The Ultimate Future of Artificial Life: Towards Artificial Cosmogenesis

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Abstract

This philosophical paper tries to tackle the question of what could be the ultimate future of ALife from a cosmic viewpoint. We first argue that the natural direction of ALife is a simulation of an entire universe. Two new challenges naturally arise. The first is to simulate open-ended evolution at all levels in a single simulation; i.e. not only in biology, but also to link it up a level below (physical evolution) and a level above (cultural evolution). The second challenge is to probe what would happen if we would "replay the tape of the universe". Assuming that intelligent life would indeed simulate an entire universe, this leads to two tentative hypotheses. Following the soft-ALife program, some authors argued that we could be in a simulation run by an intelligent entity. Following the hard/wet-ALife program, this would lead to an artificial cosmogenesis. This last direction is argued with a careful speculative philosophical approach, emphasizing the imperative to find a solution to the heat death problem.

> *Now that we are on the verge of synthesizing life artificially - now that our artifacts are becoming more and more like us - and now that we are becoming more and more like our artifacts, where will life go from here?*
>
> (Langton 1992, conclusion)

Introduction

As Langton wrote above, the practice of ALife has certainly very rich and deep philosophical consequences that remain to be explored. The goal of this paper is to examine one original direction. What could be the ultimate future of ALife, if we consider a cosmological time scale? Our focus is larger than the "influence of machines on the next major evolutionary transition of life" (challenge 12 proposed by (Bedau et al. 2000)). We simply assume that there will remain an intelligent civilization (whatever its form) after interactions of humans and their artifacts. We would like to continue and radically extend Dennett's idea that ALife can be viewed as a kind of philosophy which allows the "creation *and testing* of elaborate thought experiments" (Dennett 1994, 291). We believe however that in the far future of scientific enquiry, ALife has the potential to become much more than that.

From a cosmic perspective, we can wonder : "What is ALife?". A simple answer is: "it is *life simulating itself*". It means that the process of life evolved organisms capable of reverse engineering the very processes that gave rise to them. This self-referential aspect of life has certainly a deep meaning, which has been most often noticed in discussions about the existence of sentient beings. Thanks to general evolutionary theory, we can partially understand the origin of this "phenomenon of science" from simple biological organisms to the complexity of science as a social system (Turchin 1977). What about the ultimate future of this phenomenon, and its relation to the future of the universe?

It should be immediately stressed however that most often the goal of ALife is not to model life exactly as we know it, but to decipher the most simple and general principles underlying life, in order to implement them in a simulation. With this approach one can explore new, different life-like systems. Traditional science focuses on modelling or simulating reality, whereas it is not the case of most of the endeavour in ALife. There is thus a fundamental *creative* aspect in ALife. This is certainly why many artists have been enthusiastic about employing ALife systems for creating imaginary worlds.

We start by arguing that the path towards a simulation of an entire universe is the natural and most likely evolution of our simulations endeavours. We then examine how such a simulation could solve the famous heat death of the universe expected to happen sooner or later.

Towards a simulation of an entire universe

In this section, we will suggest two extensions of existing challenges for ALife. The first is to simulate open-ended evolution not only in biology, but also to link it up a level below (physical evolution) and a level above (cultural evolution). The second challenge is to probe what would happen if we would replay the tape of the universe. Let us first summarize the steadily increase of computer resources.

Increase of computing resources

I note two important transitions in the history of human culture. The first is the *externalization of memory* through the invention of writing. The second is the *externalization of computation* through the invention of computing devices. The general purpose computer inspired by the work of Church, Gödel, Kleene and Turing, because of its formal specifications constitutes the most general computing device. The consequences of this last transition are arguably as significant -or even more significant- as the invention of writing. In particular, the changes induced by the introduction of computers in scientific enquiry are important, and certainly still underestimated and understudied (see however e.g. (Floridi 2003) for a good starting point).

What can we expect in the future concerning the increase of computing resources? There is a lot of literature about this subject (see e.g. Kurzweil 1999, 2006)). Moore's law famously states that the number of transistors doubles every 18 months on a single microprocessor. The increase in processing speed and memory capacity are direct consequences of the law. What are the limits of computer simulations in the future? Although there is no Moore rule for the efficiency of our algorithms, the raw computational power leaves us free computational energy to increase the complexity of our simulations. This should lead to longer term and more precise predictions. Apart from the computational limitation theorems (uncomputability), the only limit to this trend is the physical limit of matter or the universe itself (Lloyd 2000; Krauss and Starkman 2004). As argued by Kurzweil (2006, 362), it should be noted that the ultimate computer that an intelligent civilization could use in the distant future is a very massive object, i.e. a black hole.

From a cosmic outlook, Moore's trend is in fact just a small subset of a much more general trend which started with the beginning of cosmic evolution. The cosmologist and complexity theorist Eric Chaisson proposed a quantitative metric to characterize physical, biological and cultural complex systems (Chaisson 2001, 2003). It is the *free energy rate density* (noted Φ_M) which is the rate at which free energy transits in a complex system of a given mass. Its dimension is energy per time per mass (erg s^{-1} g^{-1}). Let us illustrate it with some examples (Chaisson 2003, 96). A star has a value ~1, planets ~10^2, plants ~10^3, humans ~10^4 and their brain ~10^5, current microprocessors ~10^{11}. This increasing efficiency develops at an exponential rate, to do ever more, requiring ever less energy, time and space; a phenomenon also called *ephemeralization* (Fuller 1969; Heylighen 2007), or "Matter Energy Space-Time Compression" (Smart 2002).

In Tom Ray's simulation *Tierra* (Ray 1991), digital life competes for CPU time, which is analogous to energy in the organic world. The analogue of memory is the spatial resource. The agents thus compete for fundamental properties of computers (speed, memory) analogous to fundamental properties of our universe. This design is certainly one of the key reason for its impressive success.

Bridging physical, biological and cultural evolution

We saw that a metric can be found to compare complex systems traditionally considered as different in nature. This important insight is just a first step towards bridging physical, biological and cultural evolution. The information-theoretic endeavours are certainly going in this direction (e.g. (Von Baeyer 2004; Prokopenko, Boschetti, and Ryan 2007; Gershenson 2007; Floridi 2003)A general challenge for ALife is to obtain an artificial system capable of generating open-ended evolution. Some results have been obtained linking for example the evolution of language with biological traits. One step forward is to seek a digital universe simulating this rise of levels of complexity in the biological, physical and cultural realms. In short, this is the challenge of simulating an entire universe. An important step in this direction, although it stays on the physical level, is the simulation "Millennium Run", which starts from the very beginning of the universe to generate the large scale structures of the universe (Springel et al. 2005).

In such an endeavour, we should forget human-made social and academic boundaries between disciplines of knowledge. There should be a smooth and natural link between simulations in physics, biology and social sciences (culture). In fact the search for such bridges is obviously necessary if we want to tackle such problems as the origin of life, where we aim at explaining the emergence of life out of physico-chemical processes.

Replaying the tape of the universe

A natural extension of the challenge of replaying life's tape is replaying the tape of the universe. Paraphrasing (Gould 1990) the question becomes: "what would remain the same if the tape of the universe were replayed?" By exploring other simulated universes, this approach would allow us to face one of the main difficulties in cosmology, which is that -as far as we know- there is only one object of study: our unique universe. Interestingly, it is a natural and very relevant research program for tackling the difficult "fine-tuning" problem in cosmology, which states that if any of a number of parameters, fundamental constants in physics and also initial conditions in cosmology were slightly different, no complexity of any sort would come into existence (see e.g. (Leslie 1989) for a good review).

Such a simulation of an entire universe is the natural and ultimate challenge of simulations in science. Importantly, let us stress that such a simulation should resemble ALife simulations in the sense that the aim is to simulate *an* entire universe, *our* entire universe being just a special case.

Consequences for the soft ALife program

We will now draw some more philosophical consequences of the picture we proposed. We thus assume what we have argued in the previous section, i.e. that intelligent life will indeed be able at some point to simulate an entire universe. If such a simulation is purely digital, thus pursuing the research program of soft ALife, this leads to the *simulation hypothesis*, which has two main aspects. First, if we look into the future, it means that we would effectively create a simulation, realizing what was imagined in science fiction novels such as the ones of Greg Egan. Very well then! A second, much more disturbing implication is that we ourselves would be part of a simulation run by a superior intelligence (e.g. (Bostrom 2003; Barrow 2007; Martin 2006). Although these scenarios are fascinating they suffer from two fundamentals problems. First, the "hardware problem" : on what physical device would such a simulation run? Is there an infinity of simulation levels? Second, such an hypothesis violates Leibniz' logical principle of the identity of the indiscernible. It states that "if, for every property F, object *x* has F if and only if object *y* has F, then *x* is identical to *y*". Let *x* be reality, and *y* be the supposed simulated universe we would be living in. If we have no way to distinguish between them, they are identical! Unless we find a “bug” in reality, or a property F that could only exist in a simulation and not in reality, this hypothesis is useless. A more comprehensive criticism of these discussions can be found in (McCabe 2005).

More interestingly, what would be the philosophical consequences if the artificial universe is not “soft” (simulated), but follows the path of the “hard” or “wet” (embodied) ALife? We examine this question in the next section.

The heat death problem and cosmological *artificial* selection

The unhappy end of our universe

The second law of thermodynamics is one of the most general laws of physics. It states that the entropy of an isolated system will tend to increase over time. Herman Helmholz applied it to the universe as a whole in 1854 to state the heat death (HD) problem, i.e. that the universe will irreversibly go towards a state of maximum entropy (it is estimated that even black holes will evaporate in about 10^{150} years (Adams and Laughlin 1997)). Let us note however that there are some other models of the end of the universe (such as Big Bounce, Big Rip, Big Crunch...) but the point is that none of them allows the possibility of the infinite continuation of life as we know it. The study of the end state of the universe, or *physical eschatology*, is a rich field of research that we cannot detail more here (see (Ćirković 2003) for an extensive literature guide).

In an optimistic picture, that is if our civilization does not self-destructs (or if it does, we can add the hypothesis that we are not alone in the universe...), we can see the HD problem as the longest-term problem for intelligent life in the universe. How should we react to this? Charles Darwin's thought is still perfectly relevant: “Believing as I do that man in the distant future will be a far more perfect creature than he now is, it is an intolerable thought that he and all other sentient beings are doomed to complete annihilation after such long-continued slow progress” (Darwin 1887, 70).

A speculative topic better tackled with a philosophical approach

The shrewd reader may have guessed that we will propose a solution to the HD problem. However, we have to make a methodological clarification at this point. The solution proposed in the next section will be approached from a *speculative* philosophical stance (as opposed to *critical* philosophy (Broad 1924)). We should be well aware of the difficulty of the question that we are tackling, which is in fact an age-old philosophical problem “what is the ultimate fate of humanity and the universe in the very distant future?”. The problem is philosophical because (1) we do not have unambiguous empirical or experimental support in is its favour; (2) it is such an ambitious question, that the proposed answer can only be tentative and speculative. It is however still very worth considering because the philosophical enquiry aims to answer our deepest existential question here and now, whatever their difficulty (Vidal 2007); and it also fits very well with all the elements we have outlined so far.

From cosmological natural selection to cosmological artificial selection

The cosmologist Lee Smolin proposed a theory called Cosmological Natural Selection (CNS) in order to tackle the fine-tuning problem (Smolin 1992, 1997). According to this natural selection of universes theory, black holes give birth to new universes by producing the equivalent of a Big Bang, which produces a baby universe with slightly different physical laws. This introduces variation, while the differential success in self-reproduction of universes via their black holes provides the equivalent of natural selection. This leads to a Darwinian evolution of universes whose laws and constants are fine-tuned for black hole generation, a prediction that can in principle be verified.

It should be noted that the roles of life and intelligence in the universe are incidental. Another problem is that the theory does not propose a mechanism for universe replication. Is it possible to overcome these two shortcomings? A few authors have dared to extend CNS by including intelligent life into this picture, correcting those two problems and also bringing indirectly a possible solution to the HD problem (Crane 1994; Harrison 1995; Baláz 2005; Smart 2000; Gardner 2000, 2003). Simply stated, the thesis is that advanced intelligent civilization will solve the HD problem by reproducing the universe. This direction can be seen as the ultimate challenge of strong/wet ALife.

The research program leads in this framework to an attempt at what we could call *artificial cosmogenesis*. Let us note however that there is not yet a uniform terminology among the afore mentioned five authors. Inspired by Smolin's terminology we could speak of a “Cosmological *Artificial* Selection” (CAS), artificial selection by intelligent life replacing natural selection (Barrow 2001, 151). Indeed, instead of having many generations of universes needed to generate randomly an interesting fine-tuned complex universe, a CAS would dramatically improve the process by artificially selecting (via simulations) which universe would exhibit the desired features for the next generation universe. This would facilitate and guide the (certainly) extremely difficult task of producing a new universe.

This solution to the HD problem gives a general challenge to intelligence in the universe: to continue to explore and understand the functioning of our universe so as to possibly reproduce it in the far future. It also fits with the ultimate goal of evolution as a whole: survival. It is likely to be a difficult and stimulating enough challenge to encourage and occupy many generations of scientists.

Conclusion

We showed that ALife constitute a revolution in the way we do science. We outlined the trends of the accelerating changes occurring in our universe, and suggested that the natural limit of simulations will be a simulation of an entire universe. Given this perspective, we suggested the speculative hypothesis that the heat death problem of our universe can be tackled through what we have called an *artificial cosmogenesis*.

Scientific inquiry is today mainly a search for understanding the world; in the long run, it will tend to become a simulation or computation of our and other universes. Such simulations would be an indispensable tool if intelligent civilization engages towards an artificial cosmogenesis. To conclude, echoing Galileo we can write: "if today's science is *reading* the book of Nature, the science of tomorrow will contribute to *writing* its following episode."

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