Emergence of signaling in colonies of simulated mobile robots

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Motivation

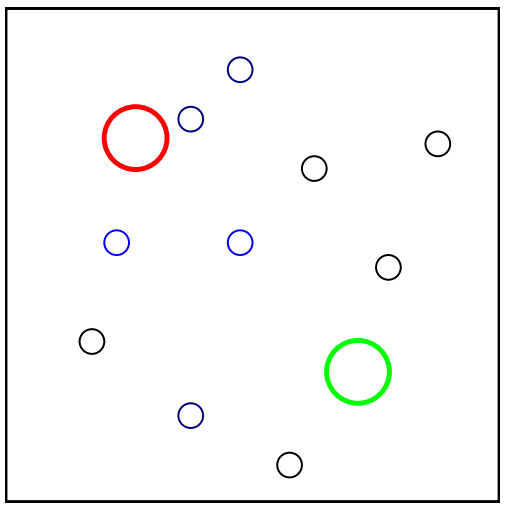
We explore the emergence of signalling in a colony of simulated mobile robots. Using a simple neural network architecture (single layer, feedforward), we generate the controller through artificial evolution.
We explore the consequences and influence of several evolutionary conditions and different levels of selection.

The experimental setup

Ten robots are placed in a square arena of 3x3 m with two objects:

- Food, which increases fitness of any close robot.
- Poison, which decreases fitness of any close robot.

One object is green, the other is red. The association of the color and the type of object is randomly chosen at the beginning of each trial.



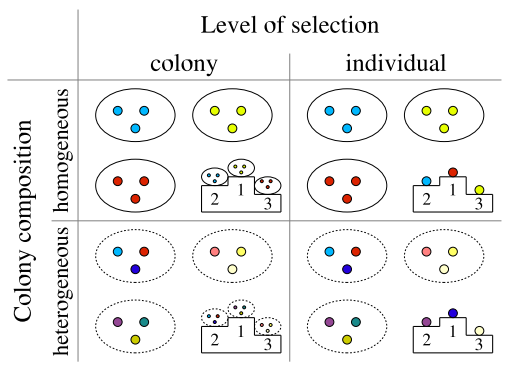
Each robot has to maximize collected food during a fixed amount of time.

Evolutionary conditions

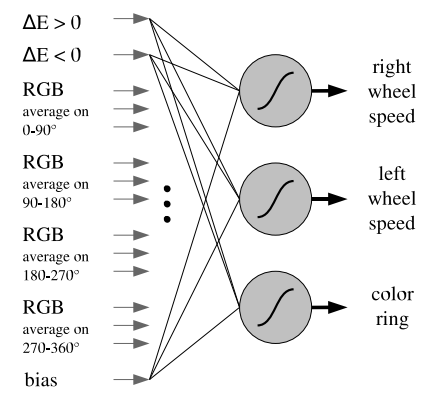
Many parameters can affect the evolution of agents living in colonies. We look at the effects of two of them:

- Colony composition
  - Homogeneous colonies, all individuals are clones.
  - Heterogeneous colonies, every individual has a different genome.
- Level of selection
  - Colony level selection, the fitness is the sum of all individual fitnesses.
  - Individual level selection, the selection acts on an individual base.

Using all combinations, we have four types of colonies: HomCol, HomInd, HetCol, HetInd.



The neural controller



Inputs (12 total):

- Circular 1D camera, one pixel for each 90 aperture angle, RGB
- $\Delta E > 0$, 1 if robots gains fitness, zero otherwise
- $\Delta E < 0$, 1 if robots looses fitness, zero otherwise

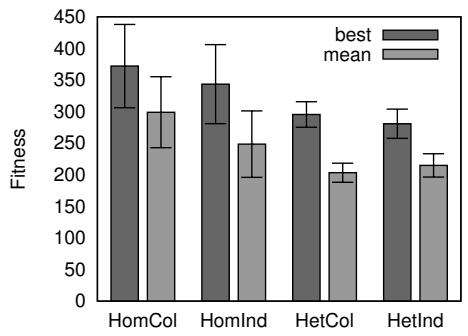
Outputs (3 total):

- Left and right speed
- Blue intensity of the color ring

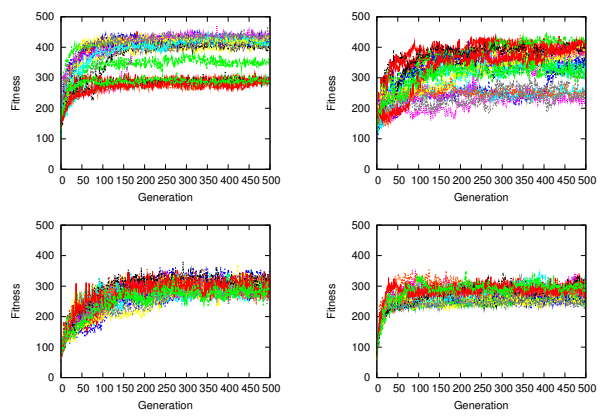
Single layer sigmoid feedforward network.
It is the simplest architecture possible with a neural network and is sufficient to have robots that succesfully accomplish the task.

Fitness

The mean fitness of the last 50 generations over a total of 500 in the four evolutionary conditions.



The fitness of the best individual through evolution for the four evolutionary conditions.



Emergent behaviours

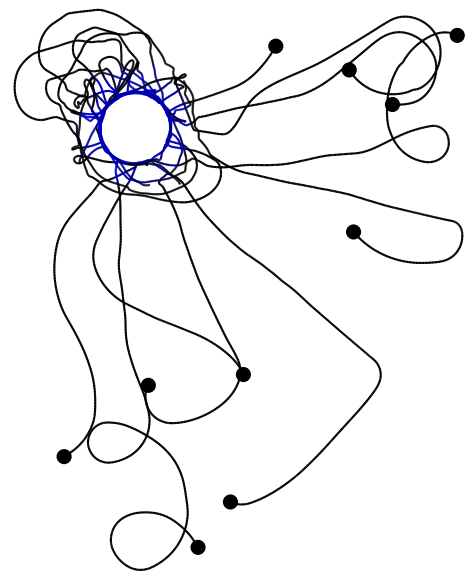
We observe three types of behaviours:

- Selfish. Robots do not communicate.
- Cooperative. Robots signal poison.
- Cooperative. Robots signal food.

The last one leads to better fitnesses than the first two ones.

Trajectories

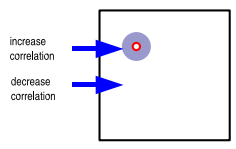
The trajectories of individuals from the best colony.



Food-color correlation

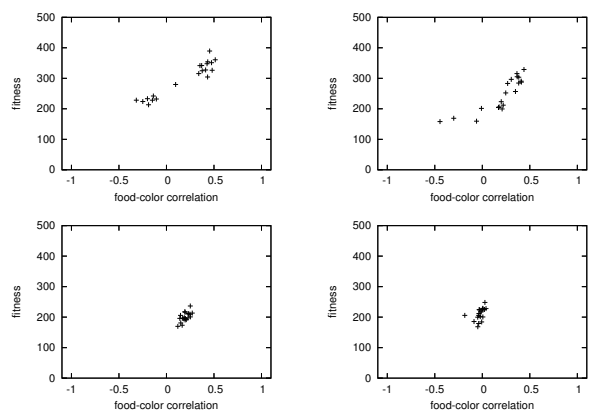
To measure the relation between signaling and proximity of food, we have devised a food-color correlation test:

$$\frac{1}{N}\sum_{n=1}^{N} O_n \cdot B_n$$



where:

- N is the number of steps of the test
- O_n is $\begin{cases} 1 & \text{if robot object distance is} < 30 \text{ cm} \\ -1 & \text{if robot object distance is} \geq 30 \text{ cm} \end{cases}$
- B_n is the intensity of blue



Robot

We use a simulated version of the s-bot mobile robot.