What mechanisms underlie dyadic cooperation? A study with neuro-robotics models.

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Abstract . Cooperation allows individuals to reach goals that one single cannot achieve. In ethological studies the mechanisms of cooperation have been widely investigated; new experimental paradigms are now introduced in controlled environments to simplify the approach and to go deep inside the strategies of cooperation. One of these experimental paradigms is the "loose string task", for example used with chimpanzees and birds. Analyzing the strategies and the mechanisms used by artificial organisms to perform a cooperation task, we observed that vision can help agents to solve the problem better than communication.

Keywords : Corvids, Loose String Task, Diadic Cooperation

1 Introduction

Cooperation allows to reach goals that are precluded to a single agent. This principle is well-known in animal reign where various and outstanding examples of cooperation can be observed. Consider for example grooming in primates, an activity in which individuals in a group clean one another's body by which animals who live in proximity can bond and reinforce social structures, family links, and build relationships or the structured social organization of insects such as ants, bees, wasps or termites where every subject covers a specific role that sustains the hierarchy feeding the entire group.

The ethological observation of these phenomena has been recently complemented with the study in controlled situation using specific experimental paradigms: these paradigms represent a simplified version of cooperation chances that animals encounter in natural environment. The loose string task is an experimental paradigm to study cooperation developed by Hirata [1] and then used by Melis [2,3] to study chimpanzees, birds [6], and recently elephants [4]. In this task two agents have to cooperate to obtain a reward, i.e. food, which is clearly visible, but not directly reachable. The dyad gets the reward if the two tips of a string are pulled at the same time.

This approach's main drawback is that attention is focused in verifying if a certain ability/capacity can be found in another species or not. In other words it seems that a catalogue has to be compiled: dogs do this thing, cats don't, etc, whereas there is no interest in understanding if there are different

strategies in solving that task between species or rather a common underlying mechanism. We try to overcome, at least partially, this issue with the present contribution in which we describe a dyadic cooperation task solved by artificial organisms whose we can analyze the solving strategies and mechanism.

2 Materials and methods

2.1 The task

A dyad of robots must solve a cooperative task that represent the simplified version of the loose string task (fig.1): a bar must be brought on two areas by the two robots at about the same time to receive a reward.

This way robots must cooperate to bring simultaneously the bar on the reward areas because the delay of one robot cause the failure of both.

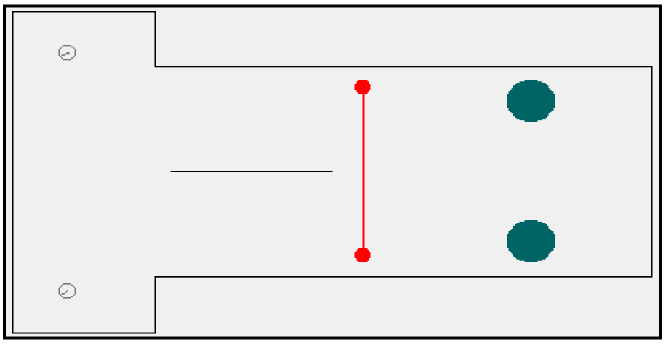

Fig. 1. The experimental set-up with the bar and the reward areas.

The robots starts from fixed positions inside a T-shaped corridor where, in the centre, there is a wall.

2.2 The robot

The robot is a simulation inspired by Khepera with two motors on the bottom side and three bump sensors, as shown in the figure. Each sensor encodes the stimulation this way: 00 corresponds to no impact (Fig.2).

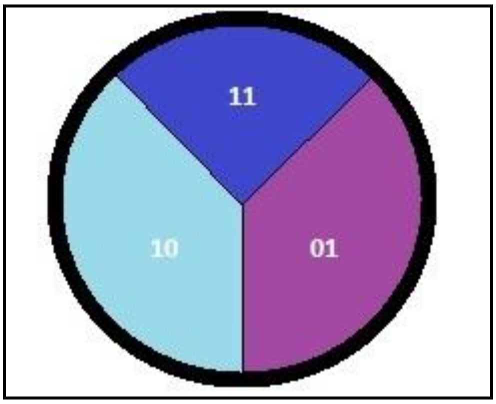

Fig. 2. The bump sensory system

The robot control system (Fig.3) consists of three layers: the input layers is made up by 2 bump neurons, 18 neurons associated to the visual system of the robots and by a neuron that encodes the ground sensor.

The visual system of the robot encodes on a gray-scale the input from the artificial retina of the robot whereas the ground sensor signals if the robot is on a specific area. The output layer is made up by 2 neurons that control the motors. The hidden layer is made up by 5 neurons.

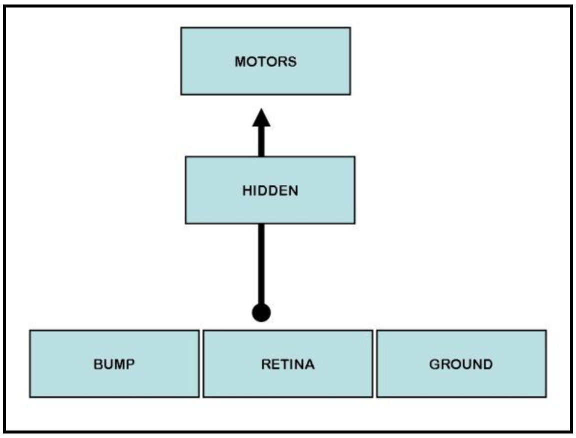

Fig. 3. The robot control system

The layer that controls 18 retina photoreceptors is formed by neurons that receive a value from 0 to 1 according to the gray-scale acquired from 1 of the 18 retina photoreceptor. The retina receptive field goes from -90 degrees to +90 degrees considering face direction so every photoreceptor cover an area 10 degrees wide.

2.3 The evolutionary process

The robots are evolved using a genetic algorithm with an initial population of 100 dyads of agents whose genotype are randomly mutated. At the end of their life they receive a score according to their ability to solve the task described above (they can try 20 times) and their chance to reproduce depends on this score. This selection procedure is iterated 300 times and from one generation to the next the 2% of offspring genotypes are muted. The whole process is repeated 10 times with different starting conditions.

2.4 The experimental conditions

In the present paper, we would like to understand how cooperation evolves with different channels of communication. The task we have described, in fact, implies that a subject in the dyad considers the presence of the other and that wait each other. It is moreover clear from the ethological observation that animal use some channel of communication to coordinate and solve the cooperative task correctly.

We have then compared 4 different conditions:

- no communication and no vision;
- communication (with an auditory signal) and no vision;
- no communication and vision;
- communication and vision.

3 Results and conclusions

3.1 Statistics

The first results regard the number of successful trials by the robots in the four conditions (Fig. 4). From the graph below it is clear that the most successful condition is the no-communication and vision. The difference between the second condition (no communication – vision), evaluated with t tests, and all the other ones, is statistically significant. The statistical difference between the first, third and fourth condition (in the graph) seems not be significant.

3.2 Strategies

The above described results are counterintuitive: one would expect that communication and vision together could be more helpful in solving the task. On the contrary vision alone works better.

If we observe the behavioural strategies (Fig.5), we can see that the robot, exploiting the lateral vision see each in each moment (left). If a robot is late, the other waits for its companion to go to the bar in order to reach the reward area and pull the bar at the same time and solve the task. In other words they synchronize.

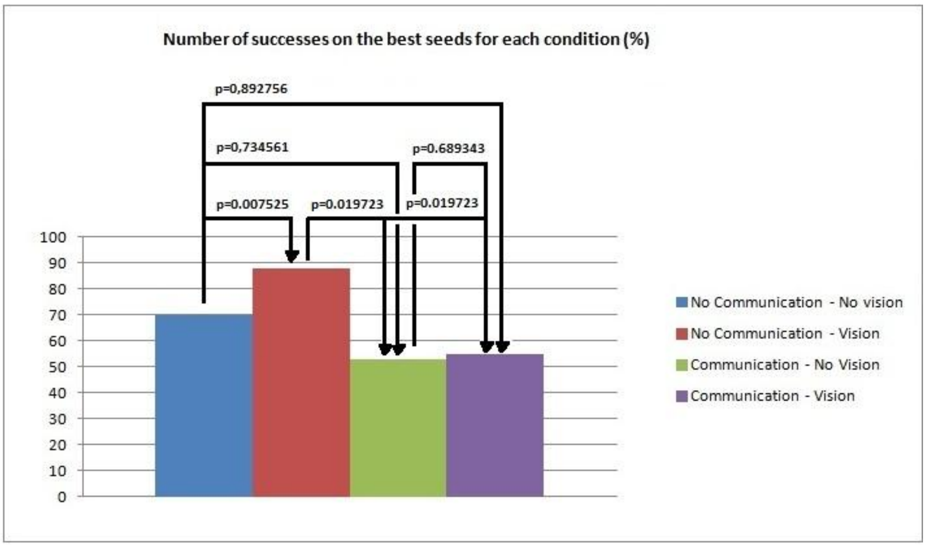

Fig. 4. Number of successes by the robots

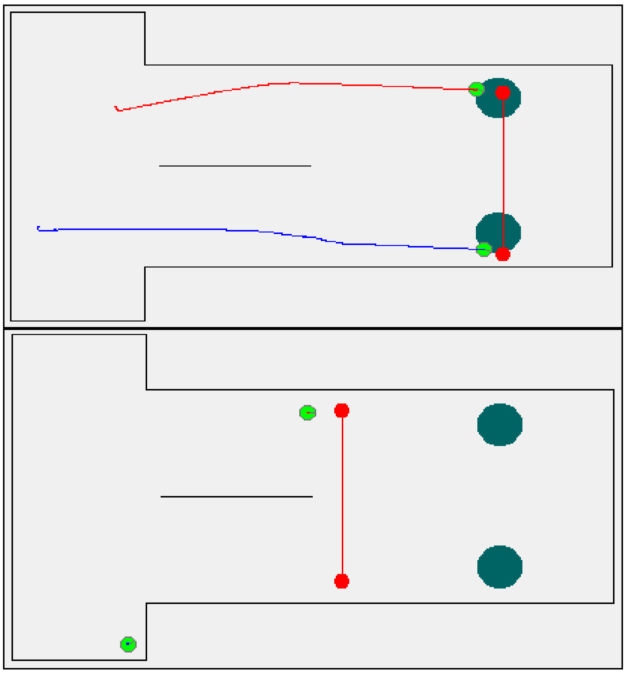

Fig. 5. Behavioural Strategy

On the contrary the other three conditions do not produce strategies as efficient as the one described and this reflects also on the indexes reported above.

How can we explain these puzzling data?

In our opinion, the present evolutionary process doesn't allow the signal to become a communication signal: in other word in no case the dyad arrives to interpret the auditory signal as something that can be useful to understand others' intention. On the other side, vision automatically and naturally gives information about others' position, an information that is clearly relevant in this kind of task.

What is relevant in our opinion, is that this approach allows us to study the cooperation issue trying to go deep inside the mechanisms that regulate it. In fact with the artificial organisms we use, there is the chance to control more variables: how can you control the elephant vision? For us it is much easier and allows you to understand how vision determines cooperation and through which mechanisms.

4 Rereferences

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