Collective Adaptive Agents as Techniques to build-up Edutainments Systems

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Abstract. Artificial Life since its first inception has changed the way many scientists use to design and carry out experiments in different disciplines such as psychology, sociology, biology, chemistry and the like. In the last two decades Artificial Life has become a great tool to shed light on different and profound scientific questions, however its potential in educational environments has not been completely exploited. In this article we describe two case studies in which Artificial Life has been used as a powerful learning tool for the theory of evolution, BreedBot and co. (actually Breedbot, BestBot and BrainFarm), and for group dynamics, Learn2Lead. BreedBot and its sequels Bestbot and Brainfarm are integrated hardware/software platforms that allow users to evolve a robot able to explore effectively a customized environment made up of walls and colored obstacles. Each robot is controlled by an artificial neural network whose parameters are encoded in a genetic string. Users can opt either for a natural or an artificial selection. In Learn2Lead, each learner manages a simulated team of employees which competes against other teams to maximize its objectives (e.g. profit, volume of services delivered, customer satisfaction). Both serious games provide children and older users a very easy tool to understand complex concepts like evolution an group dynamics within a playful learning context.

1 Introduction

The term Artificial Life (shortened in ALife) was originally coined by Cristopher Langton with the aim to shed light on life as it could be possible in a vast number of settings and ways [1]. Without describing what is or is not Life (see [2] for this issue), that is beyond the scope of this paper, we can state that the milestone that made feasible the shift from biological to artificial life was the possibility to replicate, in modern computers, life-like phenomena through dynamical systems made-up of interacting agents (the bigger the system, the better the result). One of the first attempt was the Conway's Game of Life, a simple game in which every cell of a lattice could switch from alive do dead following some basic rules (it is easy to trace the roots of this work back to von Neumann and his cellular automata), but only in the last two decades this field has flourished in a rich and interesting manner, covering many disciplines spanning from biology to social sciences. So far, within ALife, a lot of tools has been fruitfully used: cellular automata, neural networks, agents simulation and the like, aiming to study quite different scientific phenomena that share a common trait in being the emergent outcome of dynamical interactions among simple agents at a lower scale [3]. Useful examples are those coming from social insects life, hoards of ants are able to find food in effective way by interacting each others through stigmergy, bees can communicate the presence of food with a fancy dance, and fireflies can synchronize their firing rate using a simple visual feedback [4]. With tons of fascinating examples in nature, very soon ALife scientific toolkit was borrowed to understand the life as it is along with the life as it could be [5]. The impact ALife has had in scientific investigations is very impressive, unfortunately we cannot say the same about the field of education where ALife is waiting to unleash his power. In particular the fast growing field of Edutainment can be greatly improved by such techniques. Edutainment is a neologism that puts together education and entertainment. In other words it is a field in which education and learning are linked with ludic and playful experiences [6]. Although historically not new, the idea has grown thanks to modern computers (provided with appealing graphics and sound quality) and Internet. A step furhter, we can define an edutainment system an interactive system able to provide a specific knowledge in a playful way so as to engage students' attention, a very scarce resource nowadays. Recently, a new strain of games called *Serious Games* has gained consensus among educators. The reason is quite simple since videogames are very popular ludic systems and their sales outperform even Hollywood movies [7]. Thus, putting educational contents in games has been the first choice in designing edutainment systems. Unfortunately, the worst enemy of any videogame is the loss of interest and engagement. Video games industry first tried to solve this problem providing video games with some fancy artificial intelligence (i.e. football players, fighters etc.) then moving games to social networks. This latter solution has also changed the business model of the industry from product producer to service provider (many video games require a monthly fee to be played on line). The importance of using Artificial Life techniques in edutainment systems is twofold. First, artificial life techniques can add natural intelligence to edutainment systems in order to make them more intriguing and engaging. Second, the techniques can be used also as a source of knowledge themselves revealing how to model a particular natural phenomenon by encouraging inquiry skills in students [8]. In this paper we present two edutainment software used to learn evolution theory, Breedbot (along with its sequels Bestbot and Brainfarm) and group dynamics, Learn2Lead. Both edutainment systems are based upon an artificial life core made up of agents whose behavior is controlled by a neural network encoded in a genetic string and is determined by the interactions with the surrounding physical and social environment. Moreover, both software are also able to be played online in order to give students a more immersive learning environment.

2 Breedbot, Bestbot and Brainfarm

Breedbot, Bestbot and Brainfarm are integrated software/hardware platforms. By using these software every user, without any particular skill, can train/breed artificial organisms behaving in a virtual world that can be downloaded onto the real counterparts: real robots made up of Lego components. The rationale behind those edutainment systems relies on the possibility to give users a rich interactive system that links virtual and real environment through intelligent hardware. Nowadays robotic hardware is very affordable, the market is full of toy robots and also our houses start to host little and efficient robot cleaners. From an edutainment perspective, using robots in education means the possibility to exploit users' manipulation skills to favor a better and a deeper learning process. In the next sections we describe with more details the three edutainment systems.

2.1 Breedbot

Breedbot has been developed as an edutainment system for evolution theory [9]. The software side of Breedbot allows users to breed a population of 9 wheeled robots. Every robot is provided with three infrared sensors, to detect nearby obstacles, and two motors that control wheels speed. The three infrared sensors are placed on the right, on the center and on the left of the robot's body in order to maximize its visual field. A differential drive system allows robots to steer in any directions (see Fig. 1 Right).

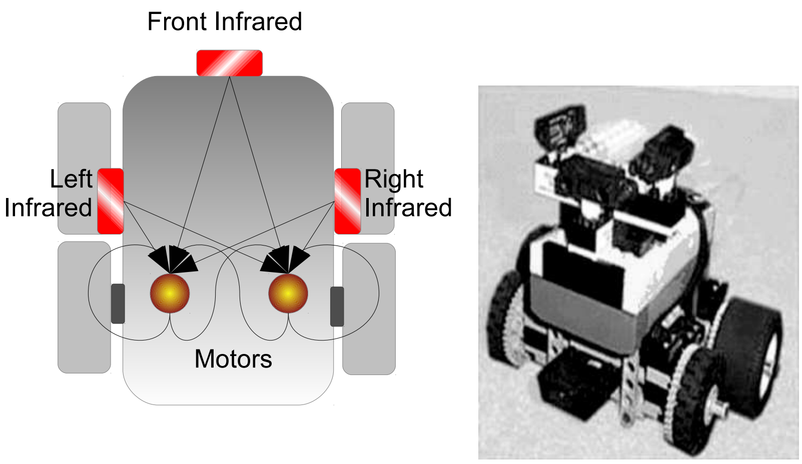

Fig. 1. Left: Schema of the robot used in Breedbot provided with a neural contoller that links ifnrared sensors to two recurrent motor neurons. Right: Real robot made-up of Lego components.

Each robot is controlled by a simple neural network depicted in Fig. 1 Left. Infrared sensors values are normalized between the range [0-1] an then fed as input layer of the neural network. The input layer projects connections to the motor layer, made up of two recurrent motor neurons. Motor activation ia computed according with the standard logistic equation (Eq. 1).

$$O_j = \frac{1}{1 + e^{-A_j}} \tag{1}$$

Where O_j and A_j are respectively the output and the net input of the j_{th} motor neuron. Robot's speed, finally, is updated according to the activation of the motor neurons ranged betweeen [-14,14] mm/s. The neural network parameters are in turn encoded in a genetic string that will undergo to an evolutionary process guided either by users (artificial selection) or the machine (automatic selection).The real robot is made up of Lego RCX 1.0 components and custom infrared sensors (Fig. 1 Right). The software side communicates with the robot by an infrared link.

Breedbot simulates, in a fully customizable digital environment, a population of 9 robots. At the beginning of each simulation, the computer screen shows the initial generation of robots, generated with random genetic strings, in action. Users can observe robots behaving and decide whether use an artificial or automatic selection. In the first case users, whenever they want, can select up to three robots as parents to generate a whole new population. To assure an evolutionary process, offspring are generated by cloning and mutating parents' genotypes [10]. These steps (selection, cloning and mutation) can be reiterated util users (breeders) find a satisfying solution. In the second case the software selects robots by their ability to explore the surrounding environment. In both cases and at any time, users can download their neural controller onto the real robot, through an infrared protocol, in order to evaluate how it performs in real environments reacting to real obstacles.

Breedbot as and edutainment system has been primarily shown in many scientific events in Italy (Genoa Science Festival, Science City in Naples, Rome Science Festival etc.) In these events many children had the chance to use both software and robots following didactic trails into the evolution theory. With Breedbot, users could understand the power of evolution quite straightly because they could see immediately the results of their own selection on the features presented by the relative offspring. The use of computer simulations as a learning aid has been well studied [11] but nothing was present about a robotic support based on ALife techniques, thus a pilot study was set up in order to understand how the Breedbot integrated platform could improve learning and comprehension of a biology lesson about evolution. Two group were administered with a classical face to face lesson followed by a simple computer lesson (hypertext based) and a Breedbot supported lesson. The topics were creationism vs evolutionism, Lamarckian vs Darwinian evolution, selection mechanisms, artificial vs natural selection, and the role of the environment in the genotype-phenotye mapping. Knowledge about the topics was evaluated before the face to face lesson, after the face to face lesson and, finally, after the supported lesson (hypertext or Breedbot based) through a multiple choice questionnaire.

Results showed a better learning for the group supported by the Breeedbot based lesson, demonstrating the importance of an integrated software/hardware based on ALife techniques (i.e. neural networks and genetic algorithms) in supporting learning process of such topics. Moreover, users appreciated the possibility to manipulate an evolvable system in order to reach a desired target behavior (it is worth to mention a user that evolved a set of following robots able to make chains).

2.2 Bestbot

Bestbot[3] is an online game stemmed from Breedbot. Nowadays social game are gaining consensus as well as thousands of players, so it was natural thinking about a simple porting of Breedbot. The ALife engine is the same of Breedbot but Bestbot introduces a new graphical interface (3D physics engine powered by Unity) a new gameplay, two robots instead of nine, a more complex neural controller and an improved sensory systems (3 infrared sensors plus a camera). Users can train through a genetic algorithm their robots to reach as soon as possible a colored target placed into a rectangular arena (Fig. 2 Left), that later on can challenge other users' robots. A final ranking shows robots' performances quality (Fig. 2 Right).

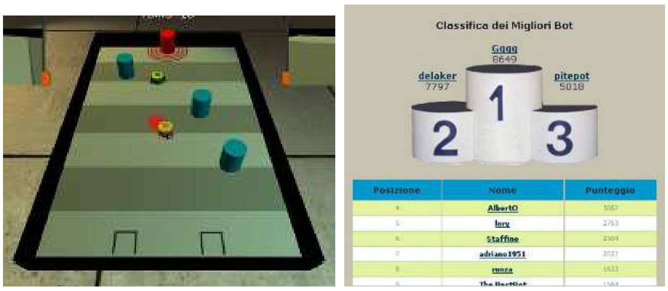

Fig. 2. Left: Bestbot arena with two robots. Right: online ranking.

2.3 Brainfarm

Brainfarm represents a direct upgrade of Breedbot. The reason behind the name reveals new features related to the possibility to design the architecture of robots' brain (Fig. 3 Center). Users can use a simple feedforward network or more complex architechtures. Brainfarm, in fact, is an edutainment system designed to

[3] http://eutopia.unina.it/bestbot
http://eutopia.unina.it/bestbot2

introduce students in what has been defined the century of the brain. Moreover, Brainfarm allows user to choose more robots than ever in order to get more fun and more hints about how brain and body work tightly coupled to solve survival problems [12]. Robots can be trained genetically or with on line learning algorithms such as Hebbian and the like. As usual the robot's virtual controller can be evolved in a fully customizable environment (Fig. 3 Bottom) and downloaded into several robots from Lego Next custom robot to Khepera and E-puck robots (Fig. 3 Top).

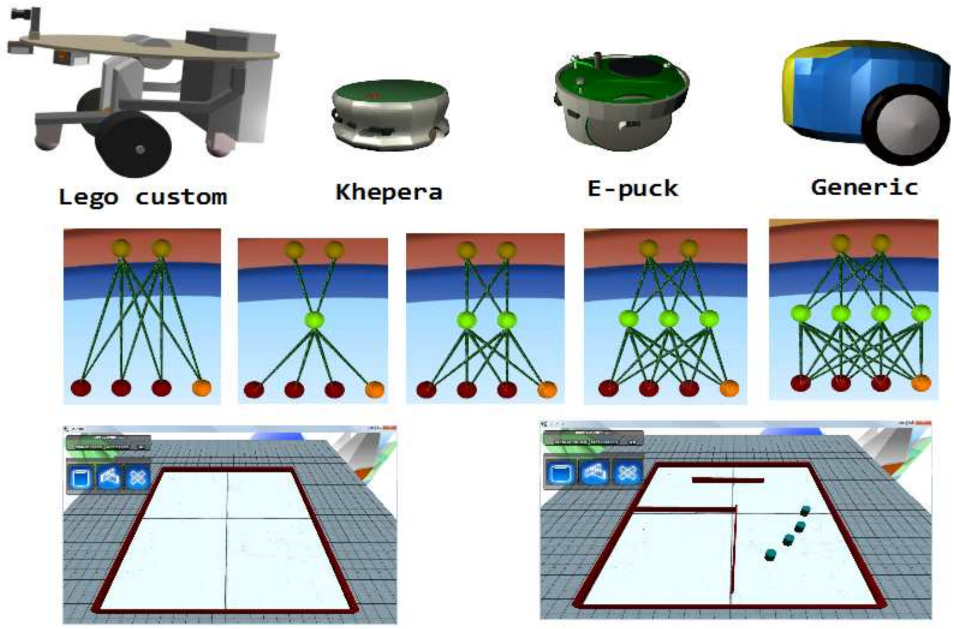

Fig. 3. Top: Robot suppported in Brainfarm. Center: Custum neural networks. Bottom: arenas

3 Learn2Lead

Learn to Lead (L2L) is a digital laboratory (2D web based game) where a user (the leader) learns psychological leadership theories by governing a team of artificial agents (the followers). The game is based on the Full-Range Leadership Theory, a well known scientific theory about leadership dynamics in small groups. The game mechanics is developed by using Artificial Life techniques (agents based modeling and artificial neural networks). The first version of L2L was used in several European vocational courses about Leadership and Human Resources Management.

To become a good leader one have to study a lot of psychology, to attend very costly MBA courses or maybe to observe as much as possible human behaviors. This latter solution at first glance may seem very time and resource demanding but implemented in the right way can be the best solution in leaders education. In fact, modeling human behavior in a proper agents simulator can offer learners the possibility to check how agents' behaviors change varying a set of psychological variables. Although Learn2Lead could not substitute a long and professional training, as an implementation of a psychological theory in an agents simulator [13] can be used as a powerful supporting tool in teaching how to successfully manage a group of followers.

Fig. 4. An L2L environment

Each follower has to accomplish a task, allocated by the leader, in different kind of environments . The maximum workload is determined by two variables: ability and motivation. The player/leader can vary those variables through a series of possible actions (for example by sending the follower to a training course, or by stressing them). Leaders get a score on the basis of the motivational and skill development of the followers. In the gameplay leaders are human players whereas followers are artificial agents controlled by a connectionist network. The idea underlying this general framework, is that in some given conditions, the leader agent (i.e. the user) has to take some decision about one or more followers. These decisions are then encoded in the followers network as some combination of inputs. Based on the inputs received from the leader, and the ones coming from the environment, the agents' internal states will change and influence his contribution to the team job. The followers neural network represents the implementation of the Full Range Leadership theory.

4 Conclusions

In this paper we showed two ways to build edutainment systems exploiting the power of ALife techniques. In particular, we applied agent modeling, neural networks, genetic algorithm, and evolutionary robotics. It is important to stress out the different meaning of the neural network in the two cases (Breedbot, Bestbot and Brainfarm vs L2L). In the first one, a neural network is just an artificial *brain*, or better a system that resembles the functioning of living brains; while in the second case, the neural network is the mathematical implementation of a psychological theory. Our two cases show how ALife techniques can boost edutainment systems toward a new level of usability in the context of the evolution theory and in the field of management training. The importance of such tools relies on the possibility they offer to train a target audience with ease and possibly with fun. Especially nowadays, in which cultural transmission is more horizontal (because of the heavy impact of social networks) than vertical these ALife based edutainment system can offer reliable source of knowledge in a comfortable *horizontal* setting.

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