These living things

by Alex Babeanu

4th July 1998. After its Final approach, Mars Pathfinder enters the thin atmosphere of the rusty planet, after a 8 month journey across space. The little spacecraft, built by NASA the previous year, lands safely in the region of Ares Vallis, and opens-up, like a flower, thus uncovering its solar panels. After a short while, Sojourner, the 65 cm long, 32 cm high little robot, single passenger of this mission to Mars, is freed on the dusty orange surface of the planet. For the next three month, duration of its whole short life, and thanks to its 3 cameras; it will send back high resolution pictures of the planet back to earth, along with a spectral analysis of the ground and stones it encounters there. It will navigate on its own across the close vicinity of its carrier, thus providing earthlings with precious information.

This is not science fiction. This is happening now. As well as the exploration of unknown extra-terrestrial worlds has already started, the progress made in robotics in the past few years marks the eve of the rising of a new civilization, the civilization of the All-Mighty Man, eager to understand and to conquer the whole of Creation. Robots are becoming more and more common nowadays. They can already efficiently replace Man in various tasks. But when then shall Man stop? Are we going to create an artificial being yet, capable of understanding and communicating, an electronic Man? Are we to fear this progress ? Is it yet necessary to postulate the 3 laws of Robotics, as expressed by Isaac Asimov in his " I Robots" ("First Law: a robot cannot harm a human, nor, by its passiveness, leave a human endangered. Second Law: a robot must obey human orders, unless these orders go against the First Law. Third Law: a robot must protect its own existence, unless this protection goes against the First or Second Law.") ?

Robotics and Artificial Life have given astonishing results in various tasks all of a sudden, it seems. Until several years ago, robots were just brainless metallic things, which behaviour was only pre-recorded, as series of simple and well defined tasks, and played back again and again. They were, and still mostly are, highly specialized in simple recurrent tasks. The robotics specialist would just program in the memory units of the robot (usually an arm with a certain number of degrees of freedom), a number of positions, as co-ordinates in the space which origin usually is the base of the robot itself (typically x,y,z coordinates). The robot would then just need to go through each one of these pre-programmed points in order to perform its overall task. Most of the time, such a robot would not have any kind of clue whatsoever of the nature of this task. It would just perform simple actions blindly.

Nowadays, the latest and most common robots (mainly artificial arms), are just capable, given these points in space, to work out on their own the spatial geometry of their effector, required to go through all these points. Thus, if such a robot needs to go through points A, B and C, there might be several trajectories addressing the problem, depending on obstacles in the workspace of the robot, or other constraints (such as efficiency, energy saving, etc.). Given these constraints, the current robots, thanks to sets of sophisticated sensors (tactile sensors, grey-scale cameras, laser range cameras, infra-red, etc..), are able to work out on their own the way to place their elbow in space, for example (upwards, downwards, sideways), to optimize their movements, or to grasp an object the safest way. These types of robots are already in use in the industry, and some companies are already selling their own versions. Even though they represent a real technological challenge, as implementing the latest techniques and technology, these machines are still far from James Cameron's frightening "Terminators".

Nevertheless, a new 'species' of robot is rising thanks to the progress made in the field of artificial intelligence in general, and artificial neural networks in particular. Nowadays, there is considerable effort made in research in the field of autonomous intelligent robotics, throughout all the major universities and laboratories around the world. All research aim to the creation of an intelligent autonomous agent, capable of navigating and finding its way on its own in an unknown environment. There are various approaches to the problem, and various paradigms, but all are inspired by nature. Many models have arised, inspired by insects, animals or cellular biology. This effort is ambitious, and might unravel some mechanisms involved in intelligence, but still, how dangerous is it to tackle such problems as intelligence and conscience? Let's have a closer look at an example of this kind of research...

The evolutionary robot.

In 1992-93, D. Cliff, P. Husbands and I. Harvey, researchers at the university of Sussex, England, have started looking at a brand new way of programming "autonomous agents": the use of Genetic Algorithms to design efficient neural networks, which in turn would control the engines of a robot (Harvey, Husbands and Cliff, Technical Reports CSRP 219, 220, 256, 264 and 265, University of Sussex, School of Cognitive Science and Computing Sciences, 1922). The problem they proposed to tackle was that of navigation in any unknown environment, the avoidance of obstacles thanks to video cameras and the grasping of unknown objects.

Before going any further, it is necessary to first define some terms. Thus, Genetic Algorithms (GAs) refer to algorithms inspired by the process of evolution. GAs are a new way of solving specific problems. They are usually used to optimize (find maxima or minima) in mathematical functions. They provide means by which it is possible to breed, mutate and apply crossing-over to artificial chromosomes.

Artificial neural networks (NNs) are also new algorithms used to optimize functions, or match patterns. They are composed of a set of single units called neurones (electronic components or bits of code in a program). Each simple unit of a neural network performs a simple task: the calculation of an output in function of its inputs. The relationship between Input and Output is defined by a simple mathematical function (output = f (input)). By the combination of several units, it is possible, by acting on the links between these units, to make the whole net "learn" to do something. Such a net would thus be able to match an input pattern to a particular output (action or movement). The surprising property of a neural net, is that it is capable to generalize. Therefore, after a training period, during which it learns to perform the basic tasks involved in what it has been built for, a neural net is able to tackle with any unknown input of the same domain.

In the case of our autonomous artificial being, the chromosomes involved in the GA consist of a series of binary digits (0's and 1's), each of them representing a feature of the final neural network to create, or a property of the robot. The genotype of the robot therefore consists of 2 chromosomes: one codes for the future neural network architecture, the other for properties of its visual sensors. The visual sensor chromosome is a simple fixed length bit string which decodes into a set of parameters giving the angle and orientation of the robot's two photoreceptors.

The neural architecture chromosome is more complex. In this chromosome, bits correspond to neuron units and links in the neural net to be constructed. By having a big amount of these artificial chromosomes at the beginning of the process, it is possible to get a new generation of chromosomes by breeding the parent chromosomes. This is simply done by copying the sequence of bits of any chromosome and by splitting it into smaller parts, an then recombining these smaller parts with those of other chromosomes (crossing-over). Breeding can also be achieved by mutation: a random change in the bit sequence (from 0 to 1, or 1 to 0) of any chromosome. When a new generation of chromosomes is thus obtained, it is then necessary to "weight" it, in order to check if it fits the requirements of the system. This is done by evaluating a mathematical function that describes precisely the generation by giving a score. When a new generation of chromosomes is obtained, only the genotypes presenting the best score is kept and bred to get the next generations.

After hundreds of generations (evolution process), the overall best genotype is eventually retrieved. This genotype will in turn code for the neural net that will perform the expected task at best. At the end, the actual robot is able to navigate efficiently on its own in a room, and to find its way from any random starting point to any goal, considering any obstacle put in its way.

This very impressive work shows the possibilities provided by the progress made in technology. This research has been made possible only thanks to very powerful computers, and strong mathematical theories. What shall we expect next then? Are we going to see Robot clones wandering about in the streets tomorrow? Maybe some day, in the next generation; but as for our near future, robots are still far from being able to walk, to cope with any situation of the real life, or to have a conscience of their own (even though some robots which are able to cross the road or play ping pong have been built; but with poor outcome and very highly specific and limited scope).

The field of Robotics is still in its infancy. When research in artificial life makes important progress, the only way to protect Humankind from its own creation will be its "Humanity", and therefore its Laws. Let's just hope Governments and Lawyers will follow up with this research and come up with efficient solutions.

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