COS 314 - Assignment 1

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1 Intelligence

1.1 Origins

The word *intelligence* derives from the Latin word *intelligere*, meaning *to understand* [5]. The word is generally accepted to mean the capacity for reasoning, decision-making and problem solving.

1.2 Meaning in Personal Opinion

In my opinion, intelligence is the ability for some agent to comprehend the significance of its actions in the external world, with some predictions of its effects. In other words, I believe that intelligence is synonymous with some *internal model of reality*.

This model, which is either built from experience or from inherent instinct or programming, has simple rules that can be used to extrapolate outcomes arbitrarily (within the limits of the model and the agent's computational capacity). The act of learning implies adding to this model. For illustration of this idea we can look at animals:

Simple creatures, such as star-fish, survive completely on instinct. These animals can thus be described entirely by static physical and chemical processes. In this way, we can imagine these animals like any other natural system, such as the weather or rock formations. These animals are *alive*, but are not *intelligent*, and exist on predictable chemical rules.

Contrast this to a crow, which has been shown to use tools to obtain food [1]. This behaviour is fundamentally different from that of the star-fish. The crow, like us, has the ability to see a desired outcome and design (possibly new) steps to achieve that goal. Specifically:

$$\text{Physical outcome} \rightarrow \text{Access to food} \rightarrow \text{Survival}$$

Unlike the star-fish, the actions of the crow are **motivated**, **calculated** and **premeditated**. This is the defining feature between the two animals. Collectively we may call this property *intelligence*. Other characteristics we attribute to intelligence (such as self-awareness, reasoning and complex decision-making) are easily explained by this essential difference. Indeed, it is precisely for this distinction that these higher-order mental activities become useful to a living creature. Simple creatures still thrive without intelligence, and hence stay simple.

Intelligent entities can evaluate situations which they have not directly experienced, through using aggregated knowledge from other experiences to form new assumptions about their environment. We recognise this ability as that of deduction.

This is the condition of individual intelligence, however another common form of intelligence exists: *group intelligence*, also known as *collective intelligence* or *swarm intelligence*. This is when many agents come together, and their collective actions solve some problem or task that is important to all of them. This behaviour is seen in both simpler animals (ants in an ant colony) and in complex/intelligent animals (dolphins hunting a school of fish). Through working together, creatures like ants can perform complex search algorithms and maintain adaptive transport routes, and dolphins can hunt large amounts of fish, with **proficiencies far beyond that of the individual**.

This is of course intelligence in a more *abstract form*, but as we investigate we discover it is the same intelligence as described for the individual, but simply **executed in distributed fashion**. The group has a collective awareness of the environment. The group will make decisions as a group, through the aid of some communication medium (sounds for dolphins, pheromones for ants). The animals can connect cooperation with mutual success (and of course humans do this too). One might say that these groups are greater than the sum of their parts.

Intelligence is closely linked to perception. A larger perception implies a more comprehensive model of the environment. The more nuanced the internal model, the more varied the expected outcomes become, and hence give rise to a greater capacity for decision-making. Chess is a more intelligent game than Checkers, simply by the fact that there is more information in any given state of a chessboard, than that of a checkers board. Thus, an intelligent entity that wants to play chess proficiently must first perceive the significance of the pieces and the rules. Any ability beyond this comes from the agent's capacity to evaluate board states, and extrapolate these forward, directing to a desired outcome of their choosing. This is what a decision fundamentally is. Since energy is a scarce commodity in nature, some heuristic for solving problems is usually observed in biology. It is unlikely that evolution would ever produce an animal to play perfect Chess.

It is still a matter of debate whether intelligent creatures are deterministic in the same way bacteria and parasites are. It may be the case that complexity is the only factor that separates the star-fish from the crow. Of course we would like to think that intelligent creatures such as us actually make decisions, and are not inherently predictable. These concerns inevitably link to questions of the existence of free-will and the true nature of conciousness. Such philosophical questions are beyond the scope of this discussion, but I believe that I have sufficiently illustrated why I feel that intelligence is so closely tied to an internal representation of reality, whether held by the group or the individual.

2 Artificial Intelligence

2.1 Origins

The term *Artificial Intelligence* was coined by John McCarthy in 1955 [11]. The phrase is generally accepted to mean synthetic creations (particularly software) that demonstrate reasoning capacity comparable or similar in nature to that of humans.

2.2 Meaning in Personal Opinion

As described in SECTION 1 - INTELLIGENCE, I believe that intelligence is best described as a sandbox model of reality that an agent can use to evaluate scenarios in which they have a desired outcome. Hence I am of the opinion that we can make machines intelligent in the same manner that humans are, assuming a sufficient model and adequate processing. In most applications of Artificial Intelligence we have the following:

- a value to optimize or a task to complete.
- features, methods, or ways in which a strategy might be modified.
- feedback, in the form of some model (typically number of successes versus failures in environment).

With these conditions, and sufficient data/time to iterate, many tasks that we deem intelligent (image recognition, language-processing and language comprehension), have been effectively simulated on computers.

Therefore, I personally define artificial intelligence, in its broadest terms, as the creation of systems (whether physical or in software) that can *make calculated decisions*, based on one or more *desired criteria*, with some awareness of the decisions' probable outcomes. These expectations may be developed by machine learning, or through direct input of the programmer.

2.3 Main Purpose of The Field

Artificial Intelligence is primarily concerned with creating programs and machines that can reason with similar faculties as humans, in the aim of solving complex problems that traditional empirical programming paradigms struggle to solve. To this end, Artificial Intelligence is a tool which humans can use to vastly extend their problem-solving reach, and someday abstract general reasoning into mechanical processes. Artificial Intelligence allows us to imbue environments with intelligent devices, and thus live in a world that is more engaging, dynamic and responsive.

Artificial Intelligence enables other fields of study to grow in new directions and in faster rates. Artificial Intelligence can be taught to evaluate the validity of mathematical propositions in formal proofs [13], which accelerates mathematical research. In medical research, Artificial Intelligence can estimate side effects of new medicines, and help doctors identify diseases and suggest treatment [9], all of which directly equates to helping human life. Artificial Intelligence can identify inefficiencies in man-made systems, and through doing so help us create smarter cities, smarter homes and better tools.

A large section of Artificial Intelligence involves the automation of tasks that were previously fulfilled by humans. Of course this raises a lot of concern among the general populace. However, we must ask ourselves whether the jobs that Artificial Intelligence automates are worth preserving. Menial jobs such as those in transport, logistics and record-keeping do not inspire the best of human creativity and innovation. The jobs that require the most humanity are the ones that survive, and are expected to survive long into the future.

A bi-product of these studies is further understanding in the cognitive process in biological animals, such as humans. Artificial Intelligence can help us deliberate on important questions in biology and neuroscience. Such investigations include whether conciousness is an emergent property (whether self-awareness simply falls out of mechanical structures like the brain), and the computational limits of the human mind. Further, Artificial Intelligence gives us new insight into the nature of intelligence. *Biological intelligence*, the intelligence that we are familiar with, is only an infinitesimally small fraction of all possible intelligences. This fact means that through artificial intelligence we can explore realms of intelligence foreign to our own. Summarised:

$$\{\text{Human Intelligence}\} \subset \{\text{Known Intelligences}\} \subset \{\text{All Possible Intelligences}\}$$

2.4 Contemporary Success in Real World

Recently (October 2016), the mining firm Rio Tinto deployed a fleet of 69 self-driving industrial vehicles, to haul minerals for a mine in Pilbara, Western Australia. This is only the latest addition to this mine, which also features autonomous trains and drills. Andrew Harding, their iron ore chief executive said,

> *"Our autonomous fleet outperforms the named fleet by 12 per cent."*

These machines can operate at all-hours, every day of the week, and are monitored remotely more than a thousand kilometres away. The mine can operate with *no humans on site*. This demonstrates that while it may take a few more years for self-driving cars to achieve mass-adoption in the mainstream, their deployment in industry is already in progress. This shows that the software controlling these machines has reached a proficiency that meets or exceed a humans', with regards to the scope of the problem. **It is now in the financial interest of industrial companies to utilise intelligent systems**. This is a massive milestone for Artificial Intelligence.

3 Life

3.1 Origins

The word *life* comes from Old English. It is most likely Germanic in origin, and has kept its original meaning through history [5]. Life is a fundamental concept for mankind (for obvious reasons), and features heavily in religion, ceremony and human experience.

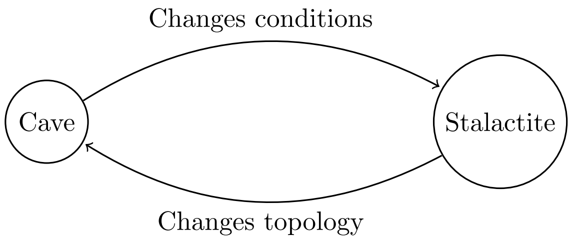
3.2 Meaning in Personal Opinion

Life is a very alluding concept. Although living matter conforms to the same physical laws as most other matter, it does not initially appear to behave like any familiar substance. We are often told that “nature takes the path of least resistance”, but life seems contrary to this rule. Life feels unnecessary, perhaps even superfluous, in comparison to the stubborn, persistent processes in inorganic nature (think weather systems; movement of tectonic plates).

Physics, in our understanding, “wants” to increase entropy and homoeostasis until energy is evenly dispersed across the universe. So why then, have living things arisen to essentially become sinks of energy? Living beings hoard energy as much as they can, and use it far slower than a fire might. On face value, life does not quite fit in. There are more efficient ways to disperse energy than life. I believe this is one of the major obstacles of studying life, because it already feels an incorrect act to try and harmonize life with non-life. This dichotomy gives life a mystical quality, and it may be more profound that life may not exist for a reason, than if it did. Regardless of the purpose of life, life exists, and below I have tried to summarise my own opinion on a definition:

There are formal biological definitions of life. I feel that the measures used to describe life in biology are accurate in identifying life, but not necessarily in defining life. In my opinion, life as we know it is an abstract concept describing **regular patterns in carbon-based molecules**. As minerals and crystals are the regular forms of atoms, so life (in its denominations) is the regular form of primordial carbon substances through time. Living things take in raw materials, and use these to build regular structures, as prescribed by DNA, and spawn new structures. Living creatures are also *regular in “time”*, in that life forms will generally be born, mature, and die in repeated patterns through generations.

One can try to perceive life almost as a stalactite, growing from the floor of a cave. Given enough time and resources (calcium rich water dripping from the ceiling), the stalactite will grow continuously. The stalactite may change course to accommodate changes in the water supply (evolution in the analogy). Changes in the cave topology may permit of forbid certain stalactites, and equally growth in stalactites will change the shape of the cave. So we have this inanimate, but “symbiotic” relationship:



This concept links closely to life, which is shaped by it's environment (via evolution and natural selection), and in turn the environment is modified by the presence of life. When thought about globally, it is inevitable that these living systems would result from inanimate processes. Non-living substances stay as there are (with a non-zero chance of becoming "living"), and living things continue to live, or proliferate in reproduction. There is an implicit "pressure" for life to emerge from the inanimate. It is only the fact that living systems ensure their own survival, that separates coral growing in a reef from a stalactite growing in a cave.

This may seem a bit of a stretched, perhaps sensationalist idea. **My goal is not to equate static minerals with living beings**, but rather to demonstrate that they are both representative of repetitive structure, and both manifestations of ideas of symmetry and pattern. This is done to try harmonise living things with the rest of the natural world, which of course seems so fundamentally different. The diagrams below perhaps illustrates my point better:

(a) Shelled sea animals [7]

(b) Crystallized minerals [6]

Figure 1: Similarities of crystalline and biological structures.

4 Artificial Life

4.1 Origins

The term *Artificial Life* was coined by the theoretical biologist Christopher Langton in 1986 [12]. It is generally regarded to describe a field of study that researches the creation of life via synthetic means, whether it be robotic, bio-chemical or completely simulated in software.

4.2 Meaning in Personal Opinion

In my opinion, Artificial Life is any man-made system that performs or simulates most, if not all, of the traits commonly associated with biological life. This includes (but is not limited to): Consumption/processing of energy, Growth, Reproduction and an implicit need for self-protection [2]. Artificial Life can also include subsystems of life, in which one crucial aspect of some life-form is isolated and studied in depth. Further, Artificial Life is any biological life that is created synthetically, and cannot be observed in undisturbed nature.

4.3 Main Purpose of Field

Artificial Life is concerned with, among other things, using nature as inspiration to design *better machines*, more *organic software systems*, and more *sophisticated bio-chemical solutions* to modern problems. Practical applications of this field include creating robots that have better kinetic abilities and proficiency through emulating nature [3]. In software, *artificial immune systems* help maintain the security of a network by copying behaviours seen in biological immune systems [10]. In agriculture and medicine, artificial life is being tested and used as delivery mechanisms for pesticides and medication [4].

Artificial Life complements the field of Artificial Intelligence, particularly in applications of *particle swarm optimization* (PSO) [14], in which simple agents form to find some optima in a system, by emulating the movement of flocks of birds and insects. Similarly, evolutionary and genetic algorithms emulate evolutions with possible solutions to problems as "creatures", and based on their success will determine the proliferation of that strategy in the next "generation" of algorithms. This allows us to "grow" algorithmic solutions bottom-up. Many of these solutions are new to humans, because this evolutionary method has no pre-conceived bias to any particular form of problem solving, except to avoid those that do not solve the problem.

By studying artificial life, we may also learn the probable origins of life on Earth, and discover the likelihood of life being a spontaneous process. With the help of genetic and evolutionary algorithms, we can begin to observe how evolution works in repeatable and controlled simulations. This synthetic environment (whether digital or natural), allows biologists to explore foreign forms of life, new biological processes and repeatable biological outcomes that may be yet unknown to mankind.

Artificial Life is also *philosophically* significant, in that it seeks to determine whether life created or simulated by humans should be considered life in the same way that biological life in nature is regarded. This can be summarised in the question: Should artificial life receive animal rights? Or even further: should artificial life, of a sufficient complexity, receive *human* rights? This may sound ridiculous, but in these seminal times we do not yet know the limits of artificial perceptual existence. We do not know what an artificial lifeforms' capacity for suffering might be.

Some individuals argue that biological life is bound by an ethereal soul, and hence it cannot be replicated or fully simulated. Artificial Life takes these arguments, as delicate at they may be to personal belief systems, and evaluates them in a non biased, constructive, scientific manner.

4.4 Contemporary Success in Real World

One of the most successful Artificial Life projects is called OpenWorm, which is "the first comprehensive computational model of the *Caenorhabditis elegans*, a microscopic roundworm" [8]. It is the first purely software based simulation of a natural animal.

The creature in nature is only comprised of roughly a thousand cells, and only a few hundred neurons. This made the animal easy to fully simulate physically, chemically and electro-mechanically. The team working on this project are using a "bottom up" approach, and are simulating physics to observe the emergent behaviour of this digital creature.

The initial results of this project have proved very successful. All of the results are publicly available to any individual, and the software itself is open source, such that any other research team can conduct their own unprecedented investigations. This "Open Science" approach means that this research has gotten to those who need it the most, accelerating development. The hope is that this work will someday lead to much larger simulations of more complex organisms.

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