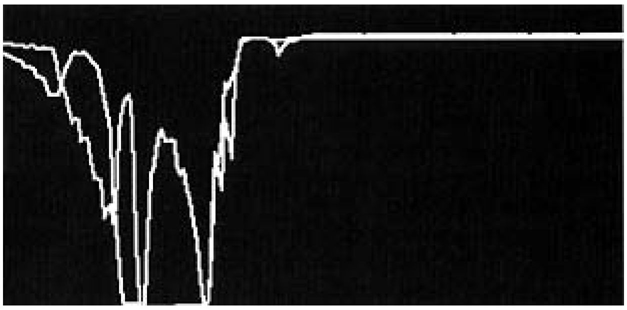
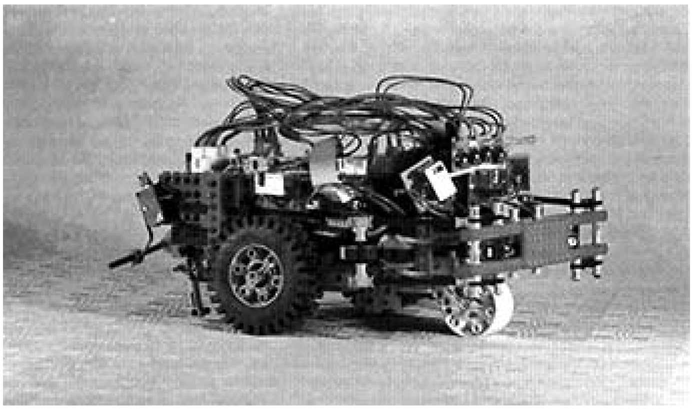
The Origins of Inteligence in Artificial Systems
LUC STEELS





Großaufnahme der im Alife-Experiment verwendeten robotischen Agenten

We have created in our laboratory a group of robotic agents which are "playing the game of life". Each robot is built from electronics and Lego building blocks in the spirit of Braitenberg's vehicles. A robot has both batteries and computational power on board in the form of a powerful microprocessor. It has also about a dozen different sensors: touch sensors, infrared sensors for detecting obstacles, visible light sensors, microphones, etc. The robot can control the speed of two motors connected to the left and right wheels. The robots can recharge themselves by sliding into a charging station.

There is a regular flow of energy into the charging station. However, the ecosystem also includes parasites in the form of lamps that take away energy from the total ecosystem. When all the parasites are fully in force, there is not enough energy for recharging. The robots may temporarily disable the parasites by pushing against the boxes in which they are housed. But parasites regrow. Also, one robot is in competition for the energy in the charging station with other robots, although we set up the experiment in such a way that one robot cannot survive on its own.

Through this experiment we study how intelligence may have evolved starting from simple reactive systems. We are investigating how robots may build up a primitive repertoire of behaviors, and how they then team to combine these primitive behaviors into more complex ones. We are investigating how altruistic cooperative behavior may emerge even though every robot has to be selfish in order to survive. We are looking at the emergence of language and how language could become more complex. We are studying ways in which a social stratification could evolve within groups of robots and how this impacts the levels of intelligence.

In all these efforts we are using various mechanisms gleaned from biology for generating new complexity. Here are some of these mechanisms:

Adaptation: Adaptation means that the parameters of certain behaviors are adapted based on feedback about the performance of behavior. For example, infrared emission and interpretation is parameterised and adapted like the focus of a lens. Real world robots have to be adaptive because the environment is, to a large extent, unknown and changes in unpredictable ways.

Edge of chaos: Dynamic systems of a certain type (such as the logistic equation) may exhibit deterministic chaos for certain parameter settings. When systems are in competition they tend to evolve towards more complexity, bordering on (but not exceeding) chaotic behavior. We have applied this mechanism to the evolution of more complexity in signalling between pairs of robots.

Coupling chaotic elements: When the behavior of robotic agents (or dynamic systems in general) is coupled through a global resource (in this case the charging station), various behaviors may emerge, including clustering and period doubling towards chaos. We have applied this in one experiment to show that social diversity between agents spontaneously occurs starting from identical agents.

Evolution: Heredity and variation are the motors underlying evolution by natural selection. These ideas can be applied to the development of new complexity by assuming that behaviors are caused by populations of behavior cells. In experiments we have shown that evolutionary techniques can be used for deriving a primitive repertoire of basic behaviors.

Level formation: Biological systems have spontaneously developed new levels of complexity. For example, chromosomes have emerged from genes, cells have emerged from the combination of simpler structures such as mitochondria. Level formation is, as yet, only partially understood, but appears to provide an important key in understanding how a cognitive level may emerge from the subsymbolic level.

Our research is far from finished and forms parts of larger efforts known as the behavior-oriented or artificial life approach to artificial intelligence. This approach contrasts with the top-down approach emphasising the use of logic and knowledge representation, which has tended to dominate more classical work towards artificial intelligence. Applications are being considered in such areas as autonomous robotic sewage robots or micromachined nanorobots operating in the human body. The same principles are also relevant for the development of intelligent autonomous software agents.

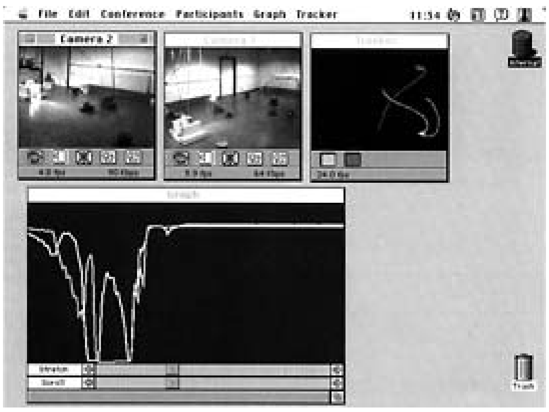
During Ars Electronica the robotic ecosystem is made available through Internet and the World Wide Web. We have created, through a radio communication link, a system whereby the internal states of the robots are captured and broadcast through Internet. At the same time we broadcast visual images of the ecosystem and provide textual information and forums for discussion about the experiment. We are also considering the possibility that participants from anywhere in the world may (partially) control a robot through the Internet, for example by setting some of the parameters of the ecosystem or its environment. These facilities are available through the home page of our laboratory:

http://arti.vub.ac.be/welcome.html

where you should navigate via the "research" page to the "robotic agents" home page.

Home-Page des "World Wide Web" für das elektronische Shopping.

Through the laboratory's home page one can also access an experiment with software agents as used for electronic commerce in the fashion domain. We are experimenting with software agents that travel together with a user over the Internet and encounter other software agents in particular locations. A session starts by constructing (or retrieving) your own personal agent. When going to an electronic shop one encounters other agents playing the role of fashion advisers, sales people, or maybe the personal agents of your friends. These software agents engage in conversations with each other as well as with the user. Although these software agents use more traditional artificial intelligence techniques for representing knowledge and planning and executing their tasks, they share certain aspects with robotic agents in the sense of limited resources, problems of adaptation to new environments, etc.



Home-Page des "World Wide Web", um das physische robotische Ökosystem in Brüssel zu beobachten und zu steuern.