Cooperation in corvids: a simulative study with evolved robot

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1. Introduction

Corvids (Corvidae) include various birds species characterized by high complexity in cognitive functions: they can be compared with primates both on brain relative dimensions and on social organization complexity. They are capable of long term cache recovery, tool manipulation and social reasoning and we can observe them in dyads as well as in small or large colonies. Corvids are also able to cooperate in order to obtain a goal. In the last twenty years, as underlined by Noe (2006) in his quite recent review on the theme, many studies have been run on cooperation observing two conspecifics that could get a reward through cooperation, mainly addressed by "three different motivations: (1) detecting the mechanistic basis of naturally occurring forms of cooperation; (2) analysing behavioural strategies specific to cooperation; and (3) testing game-theoretical models" (ibidem). In many cases these experiments study cooperation by using very abstract and artificial conditions to which animals, especially vertebrates, must be trained to, thus making it difficult to distinguish if dyads are "coordinated trough communication or acting apart together"(ibidem). It seems therefore quite relevant trying to understand how communication allows dyads to cooperate indeed. This issue can be approached to in a comparative natural and artificial behavioural science (Ponticorvo *et alii*, 2006) in which artificial organisms, such as robots or simulated agents are compared with natural organisms. Nowadays, thanks to Artificial Intelligence and Robotics tools, it is possible to build artificial systems that are able to simulate, at least for some aspects, animal or human behaviour. This methodology can be used for theoretical goals because the reconstruction, both in simulation or with physical artifacts, of a model about a certain phenomenon allows to verify synthetically its explicatory potential. In building a machine, one can choose to define a priori what an artifact must look like, for example programming a robot to solve a task following stated rules. But it is possible to follow another route allowing the robot-environment system to self-organize and then analyze how it came to a solution. This is the idea below Evolutionary Robotics (Nolfi and Floreano, 2000), whose models can be divided in two categories: idea and data models. In 'idea models' evolutionary techniques are used to reproduce very general phenomena, while in "data models" the artificial organisms accurately reproduce quantitative observations (behavioral indices) of animal behavior in well-defined experimental set-ups. In a certain sense Artificial Life systems are labs in which to test hypothesis. The experimenter can compare natural observations with what emerges from artificial reality which he has given the *fiat lux* to and whose development he can not predict. The understanding of a general function (cooperation, spatial orientation, communication, learning) can be reached by comparing different living forms (biological organisms). We look for similarities in differences. Through Artificial Life we can add artificial organisms to the number of species to compare with. This methodology, in recent years, has been widely applied to the emergence of communication, see for example Di Paolo (1997, 2000), Quinn (2001), Quinn *et al.* (2001), Baldassarre *et al.* (2002), Trianni and Dorigo (2006), Marocco and Nolfi (2007). In the present study we propose a model to study how emerging communication leads to cooperation in the 'loose string' paradigm derived from the most popular paradigm used in game-theoretical model: the Prisoner's Dilemma (Ashlock *et alii*, 1996; Clements and Stephens, 1995; Gardner *et alii*, 1984). In the 'loose string' task two agents, for example corvids, must 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. In the present study we model this task with artificial organisms to verify the emergence and maintenance of cooperation in artificial organisms.

2. Method

2.1. *Experimental setup*

The experimental setup involves two robots situated in an arena consisting of a square room where robots begin each trial and of a wide corridor with a target area and some landmarks in it. Once they've reached the target area, robots have to drive towards the same landmark. This task is derived by the "loose string" task and represents a situation in which the robots should coordinate themselves/cooperate to get a reward.

2.2. *The environment and the robots*

The environment consists of a 40x50 cm square arena and of a 50x30 cm corridor both surrounded by walls. The corridor presents a target area and three landmarks whose positions are randomly assigned when the robots enter in the area. The robots are two e-Puck robots (Mondada and Bonani, 2007) provided with a diameter of 7.5 cm, 2 motors which control the 2 corresponding wheels, 8 infrared proximity sensors located around the robot's body, 3 more infrared sensors placed on the front side of the robot and oriented toward the ground, a VGA camera with a view field of 36 degrees pointing in the direction of forward motion and a LED ring on the circumference. The camera and the LED ring can be used to send and receive signals.

2.3. *The neural controller*

The neural controllers of each robot are provided with sensory neurons, internal neurons with recurrent connections, motor neurons and a signal neuron.

2.4. *The evolutionary algorithm*

An evolutionary technique is used to set the weights of the robots' neural controller. The initial population consists of 100 randomly generated genotypes that encode the connection weights of 100 corresponding neural networks. Each genotype is translated into 2 identical neural controllers which are embodied in 2 corresponding robots situated in the environment (i.e. teams are homogeneous). The 20 best genotypes of each generation are allowed to reproduce by generating 5 copies each, with 2% of their bits replaced with a new randomly selected value. The evolutionary process lasts many generations (i.e. the process of testing, selecting and reproducing robots is iterated 1000 times). The experiment is replicated 20 times each consisting of 4 trials with 4 different starting positions in the corners of the square room. We used the following fitness function, in pseudo-code, to evolve robots:

If (two robots are on target area) Landmarks appear;

If (two robots are close to the same landmark and therefore close to each other) Fitness +=1;

3. Results and Conclusions

Results show that cooperation between robots is regulated by social interaction between robots, with communication as a medium. In our simulative scenario the emergence of communication leads to a coordinated cooperation behavior that is somewhat similar to cooperation observed in natural organisms as corvids.

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