Evolution of Acoustic Communication Between Two Cooperating Robots

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1 The fitness function

During evolution, each genotype is translated into a robot controller (i.e., modules M_C and M_M see [1]), and cloned in each agent. Then, the two robot group is evaluated two times in each environment type E_{11}, E_{00}, E_{01}, and E_{10}, for a total of eight trials. Note that the sequence order of the environment type experienced by the robots—randomly chosen at the beginning of each generation—has a bearing on the overall performance of the group since the robots' controllers are reset only at the beginning of the first trial. Each trial differs from the others in the initialisation of the random number generator, which influences the robots' starting position and orientation anytime the robots are positioned, and the noise added to motors and sensors. The robots are randomly placed in the arena at the beginning of the first trial and repositioned in subsequent trials following an unsuccessful one. Within a trial, the robots life-span is 90 simulated seconds (900 simulation cycles). A trial is terminated earlier in case a robot crashes with the arena walls, or if the group successfully accomplishes its task. For each trial $e \in [1, 8]$, the group is rewarded by an evaluation function which seeks to assess the ability of the robots to open the revolving door located at the centre of the arena. This requires the robots to be able to determine the nature of the environment (i.e., E_{11}, E_{00}, E_{01}, or E_{10}) by using acoustic communication. The final fitness F attributed to a group controlled by a specific genotype is the average group score over a set of eight trials, and it is computed as follows:

$$F = \left(\frac{\sum_{e=1}^{8} FM_e}{8} \right) + FC; \quad FM_e = \frac{\sum_{r=1}^{2} (\psi_r + fm_r \kappa_r \rho_r)}{2}, \; FM_e \in [0, 2.4]; \quad (1)$$

$$FC = \begin{cases} 0, & \text{if } \dfrac{\left(\sum_{e=1}^{8} \sum_{r=1}^{2} fc_{er} \right)}{2} \leq 0; \\ \dfrac{\sum_{e=1}^{8} \sum_{r=1}^{2} fc_{er}}{2}, & \text{otherwise;} \end{cases} , \; FC \in [0, 1.0] \quad (2)$$

$\psi_r = 0$ if robot r didn't terminate the first phase of a trial, otherwise $\psi_r = 1$. $\rho_r = \frac{1}{5}$ if robot r collided with the arena walls, otherwise $\rho_r = 1$. $fm_r = 1.0 - (d_{rL_i})$ with d_{rL_i} corresponding to the normalised distance between the robot r and the light L_i. During the first phase of a trial $i = 1$ for the robot r

located in the lower side of the arena, and $i = 2$ for the robot r located in the upper side of the arena. During the second phase of a trial, $i = 1$ for the robot r located in the upper side of the arena, and $i = 2$ for the robot r located in the lower side of the arena. $\kappa_r = 1$ if robot r didn't terminate the first phase of a trial, or if, after having done so, it exerts pushing forces in the rotational direction of the revolving door. $\kappa_r = 0.5$ if robot r, after having terminated the first phase of a trial, it exerts pushing forces in the anti-rotational direction of the revolving door. $fc_{er} = \frac{\sum_{s=(t_c)}^{T}(P_{s-tc})}{T-t_c}$, where t_c corresponds to the simulation cycles at 10 seconds after the end of the first part of the task, T corresponds to the simulations cycles at the end of the trial e and

$$P_{s-tc} = \begin{cases} +1 \text{ if } ((E_{11} \vee E_{00}) \wedge (S_C = 0)) \vee ((E_{10} \vee E_{01}) \wedge (S_C = 1)) \\ -1 \text{ if } ((E_{11} \vee E_{00}) \wedge (S_C = 1)) \vee ((E_{10} \vee E_{01}) \wedge (S_C = 0)) \end{cases} \tag{3}$$

In other words, during the first phase of a trial, FM_e rewards the robots for approaching the light at the corresponding side of the arena (i.e., L_1 for robot in the lower side; L_2 for robot in the upper side). During the second phase of a trial, FM_e rewards the robots for approaching the opposite side of the arena. FC rewards the robots for setting the state of the fifth neurons (i.e., y_5) of M_C so that (a) S_C results equal to 0 during the second phase of trials in E_{00} and E_{11}; (b) S_C results equal to 1 during the second phase of trials in E_{10} and E_{01}.

Note that F doesn't refer anyhow to signalling behaviour. F rewards the robots for accomplishing the task. However, due to the nature of the task, the robots can be successful only if they coordinate their actions using the sound signalling system. By leaving signalling behaviour out of the fitness function, we clean our model from preconceptions concerning what (i.e., semantics) and how (i.e., syntax) successful group communicates, and we let evolution determine the characteristics of the communication protocol.

References

1. E. Tuci and C. Ampatzis. Evolution of acoustic communication between two co-operating robots. Technical Report TR/IRIDIA/2007-013, CoDE-IRIDIA, Univeristé Libre de Bruxelles, June 2007. The technical report can be found at http://iridia.ulb.ac.be/∼etuci/publications.html.