Evolutionary Robotics

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Declaration

I hereby certify that this material, which I now submit for assessment on the program of study as part of the continuous assessment for module CS275, is *entirely* my own work and has not been taken from the work of others - save and to the extent that such work has been cited and acknowledged within the text of my work.

Signed: Cillian Greene Date: 23/01/2016

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Abstract

In this critical review we will look on the research and discoveries of evolutionary robotics. Throughout this review we will go through the history of this subject and how it developed as well as how progress in current research is going. This article will show many applications evolutionary robotics could have in the coming years as well and will show how easy it is to demonstrate Darwinism in technology today.

In this critical review, it will be shown how scientist and mathematicians will have to deal with serious ethical problems the good and the bad that comes with it such as replacing the jobs of many hardworking people and being responsible for the downfall of the human race. evolutionary robotics tied in with the fast emergence of research in AI could change the world as we know it. These are serious implications. If we can develop sentient AI through evolutionary robotics, we would have to change our thoughts on every philosophical answer we've had.

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Introduction

Since the beginning of time the only force we know of to produce autonomous as well as adaptive machines was biological evolution. Now mathematicians and computer scientists are creating the next wave in evolution: evolutionary robotics. They want to take the simple premise that Charles Darwin discovered: natural selection and apply that to Robotics.

It has already been used in simulations and is a niche tool in creating some software and video games. Evolutionary Robotics is still in its very primordial stages. It will be decades before we see it being used in practical circumstances

This review comprises an analysis of articles and journals, some old and some new, on evolutionary robotics. The relevant data was extracted which has been used to form the foundation of research for this review. The papers that were used were downloaded from various systems such as the Maynooth University Library database which is a free to use system that is available to all Maynooth students and faculty. ScienceDirect, Google Scholar and Mendeley databases were also used, they are all libraries were users can access thousands of journals and books that are available for free or at a premium rate.

Discussion and Conclusion

The Beginning of Evolutionary Robotics

i) How it began

The goal of artificial intelligence, since its beginnings, has been to reproduce aspects of human intelligence (such as natural language processing or deductive reasoning) in computers.(Bongard, 2013) Robot engineers started designing their robots to do simple tasks such as object manipulation and walking, they then hope they can further these algorithms to make the robot intelligent. In say software that has no physical presence, that software does not react to the physical world, but a robot does, this "intelligence" is called "embodied cognition".("How the Body Shapes the Way We Think | The MIT Press,"). The very first experiments in evolutionary robotics began to shed light on embodied cognition. In one set of experiments a robot equipped with camera had to move toward certain
shapes and away from others ("Bio-Inspired Artificial Intelligence | The MIT Press,").

ii) **Conway's Game of Life**

The game of Life is a great way to show how evolutionary software can work at such a basic level. The basis of the game is very simple. The Game of life is an infinite two-dimensional grid of square cells. Each cell can be in two states either alive or dead. Every cell interacts with its neighbours which are horizontal, vertical, diagonal or adjacent to it. The player may select as many cells which are on or off. After a "step" the transitions occur based on the rules

1. Any live cell with fewer than two live neighbours dies, as if caused by under-population.
2. Any live cell with two or three live neighbour's lives on to the next generation.
3. Any live cell with more than three live neighbours dies, as if by over-population.
4. Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.(Hensel, 2005)

After a few steps in time, we start to see patterns, no matter what is inputted the same recurring patterns start to appear. This was an extraordinary discovery. It showed that even with simple inputs and a bit of software engineering we could find incredible results that appear to have very "cellular" like appearances.

AI and Robotics Today

Today, Artificial Intelligence has been applied to a wide range of fields such as medical diagnosis, law, remote sensing, etc. There have been rapid advances in the field of robotics systems (Sotala, 2012)Today Robots are used in many industrial workplaces as well as in healthcare. AI has trickled into general applications over the past few years without being identified as AI and so then once an application becomes useful enough and common enough it loses the AI label, examples of this include internet search engines and banking software used for processing transactions(Okamura, Matari, & Christensen, 2010)

i) Moore's Law

According to Moore's law, the number of transistors on a chip should double in each technology generation. For more than 30 years, compliance with this law has been driven by the shrinking of transistor dimensions. Moore's law may nevertheless survive as device engineers build layers of devices on chips or use new approaches such as molecular electronics. Moore's Law could apply to Evolutionary Robotics as hardware in the future will be much more complicated and much easier to implement Evolutionary Software.(Forever, 2003)

The digitalization of Darwinism

Darwinism as we know it is a theory of biological evolution developed by the English naturalist Charles Darwin and others, stating that all species of organisms arise and develop through the natural selection of small, inherited variations that increase the individual's ability to compete, survive, and reproduce. The question becomes, is it possible to translate that premise into software? The answer is yes. Conway's game of life is a simple example, but mathematicians and scientist are coming up with more complicated algorithms to put in robots. They want to create pool of robots that would survive and mate based on set conditions to create stronger and more viable robots. Genetic algorithms s are the most common form of algorithm which uses evolutionary ideas for search, optimisation and machine learning, however, there have been concerns have been voiced to the effect that Genetic Algorithms were intended as algorithms for complex adaptive systems as well as optimization algorithms.(Grefenstette, 1994) These were not best suited to their strengths. Evolutionary robotics typically needs adaptive improvement techniques, rather than optimisation techniques, and this critical but little understood distinction needs to be made clear.(Sciences et al., 1997)

Ethics in robotics

Imagine the face of warfare with autonomous robotics: Instead of our soldiers returning home in flag-draped caskets to heartbroken families, autonomous robots—mobile machines that can make decisions, such as to fire upon a target, without human intervention—can replace the human soldier These robots would be 'smart' enough to make decisions that only humans now can; and as conflicts increase in tempo and require much quicker information processing and responses, robots have a distinct advantage over the limited and fallible cognitive capabilities that we Homo sapiens have. (Berleur, 2006)

Not only could this happen in a military sense, but also in daily liferobots are becoming more and more in tune with our daily lives. This brings up many ethical problems. If a "sentient car "crashes who is responsible? (Markoff, 2010)With Evolutionary Robotics, we couldn't implant our moral code on the robot as it therefore would not be embodied cognition, we would be programming the robot and telling it exactly what to do, making both AI and evolutionary robotics irrelevant. So in the coming years we will have to answer these tough questions and try to figure out ways on how to solve these ethical quandaries.

Future Development

Swarm Robots

Swarm robotics is a new approach to millirobot systems. It consists of a large number of physical robots converging with collective behaviour to complete some task. A robot swarm

that evolves cooperative rather than competitive tendencies often provide new ways of thinking about how and why that trait evolved in biological populations.(Bongard, 2013)

Through simple rules and local interactions, swarm robotics aims at designing robust, scalable, and flexible collective behaviours for the coordination of large numbers of robots. We focus mainly on ideas and concepts that contribute to the advancement of swarm robotics as an engineering field and that could be relevant to tackle real-worldapplications.(Brambilla, Ferrante, Birattari, & Dorigo, 2013)

It is very possible that in the near future, Swarm Robotics combined with what we know about Evolutionary Robotics could be used in a manner of different circumstances, such as nanorobotics, mining tasks or agricultural tasks.

Evolutionary Bio-Robotics

This field is about learning concepts from nature and applying them to the design of real world systems. More specifically, this field is about making robots that are inspired by biological systems. In biorobotics, investigators implement anatomical details from a specific animal in hardware and then use the resulting robot as a physical model of the animal under study. Although much work in this area has been dedicated to nonhuman animals, there has been some work modelling bipedal humans.(Bongard, 2013). Bioroboticists attempts to model individual organisms. Evolutionary roboticists in contrast attempt to re-create the process of evolution which generates robots that may or may not resemble existing animals. Evolutionary biorobotics is a blend of these two approaches: investigators build robots that resemble particular animal, and then evolve one aspect of the robot's anatomy to investigate how the corresponding aspect in the animal might have evolved

Challenges

There are many current challenges in the Evolutionary Robotics field today. The main one is trying to figure out how to transfer software simulations into real world physical machines. There is also the “Reality Gap Problem”(Bongard, 2013)Both biological and artificial evolution are notorious for exploiting the potential relationship between the animal/robot and its environment to produce new behaviours. For instance, the lightweight property of feathers which are thought to have originally evolved for heal regulation, were later exploited for flight.

We also have an example of this “exploitation” with robots. A robot was designed to move across a beam suspended. The robot had its arms connected to a big battery pack. The robot, using its Evolutionary algorithm “found out” that it was easier to swing its batter pack, thus moving its centre of mass, making it easier to traverse the beam. This is very similar to how Human ancestors moved in the jungle. In a simulation, programs with evolutionary algorithms may exploit inaccuracies. This becomes a major problem, as when the simulation is transferred to a physical robot, it no longer has this exploit, this why it is known as the “reality gap” problem.(Bongard, 2013).

A further hurdle to be tackled is that of the appropriate design of fitness functions under which robot architectures are to be evaluated. Artificial evolution is not magic, since simulations are likely to be limited, these tests must in general be in the real world, in real-time. One way to minimise the number of evaluations is to organise the genetic algorithms efficiently. When incremental evolution is being used a sequence of tasks must be designed, 'shaping' the evolution towards desired end-goals. It's not a trivial problem to design such a sequence, and to date it has been done largely by trial and error. There is of course the

notorious tendency of genetic algorithms to find solutions which 'cheat', by complying with an evaluation function without meeting the intentions that lay behind it. A principled approach to this problem has yet to be found; co-evolution is one possible approach.

Could Evolutionary Robots overtake humans?

The premise of evolutionary robotics is that they eventually complicate themselves. Now, it is too early to say how complicated they could get, but theoretically, if there was a set of robots, programmed with pure evolution theory, it is not out of the question that the robots could become sentient.(Hawking, Russell, Tegmark, & Wilczek, 2014) We already are taking tremendous steps in Artificial intelligence. Many would agree that AI is currently one of the fastest growing fields in the Computer Science world. Government bodies and independent organisations are pumping money into AI research funds and companies all around the world are using AI to try to create the "next big thing". The possibilities are truly endless. This combined with what we know about Evolutionary Robotics could definitely mean that we could build sentient Artificial intelligence through the use of Evolutionary Robotics. If AI gets to the stage that it is intelligent as humans, will bosses fire humans so that software can take over their jobs? For any business, from a start-up to a multination, this is a financially sound idea for one reason, it would increase the company's profits as productivity would increase and they would no longer have to carry out paying employee salaries. However, just because it makes sense financially, does that make it ethical to allow for robots to take over humans' jobs? This is still a widely unresolved debate were the answer varies from person to person and is still wholly dependent on everybody's' personal opinions and understandings.(Brunette, Flemmer, & Flemmer, 2009)

Conclusion

Since its founding in the early 1990s, evolutionary robotics has remained a small but productive niche field. Although the field has yet to evolve a robot that is superior to one produced using mainstream optimization methods, the field has produced a wider variety of robots automatically. If you look at it one way, roboticists have manually designed and built a few hundred different kinds of robots with humanoid or animal body plans. Evolutionary methods, on the other hand have produced millions of different kinds of robots that can walk swim, or grasp objects. We hope that these simple premises can go onto perform more complex tasks, like working safely alongside people. Moreover, several recent advances in fields outside of robotics are providing opportunities to showcase the advantages of this evolutionary approach. Advances in materials science are making soft robots and modular robots a reality. Advances in automated fabrication are bringing the possibility of continuous and automated design, manufacture, and deployment of robots within reach. State-of-the-art evolutionary algorithms and physical simulators are making it possible to optimize all aspects of a robot's body plan and control policy simultaneously in a reasonable time period. And finally, new insights from evolutionary biology and neuroscience are informing our ability to create increasingly complex, autonomous, and adaptive machines. Today we can look and see that we are only at the genesis of this technology, it is in our hands how this technology is developed, and we must make sure that ethical codes are taken into account. If we do not then we could be at the demise of our own Frankenstein.

"And AC said, "LET THERE BE LIGHT!" And there was light"("The Last Question -- Isaac Asimov," .)

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