Robotics Exhibits for Science Centres. Some Prototypes

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Abstract. Robots are attractive for public as they represent a clear and ambitious scientific challenge: an artificial being creation similar to natural ones by man. The popular enthusiasm grows up in parallel with huge scientific research progress in this field. On this success wave many Science Centers, Science Museums and Science Festivals propose spaces and moments to spread theoretic, methodological and technical issues of this discipline.

In this paper we describe some of our exhibits prototypes that were designed and carried out to communicate main approaches of modern robotics (telerobotics, cognitive robotics, autonomous and evolutionary robotics and collective robotics). These exhibits have been conceived as laboratories where a visitor can experiment and put the hands on various kinds of robot. They have been accomplished by putting together cheap and easily available materials. This way it has been possible to present these exhibits in many important scientific divulgation events throughout Europe with a relatively modest expense.

1 Introduction

Between all the myths created by men, the automaton is one of the most ancient: since ever men have wondered of a parallel world inhabited by synthetic agents. At the same time this myth is very modern because it is a mirror of the times, as the possibility of its realization reflects the technologic level of an epoch: nowadays, more than ever, there are the right conditions to realize it. To strengthen this claim it is sufficient to remember that it is possible to find robots in factories, in research labs, between the games of children: Puma, a robotic arm, is employed in advanced research; various robots, similar to insects, show an efficient walking behaviour; the SONY robot dog Aibo, can play interacting with the environment. Technology offers the bases which is possible to work on, but gaining the challenge requires efforts coming from a varied heap of disciplines.

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In fact, the way toward the realization of this goal is still long: the described examples are just a pale imitation of what a self-operating machine should be! At the end automata should be able to support themselves energetically, reproduce, repair themselves, interact with other forms of life and being self-conscious.

Building such a machine requires knowledge from Chemistry and Science of Materials: the matter of which this creatures will be made of must be deeply different from the materials that are used now; from Biology: the reproductive and adaptive capabilities shown by natural organisms can be reproduced only with a complete understanding of biological principles; from Psychology: to have an intelligent machine, it's necessary to comprise what Intelligence is; from Computer Science and Engineering: these disciplines will be fundamental in designing this creatures and translating the indications of other sciences in the final artefact. It is clear, then, that the challenge of building a robotic creature is intrinsically multidisciplinary and needs a huge contribution of scientists and researchers, keeping in mind that the central issue in this ambitious enterprise is that the artificial agent will have to show an adaptive behaviour, a feature that is shared by every form of life that has been able to survive, namely the capacity to find solutions to specific problems (for example finding food, escaping predators, reproducing) autonomously through a dynamic interaction with the environment.

Side by side to this enterprise, it is then necessary a divulgation about the actual state of robotics and the nature of the challenge of creating a synthetic agent. An interesting and, by the way, funny way to do this, is preparing exhibitions through which visitors can entertain while learning about robotics. In the present paper we propose and describe a tour in a City of Robots, a pathways along the steps that have been already made in the effort to create an adaptive artificial agent.

It is necessary to remember that, talking about the characteristics that an artificial organism should have, we have proposed that it should be an intelligent machine. But giving a scientific definition of intelligence is itself an hard challenge. In psychological literature there are as many definitions of intelligence as the number of researchers that have addressed the question. Between these, some definitions, even if not very current, have the quality to be wide enough to include aspects of intelligence that are shared by a great part of living beings and are therefore useful for the definition of an intelligent machine. For Woodrow intelligence (1921)is the capacity to acquire capacity; Dearborn (1921)underlines the capacity to learn or to profit by experience; Pintner (1921) defines intelligence as the ability to adapt oneself adequately to relatively new situations in life and Colvin (1921)draws the attention on the ability to learn or having learnt to adjust oneself to the environment.

According to these suggestions, the notion of intelligence we aim at building along the steps that will be described later, is centred on autonomy, adaptive behaviour and on the fruitful interaction with environment as fundamental features in intelligence.

2 Towards Autonomous and Adaptive Robots

The exhibit "The City of Robots" is articulated into two sections: the first one is descriptive and follows the history of robotics, illustrating the main achieved results and delineating the future steps to do, while the second one is made up of various didactic exhibits that allow to experiment directly "what's up" in robotics. In particular, the attention will be focused on how it is possible to determine the behaviour of a machine as the visitors will be conduced to interact with robots that are more and more autonomous. Participating in it, visitors follow indeed a twofold pathway which we can be describe in two slogans: Using Animats in education and Educating about Animats. In fact, covering the stages that we will describe in detail in the following sections, visitors can learn different things at different level:

1. the biological, sociological, psychological concepts (evolutionary theory, adaptive behaviour, collective dynamics, complex systems) together with technical aspects (for example programming, robot control) that have been used to model robots' behaviour and how it's possible to move to more and more adaptive behaviour, modelling more faithfully what happens in real life.
2. different problems related to robotics (what is a sensor, an actuator, a control system, which are the problems that can be encountered moving form simulation to a real, changing and noisy environment) and how, on a higher level, the behaviour of a machine can be determined: the interaction with machines that are more and more autonomous, displaying increasing adaptive behaviours invites question on, for example, how they react to environment, what is the role of this latter in different approaches to Animats, why different ways of building an Animat produce various behaviours, in which aspects these latter are different.

The different exhibits, that are described in detail in the following sections, are built with various materials. Some of them are materials that already existed and could be purchased in common shops, but have been adapted to the specific purpose of the exhibition, while others have been realized just for it.

2.1 Extending Our Sensory-Motor Apparatus through an Artificial Body (Telerobotics)

The first step of the tour we propose is characterized by a very high degree of technological sophistication but it's quite simple on a theoretical level: visitors will be introduced to Telerobotics (Niemeyer and Slotine, 1990), the area of Robotics that is concerned with the control of robots from a distance. The robot expands perceptual and motor capabilities of man, becoming hands, legs and eyes of the humans where they cannot go. The machine, in fact, can be sent in distant or hostile environment, in the sea depth or on a planet surface, while it is controlled from a distance by a human user. This kind of robot has no intelligence or autonomy, it is just a prolongation of humans, one of the other

Fig. 1. RoboBug: the small mobile robot that can be teleguided

sensors-effectors he/she can use. It was possible to see and appreciate some examples of Telerobotics during last decade explorations of Mars: Pathfinder Lander or Sojourner Rover were guided by NASA's experts on Earth and could collect precious information on the Red Planet. Likewise, in the exhibit we propose, the visitor, with the help of a guide, can control RoboBug (Fig.1), a small mobile robot that explores an environment that is not directly accessible. The user can use a console to control the robot, while another user that controls a mechanic adjustable arm helps him/her in reaching fixed goals. The available information is provided by 3 monitors that show scenes in real time from the environment RoboBug must explore. It is constituted by a rectangular arena with hills, valleys, harshness of land. In particular the images are retaken by 3 camera posed respectively on the robot itself, on the arm and on the ceiling of the room. This arrangement of the cameras supplies different points of view: allocentric and egocentric.

The camera on the ceiling gives us a perspective that is similar to the one we have when playing a remote-control car: we see it from the outside, immersed in the environment where it moves. This view is commonly called bird eye's view (allocentric in a more formal language) and it is quite easy solving an exploration task exploiting this view, because the spatial characteristics of the environment can be seen entirely and the vehicle can be controlled with relatively few effort. On the contrary, guiding a vehicle not directly seen that sends images from its sensory apparatus (on-board camera, infrared sensors), poses in a completely different perspective: subjective or egocentric. This is what happens with the cameras on RoboBug and on the arm.

The difficulty of solving the task becomes then to put together these different frames of reference of the world to have a reliable representation of it that permits to reach the target. Moreover it proposes the problems that can be encountered commonly with Telerobotics, as the burden of analyzing data in real time or the delays in receiving signals. Robobug and its setting has been developed by the Institute of Cognition Science and Technologies of the National Research Council of Rome.

2.2 Putting Our Intelligence in an Artificial Mind (Programming a Robot/Cognitive Robotics)

The first step to provide a robot of a certain degree of autonomy is to program its behaviour, just like normally traditional personal computers are programmed. The programmer defines in detail a particular behaviour and writes the code to implement it using traditional programming languages. In this case the intelligence of the programmer is transferred in the robot that is released in the environment and can act according to the instructions it has received by the programmer. These instructions are usually expression of a "human-like" way of facing a problem, referable to high-level cognitive abilities.

The discipline that is concerned with the design of robots that function in changing, incompletely known and unpredictable environment by using high-level cognitive abilities is Cognitive Robotics. The robots produced in this frame can have knowledge, beliefs, preferences, goals, motivational attitudes, can collect information from the environment, plan and finally execute plans, can reason about goals, perception and actions. To do this the programmer has to describe, in the language of programming, the properties of the robot, its ability, its representation of the environment to endow the robot of a high-level controller.

In this exhibit the visitors will have the possibility to program Lego robots, built with the kit Lego Mindstorms ®, Robotic Invention System. It is composed by Lego Bricks, gears, pulleys, pneumatics, motors, wheels, sensors (light, temperature, rotation) and by the RCX (Robotic Command Explores), a programmable Brick that contains a microprocessor that allows for up to three input ports and controls three output ports. The RCX is also equipped with an infrared port that can be used to download programs from a computer via an infrared tower (attachable to the computer's serial port). The visitor, with the help of a guide, can build the robot, create a programs for his/her robot using Lego's own visual programming environment on a desktop computer, download it on the robot and check if the behaviours he/she has programmed are suitable for a certain goal.

This approach works with relatively simple behaviours, in fact, as soon as the behaviours to implement become more complex, it is impossible to foresee in advance every environmental condition the robot can encounter.

2.3 Training/Breeding an Artificial Organism (Adaptive Robotics)

Living beings are not programmed, they adapt to the environment they live in or, under some circumstances, they can be bred or trained by other living beings. This establishment has given the start to a wide field of research: Adaptive Robotics. The robots are endowed with the capacity of learning from their experience and their learning processes are often supervised or canalized by a human being. The exhibit allows the visitor to train a population of robots, awarding the individuals that prove to be the best in solving a spatial orientation task. In particular users are introduced to a setting consisting of some mobile robots, an arena and an associated software, in a word, they will interact with Breedbot.

Breedbot is an integrated hardware/software system that is suitable for users with no technical or computer experience using which it is possible to breed a

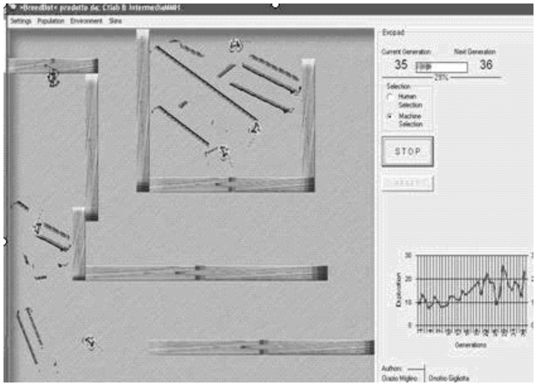

Fig. 2. A snapshot representing the Graphical Interface of BreedBot software. On the left side there are the 9 robots while they explore a rectangular arena with walls. On the right side there is a display that indicates the current generation, STOP and RESET buttons and a graph, updated after each generation, that summarizes the performance in the exploration task along generations.

small population of robots in a software environment that simulates a process of artificial evolution, based on Darwinian selection. The visitors are aided by two guides that introduce to the use of the simulator and to the physical robot. At the beginning of each simulation, the computer screen shows a first generation of robots in action. Figure 2 shows BreedBot's graphical interface. The left hand side of the screen displays the behaviour of the nine simulated robots in the arena, which is surrounded by walls. The right hand side provides information about the state of the system (the number of the current generation and a graph showing changes in the performance of the population) along with a number of commands allowing the user to stop the system and to choose between human and artificial selection. The pull-down menu in the top left corner contains system utilities (to change the geometry of the environment, save configurations etc.). After a certain time, some of the robots are selected to produce offspring. Users can let the system select the "best robots" or make the decision themselves, choosing with the radio button between human and machine selection. If the system makes the decision, it rates the robots by their ability to explore the environment, and selects those with the highest scores. Human users, on the other hand, choose the robots according to the criterion they prefer.

The exhibit merges then two key techniques used in Artificial Life: User Guided Evolutionary Design (UGED) and Evolutionary Robotics (ER). UGED (Bentley, 1999) allows users to "evolve" software and hardware objects, using a computer simulation system. The simulation system proposes a set of variants of the object users are trying to evolve, they choose a subset of these variants and the simulation system produces a new set of variants. The selection/production process goes on until users have obtained the desired objects. This technique is used when visitors operate the artificial selection by themselves.

Fig. 3. The transfer of the control system (an Artificial Neural Network) from the simulator BreedBot to the real Lego MindStorms robot, through the infrared port

On the other side, when the artificial selection is automatic, Breedbot utilizes techniques belonging to Evolutionary Robotics (Nolfi and Floreano, 2000), a field of research that evolves robots with a design process directly inspired by biological evolution. In accordance with what happens in Breedbot, small populations of robots evolve behavioral adaptations to a user-specified environment. Once the selection procedure is over, the system creates clones of the selected robots. During this process it introduces random mutations into their control systems. The robots created in this way constitute a new generation. The control systems (the rules that determine the behaviour of the robot) are different for every member of population and this determines different behaviours. This selection/cloning/mutation cycle can be iterated until the 'breeder' finds a particularly capable robot. At this point the "brain" of the simulated robot can be uploaded to a physical robot, as shown in Figure 3, built using motors, infrared sensors, bricks and an on-board computer from the Lego Mindstorms© kit (Figure 4), and observe its behavior in the real world.

Breedbot is designed to be easy to use for breeders of small robots and to be highly interactive: visitors can use the system's graphical interface, conduct their artificial evolution and if they want, they can select the individuals which will be allowed to reproduce. They can stop the program at any time, choose what they consider to be an interesting robot and use the infrared port to upload its control system to the physical robot. In fact, putting the robot near the infrared tower and pressing "implant" key the simulated robot will be transferred to the brain of the real robot. Moreover Breedbot allows visitors to design the spatial characteristics of the arena and once the robot brains have been downloaded to the physical robots, visitors can interact with the physical hardware.

Breedbot has been produced by the Institute of Cognition Science and Technologies of the National Research Council of Rome to try to merge two main families of robotics products: kit for the robot construction and pre-assembled robots. The first category contains those products with sensors, motors, materials

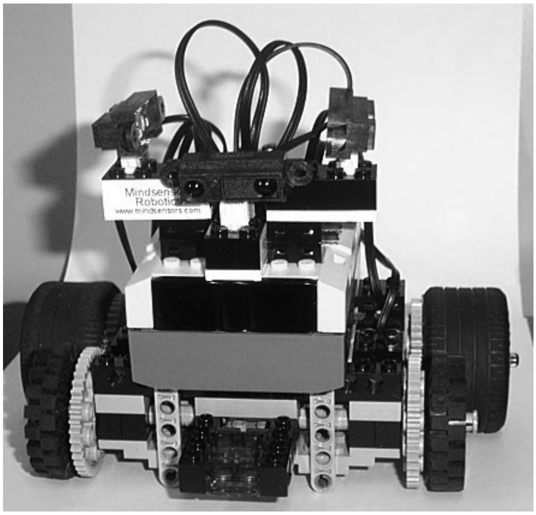

Fig. 4. The physical BreedBot built with Lego MindStorms

that users can use to build the robot body together with the software to determine the control system. This application is useful because the user is active in the designing and building process and, for this reason, is often used as an educational tool. On the other side, the second one proposes complete and ready robots that are able to interact with a human being or an other robot. The robots are conceived as artificial organisms that can capture the interest of the user through the relation and the involvement in the human/(artificial) animal interaction. Breedbot allows to build one's own robot, to make it evolve, "taking care" of the artificial organism, joining the activation of the cognitive processes such as planning and decision with emotional aspects like the anxiety of the wait, the joy for good result, etc. Moreover the user interacts both with the software (the simulation environment) and the hardware (the mobile robots). This approach is undoubtedly fascinating, but it encounters a big limit in the problem that it still doesn't exist a solid scientific theory about learning/adapting processes so the current robots are able to learn on the basis of quite simple processes. Anyway, the robots that are obtained following this approach have a certain degree of autonomy and can potentially adapt to unknown or unforeseen environmental situations.

2.4 Looking after Artificial Organisms to Produce Collective Intelligence (Swarm Robotics)

Living beings live in community and the behaviour of an individual influences other individuals. Often the sum of several simple individual behaviour produces a complex collective behaviour. This is, for example, the case of ants: every single ant has just simple abilities, but, thanks to the interaction with other simple

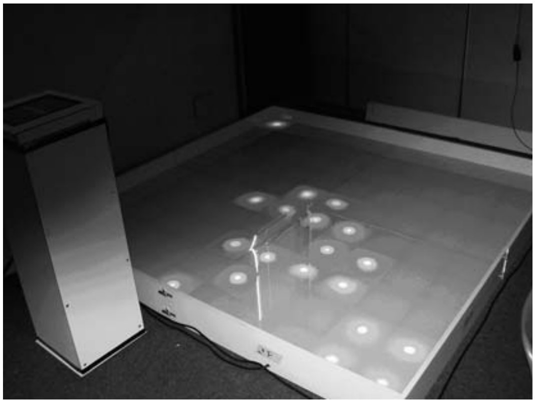

Fig. 5. ARS, a setting for artificial ethology and the console to control it

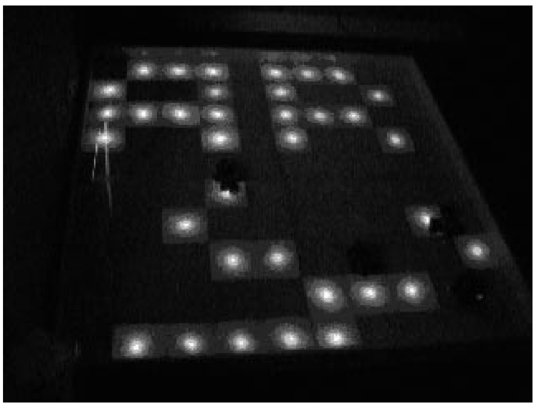

Fig. 6. The setting ARS with lights

agents, can display a complex and emergent behaviour, as cooperating for transporting objects. At this step of the tour the behaviour of robots is determined by taking inspiration from this natural phenomenon. The exhibit proposes, in fact, an experience of collective robotics in which the visitor influence the behaviour of two swarm of robots (Dorigo et al., 2004) manipulating the environment. In more detail visitors will interact with ARS, Autonomous Robotics Setting, a setting for artificial ethology, shown in Fig.5, that has been implemented by Institute of Cognition Science and Technologies of the National Research Council of Rome.

ARS is a platform of 2*2m, divided in 10*10 cells and surrounded by a wall 30 cm high. Every cell contains a lamp that can be turned on and off by an external console (Figure 6). This configuration permits to create quite easily mazes, illuminating the opportune cells, of different complexity. It is enough large for small teams of mobile robots. The visitors, after an introduction by

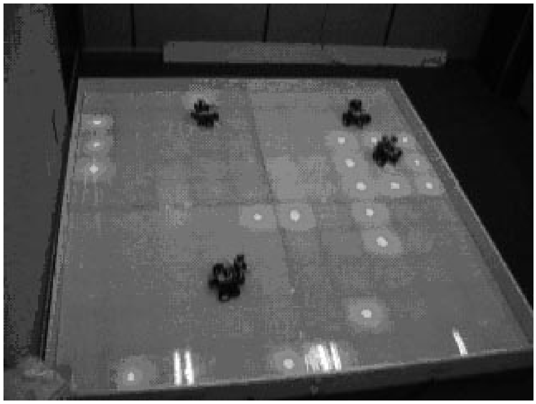

Fig. 7. Two families of robots acting in ARS

a guide, can interact with a team of 4 robots, built with Lego Mindstorms Kit (Figure 7). These robots have 2 infrared sensors (pointed toward the floor to check luminosity of cells) and 3 sensors of distance. Moreover every robot can receive an infrared signal emitted by its “companion”. Two robots halt on bright cells and move on the dark ones (group A), while the others (group B) have the opposite behaviour (move on bright cells and halt on the dark ones). When a robot is reached by a signal emitted by its companion produces a sound and changes direction to avoid bumps. The visitor can influence the behaviour of these two families, manipulating the console of the arena and creating different paths. Varying the characteristics of the environment artificial organisms face more and more complex tasks. The prototype is in fact born with the goal to permit experiments of autonomous robotics with increasing behavioural complexity. The human intervention creates at each manipulation different scenarios in which the 2 teams of robots move in dynamical interaction. This decentralized control leads to a continuously changing situation that produces emergent behaviours.

3 Conclusions

The proposed tour illustrates how artificial organisms can become more and more similar to their natural counterpart, showing at each step, an increasing adaptive behaviour. This is achieved thanks to the sequence of exhibits, all provided with physical agent, a dimension that cannot de disregarded in robotics research. Different degrees of human intervention reflect in different definitions and implementations of the control system and consequently in the different kind of link that relates the robot, the human and the environment the robot lives in that, all together, determine the behaviour. The exhibit has been shown in occasion of “Futuro Remoto” at Città della Scienza in Naples for various year. In those circumstances thousands of people, both children and adults, have interacted with the exhibition, showing a deep interest and active participation. In fact the next steps in this research will be focused, on one hand, on the attempt to measure quantitatively the reactions of the users, to understand what these products make emerge, in the point of view of robot-humans interaction. On the other side we would like to expand these exhibits with the introduction of new kind of robots, possibly more flexible and robust, as the new e-puck produced by the Ecole Polytechnique Fédérale de Lausanne (EPFL)in Switzerland.

Following these future directions will represent, for the ones who will work to realize it, as well as for the ones who will just take part in the exhibit, a further step to realize the ancient dream of living machines.

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