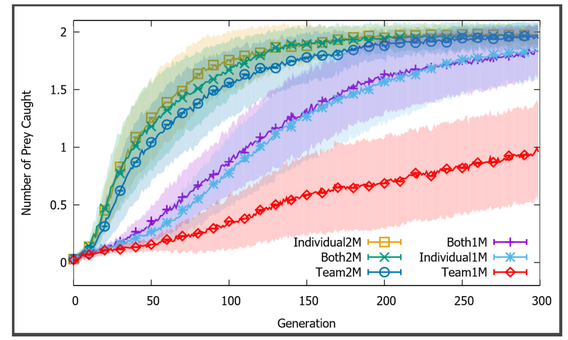
Selection

Selection is performed on each population individually by choosing the individuals with the highest fitness scores [1]. Fitness functions can reward individual behavior (individual selection), behavior of the entire team (team selection) or both.

Results

- Predators were evolved against robotic prey with a population size of 200
- 300 generations per experimental run
- 30 experimental runs for each number of modules and level of selection
- Each agent was evaluated 10 times per generation and scores were averaged across trials

Average Number of Prey Caught by Best Team for Various Levels of Selection and Numbers of Modules



- Individual: only fitness functions rewarding the predators as individuals.
- Team: only fitness functions rewarding the team as a whole.
- Both: a combination of individual and team fitness functions.
- 1M: neural networks have only one module, or mode of behavior.
- 2M: neural networks have two modules, or modes of behavior.

- Teams with individual selection performed better than those with team selection, but teams with both types of selection at the same time also showed potential.
- Teams with 2 modules performed the best even if they used team objectives. They also showed more complex, specialized behavior, including the following:
  - o Predators developed supportive roles, such as herding the prey and acting as a blocker for the other, more aggressive predators.
  - o Predators developed aggressive roles for chasing down the prey, and learned to work together with the supportive roles to surround and capture prey.
  - o Predators had the ability to switch between supportive (altruistic) and aggressive (selfish) roles when necessary.

References

[1] M. Waibel, L. Keller, and D. Floreano. Genetic Team Composition and Level of Selection in the Evolution of Cooperation. In *IEEE Transactions on Evolutionary Computation (Volume:13 , Issue: 3)*, June 2009.

[2] A. Rawal, P. Rajagopalan, and R. Miikkulainen. Constructing Competitive and Cooperative Agent Behavior Using Coevolution. In *IEEE Conference on Computational Intelligence and Games (CIG 2010)*, Copenhagen, Denmark, August 2010.

[3] Kalyanmoy Deb, Amrit Pratap, Sameer Agarwal, and T. Meyarivan. 2002. A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II. In *IEEE Transactions on Evolutionary Computation 6 (2002)*, 182-197.

hhmi Howard Hughes Medical Institute