The role of internal stimuli in building up an 'inner world'. A study with evolved 'blind' robots.

Orazio Miglino[1,2] Domenico Parisi[2] and Michela Ponticorvo[1]

[1] Natural and Artificial Cognition Laboratory, University of Naples "Federico II", Italy

[2] Laboratory of Autonomous Robotics and Artificial Life, Institute of Cognition Science and Technologies, National Research Council, Rome, Italy

1 Introduction

In order to foresee an event and produce an anticipatory action, any organism should have some knowledge concerning the environment in which it lives. It is usually assumed that this knowledge is founded upon integrating innate schemes with sensory experience, where sensory experience is provided by environmental stimuli (light, sounds, smells, etc.) and is collected by the organism's sensory apparatus, including eyes, ears, noses. However, in addition to the external environment the organism's body itself is a precious source of stimuli (Parisi, 2004). Consider, for example, internal clocks, proprioception, signals from the gastroenteric apparatus, the hormonal system, etc. This stimulation is considered relevant to regulate the organism's behaviour, but not to build up a "knowledge" of the external environment. For example, hunger can motivate an organism to choose a certain action plan to satisfy this need, but it is not useful to make up a representation of the environment the organism lives in. We will describe some computer simulations that demonstrate how the behaviour of artificial organisms can reflect the particular characteristics of the environment in which they live and can be adaptive with respect to that environment even if the organisms obtain extremely indirect information from the environment through their sensors, or no information at all. We aim at investigating the possible role of internal stimulation in building a knowledge of the environment an organism lives in. We will explain in detail this question with a concrete example. Let's imagine an organism with a motor apparatus and an internal sensory apparatus, but totally without sensory organs directly informing the organism about the external environment. This organism is completely closed inside itself. It can interact with the external environment but cannot get any direct information about it. The organism is forced to create its own inner world on the basis of purely self-generated stimuli but it is not isolated from the external environment because its actions have effects that create a relation between the organism and the environment which the organism can exploit to behave adaptively. This system isn't isolated because action warrants a relation between system and environment. Moreover it receives an indirect feedback from the environment through the selection (for

example on evolutionary scale) that allows some individuals to reproduce and some not. This "fitness signal", that cannot be assimilated to sensory information, is fundamental to adapt to a specific ecological niche, as happens in natural organisms. In nature there may be no such organisms but the tools of Artificial Life can be used to explore this type of questions because Artificial Life is the study of both real and possible organisms (Langton, 1989; Nolfi and Floreano, 2000). We can cite the challenging work by Ziemke and colleagues (cfr. Ziemke et al., 2005; Hesslow and Jirenhed, 2007) who explore the possibility of "providing robots with an "inner world" based on internal simulation of perception rather than an explicit representation world model" (Ziemke et al., 2005).
Another very interesting study has been run by Todd and colleagues (1994) who studied the emergence of adaptive behaviour in simple simulated creatures lacking direct contact with their environment in different environments. In the present abstract we describe some simulations of robots that receive information from the world only very indirectly trough the evolutionary selection and that can be able to show an exploration behaviour with two questions in mind:

1. Can robots exhibit adaptive behaviours that rely only on internal stimulation?
2. If yes, how is that possible?

Answering these questions is interesting because the possible replies may clarify how anticipation on an evolutionary scale can lead to adaptation even in this extreme example of organism with no direct feedback on the external world.

2 Method

In our experiments, we use the Evorobot simulator to evolve populations of artificial organisms (software robots) with the ability to solve two tasks: exploring a square arena.

2.1 Artificial Organisms

Each artificial organism consists of a physically accurate simulation of a round robot, with a diameter of 5.5 cm. The robots moves using 2 wheels (one on each side of the robot) powered by separate, independently controlled motors. The control system is an Artificial Neural Network. We use neural architectures that differ in this respect: the existence of recursive connections. All neural networks have an output layer with two units that control the robot's two wheels. In all neural networks, furthermore, there are five internal units which are all connected to both output units. However, in different simulations the robots have neural architectures that can be different in internal structure. There are four internal architectures: no recursive connections, recursive connections from the output to the internal units, Elman "memories" for the internal units, or both.

2.2 The tasks and training procedure

A Genetic Algorithm is used to train the connection weights of all network architectures. At the beginning of each simulation, we create 100 neural networks with random connection weights that are assigned to 100 robots. We then test each robot's ability to solve the task. Each robot is positioned at the centre of the arena with a randomly chosen face-direction and allowed to move around for 500 computation cycles (1ms per cycle). In the exploration task each time a robot visits a cell it has not visited before its fitness is increased by one unit. At the end of "life" the 80 robots with the lowest fitness are eliminated (truncation selection). The remaining 20 robots are cloned (asexual reproduction). Each parent generates five offspring, and a value randomly chosen from the uniform distribution [-1, +1] is added to 2 per cent of their connection weights. We run 4 different experiments with 4 "recursive" conditions. Each experiment is repeated 10 times with different initial conditions.

3 Results

3.1 Fitness values

For both tasks the fitness of the best individual of the last generation suggests that recursive connections are beneficial for robots with no sensory information. This clearly happens because recursive connections allow to overcome stereotypic behaviour in favour of more variable behaviours. Therefore we have an interesting answer to our first question: yes, it is possible to observe adaptive behaviours in robots with only internal stimulation under certain conditions, namely the presence of recursive connections that allow the robot to build an internal dynamic, an "inner world" in Ziemke and colleagues' words, which is coupled with the environment. They succeed in coordinating endogenous stimuli with the constraints of the external environment and to use this coordination to generate motor behaviour which is adaptive.

3.2 Output patterns

In order to answer our second question and investigate the role of endogenous stimuli in producing behavioural sequences we examined the activation patterns of the output layer for the single best agent of the last generation in each replication of the simulations. The continuous activation value of the two output units is discretized when it is transferred to the two wheels, with discrete values going from -20 to 20 for each motor. Therefore we can count the number of different output patterns, which is a measure of the variety of the robots' micro-behaviours. The results indicate that more micro-behaviours (number of different output pattern activations) are necessary to solve the with self-generated stimulation. In absence of variable external stimulation, the robots create their own internal variable stimulation. Robots without any external stimulation are able to accomplish the task to explore effectively the square arena if they are provided with recursive connections that create an internal dynamic.

4 Conclusions

The results of our simulations suggest that, at least for the simple artificial organisms we considered, an adaptive behaviour can indeed emerge even in absence of direct sensory information. Even if they are closed in their own self-generated perceptual world, the robots establish a useful relation with the environment around them through action. In fact, by realizing and exploiting a very precise coordination between produced output and self-generated input, i.e., between external and internal world, the robots are able to adapt to their environment: this is possible because action is accurately selected under evolutionary pressure. This evolutionary pressure causes the emergence of a kind of resonance between inner and external world. Through the interaction between the organism and the environment emerges, after a demanding search, the chance to utilize action to know the environment, even if there is no sensory input from the environment, and action becomes the vehicle for developing a representation of the environment.

References

1. Hesslow, G., Jirenhed, D.-A. (2007). The Inner World of a Simple Robot. Journal of Consciousness Studies, 14-7, 85-96(12).
2. Langton, C. (1989). Artificial Life In C. Langton (Ed.) Artificial Life. Addison-Wesley, 1-47.
3. Nolfi, S., Floreano, D. (2000). Evolutionary Robotics: The Biology, Intelligence, and Technology of Self-Organizing Machines. Cambridge, MA: MIT Press/Bradford Books.
4. Parisi, D. (2004) Internal Robotics. Connection Science, 16(4), 325-338.
5. Todd, P., Wilson, S., Somayaji, A., Yanco, H. (1994). The blind breeding the blind: Adaptive behavior without looking. In Cliff, D., Husbands, P., Meyer, J.-A., Wilson, S. W. (Eds.), From Animals to Animats:The Third International Conference on Simulation of Adaptive Behavior, pp. 228–237. MIT Press
6. Ziemke, T., Jirenhed, D.-A., Hesslow, G. (2005). Internal simulation of perception: a minimal neuro-robotic model. Neurocomputing, 68, 85-104.