

Can we debug the Universe?

Apostolos Syropoulos
Greek Molecular Computing Group
366, 28th October Str.
GR-671 00 Xanthi, GREECE
apostolo@obelix.ee.duth.gr

August 29, 2006

Abstract

The purpose of this paper is to try to provide an answer to the question whether it is possible to construct a computer simulation of the whole Universe. After presenting some ideas regarding the nature of the human mind and the computational capabilities of the Universe, we conclude that this is not actually possible.

1 Introduction

The prevailing model of computation is the Turing machine—a simple, yet elegant, conceptual computing device. It is an unproven statement that the Turing machine describes what can and cannot be computed. Roughly speaking, this statement is known as the Church-Turing thesis. A direct consequence of the Church-Turing thesis is the belief that no computational device can surpass the capabilities of the Turing machine. In other words, all computational devices (either real or conceptual) cannot compute more numbers or functions than the Turing machine does. Another widespread hypothesis is that the human mind is a realization of a Turing machine. Thus, human mental capabilities are actually limited by the capabilities of the Turing machine. Ergo, the human mind has (at most) the capabilities of a Turing machine, provided that the Church-Turing thesis is indeed valid.

Hayes, in a recent paper [6], has investigated the possibility to construct a computer program capable of simulating the Universe. He has reached the conclusion that although this is a particularly difficult task, nevertheless, it is a feasible one. Naturally, one should expect the emergence of intelligent “life” forms in such a computational Universe. And of course, at some later time, one intelligent being will start working on the construction of a computer program capable of simulating her own Universe!¹

Is this a reasonable scenario or is there something wrong with it?² To the disappointment of many thinkers, the answer in my own opinion is: No. First of all, no one has proved that the human mind is indeed a Turing machine. In addition, there is no proof that the Turing machine describes what can be actually computed. Proponents of the idea that the Universe is a computer base their belief on the *fact* that the Universe is discrete. However, there are no experimental data to confirm the granularity of space and time and, thus, to prove that the Universe is indeed discrete. Furthermore, there is no direct evidence that the physical laws are indeed computable.

¹Bostrom goes so far to suggest that we actually live in a computer simulation just because this is necessary in order to reach a “posthuman” stage (see [2] for more details).

²Certainly, this is a very good scenario for a sci-fi movie. Indeed, the scenario of the movie “The Thirteenth Floor,” which was directed by Josef Rusnak, is based on this idea. But of course, sci-fi movies is one thing and science is another. . .

In what follows I will make an attempt to discuss the nature of the human mind (i.e., to address the issue whether the human mind is cyber-machine or not). Next, I will present an overview of the current ideas concerning the very nature of the Universe as a computing device. The paper concludes with some remarks and ideas.

2 Is the Human Mind a Turing Machine?

Is really the human mind a computing device? In other words, are people computers equipped with sensors and effectors? The “strong AI” thesis, which was named so by John Searl in [17], claims that the manner in which computers operate constitute a model of the workings of a mind, and that a mind is just a biochemical computer. According to this thesis, brain “wetware” and computer hardware are the same type of thing. However, not everybody shares this view. Indeed, there are mainly two schools of thought that oppose this view—the one that base its objection on Gödel’s famous incompleteness theorem and the mentalistic school. Lucas and Penrose, who are proponents of the first school, advocate the idea that the mind is not better than a machine, but only different from it. Lucas’ argument is summarized in the following excerpt from [10]:

Gödel’s theorem must apply to cybernetical machines, because it is of the essence of being a machine, that it should be a concrete instantiation of a formal system. It follows that given any machine which is consistent and capable of doing simple arithmetic, there is a formula which it is incapable of producing as being true—i.e., the formula is unprovable-in-the-system-but which we can see to be true. It follows that no machine can be a complete or adequate model of the mind, that minds are essentially different from machines.

Penrose argues that certain mental activities (e.g., mathematical understanding) are non-computable (i.e., they cannot be simulated by a Turing machine). In addition, he believes that the previous remark strongly suggests that *all* mental activities should be non-computable. And since the human mind is part of this Universe, the physical laws are non-computable, in general. Similar ideas have been advocated by Weed [19]. In particular, she argues that there are certain areas of mental activity for which a computational analysis is not appropriate.

Hameroff and Penrose [5] proposed a new model of human consciousness that is based on the *Orchestrated Objective Reduction* of quantum coherence in brain microtubules. In particular, they propose that the non-deterministic free will can be explained with non-computable, but non-random wave function self-collapse. Also, since standard quantum theory does not describe any non-computable activity, in order to explain the non-computational aspects of consciousness they employ *orchestrated objective reduction*, which is a source of non-computability. In the following excerpt from [5], Hameroff and Penrose give their own explanation of the very nature of consciousness:

But what is consciousness? According to the principles of objective reduction, superpositioned states each have their own space-time geometries. When the degree of coherent mass-energy difference leads to sufficient separation of space-time geometry, the system must choose and decay (reduce, collapse) to a single universe state, thus preventing “multiple universes.” In this way, a transient superposition of slightly differing space-time geometries persists until an abrupt quantum classical reduction occurs and one or the other is chosen. Thus consciousness may involve self-perturbations of space-time geometry.

Another model of the operational structure of the human mind has been proposed by Kugel [7]. He has proposed that the human mind consists of four different units, one of them being a *trial-and-error*

machine [4, 16]. Such machines are actually classified as hypercomputers (i.e., computational devices that transcend the capabilities of the Turing machine). Typically, a trial-and-error machine is a kind of a Turing machine that can be used to determine whether an element x belongs to a set $X \subset \mathbb{N}$ or, more generally, whether a tuple (x_1, \dots, x_n) belongs to a relation $R \subset \mathbb{N}^n$. In the course of its operation, the machine continuously prints out a sequence of responses (e.g., a sequence of “1” and “0”) and the last of them is always the correct answer. Thus, if the machine has most recently printed “1,” then we know that the integer (or tuple) put in as input must be in the set (or relation) *unless the machine is going to change its mind*; but we have no procedure for telling whether the machine will change again its mind or not. Suppose now that our trial-and-error machine prints out an infinite number of responses, then after a certain point the machine will converge to a particular response and, thus, it will continuously print out the same response (“1” or “0”).

Intuition is an important mental process. Alan Turing believed that intuition is in practice present in every part of a mathematician’s thought, but when a mathematical proof is formalised, intuition has an explicit manifestation in those steps where the mathematician sees the truth of a formally unprovable statement. However, he did not believe that intuition is non-computable. On the other hand, Penrose and others are deeply convinced that intuition is non-computable. At any rate, one should note that intuition is a unique characteristic of the human mind. The human mind is clearly, a product of an evolution process and, thus, intuition is clearly a product of this same evolution process. But what is the *modus operandi* of evolution?

Figuratively speaking, nature by feeding an iterative process with external data tries to find a solution to an optimization problem. Non-optimal solutions lead to species less adaptable that eventually fade away. Also, there are solutions that are better than others and that is why certain species are more adaptable to radical changes. Thus, evolution is an interactive trial-and-error process. At this point we should note that Wegner [20] argues that interactive systems transcend the capabilities of Turing machines. Ergo, evolution is actually a non-computable process.

But evolution processes, in the sense just described, are also evident in the human cultural evolution. Indeed, Campbell’s most influential paper from 1965 [3], was one of the earliest attempts to apply the Darwinian theory to human cultural evolution. Thus, one may argue that human cultural evolution is also a non-computable process. Human culture is information transmitted from person to person via teaching and imitation. The principal tool for information transmission is the language—a highly adaptable structure. However, one should note that while genetic changes are random and slow, cultural changes are purposeful and rapid (see [1] for more details on the subject).

It seems that the “strong AI” thesis is not particularly popular even among psychiatrists. For example, Panksepp in [15] discusses the difference between *affective* and *cognitive* processes. In particular, he argues that the basic affects are examples of Mesulam’s *state functions* that “correspond to the noncomputable mass-action organic processes that are broadcast more widely and diffusely throughout the brain.”

The discussion above has made it clear that the “strong AI” thesis has been attacked by many thinkers and researchers with a different scientific background. This of course does not constitute a proof that the “strong AI” thesis is not valid. However, this is a very strong indication that the “strong AI” thesis is actually not valid and, thus, the human mind has parts that are actually noncomputable. Naturally, this leads to the following thesis:

Thesis 2.1 *Since the human mind has noncomputable parts, it is not possible to construct a computer simulation of the Universe.*

3 Is the Universe a Computer?

In 1969, Conrad Zuse published his monograph “Rechnender Raum” (Calculating Space) [23] where he advocated the idea that all processes that take place in the Universe are actually computable. In particular, he believed that one should be able to answer physical questions using the tools of automata theory. The core of Zuse’s argument is based on the idea that the continuum can be divided into discrete cellular automata.

Wolfram’s work, which has been epitomized in his latest book [22], is a more radical modern version of Zuse’s work. In this book he introduces the *principle of computational equivalence* that simply states that “almost all processes that are not obviously simple can be viewed as computations of equivalent sophistication.” This principle is used to explain the phenomenon of free will.³ In particular he believes that “For even though all the components of our brains presumably follow definite laws, I strongly suspect that their overall behavior corresponds to an irreducible computation whose outcome can never in effect be found by reasonable laws.” Thus, free will is just an illusion! He also goes on to assert that biological systems are the outcome of some simple “programs.” Clearly, this ascertainment is supported by discoveries of the algorithmic nature of certain biological phenomena (e.g., the pigmentation of sea shells [12]). However, the pigmentation of sea shells is not a process that can be compared with thought! Such an approach is at least naïve, if not dangerous. . . In brief, Wolfram argues that all processes that take place in the Universe are the outcome of some simple “programs,” somethings which this author does contest. (For a detailed overview of Wolfram’s recent book, see [21].)

Morgolus is another defender of Zuse’s ideas. In particular, he believes that “Nature is more like a spatially distributed Cellular Automaton than like a conventional von Neumann machine” [11]. Clearly, there are certain phenomena that can be explained with the use of computing devices. After all, simulation programs of physical systems have provided valuable insight to many researchers. But, it is one thing to devise computer simulations of a closed physical experiment and another thing to try to construct a computer program capable of simulating the Universe! This task requires that the Universe is actually discrete. In particular, what is actually required is that space and time are grainy at the level of atoms. Unfortunately, no one has managed yet to give an answer to the question: Are space and time discrete or continuous?

Recently, Lieu and Hillman published an article where they present evidence that space and time are not discrete [8]. In particular, they used images of distant galaxies taken by the Hubble Space Telescope to directly test whether time continues to have its usual meaning on scales of $\leq t_p = \sqrt{\hbar G/c^5} \approx 10^{-44} s$, where t_p is the Planck time formed by the speed of light c , the quantum scale \hbar , and the gravitational constant G . However, the findings of these researchers have not been unchallenged. In particular, Ng and his colleagues cannot conclude “that modern theories of quantum gravity have been observationally ruled out” [14].

But if we do not know for sure whether space and time is indeed continuous, does it really make sense to try to find the limits of computation? Not really. After all, there is no general agreement on what can be actually “computed.” In spite of this, there is a mystical trend in the scientific community to reveal the “ultimate” computer. For example, Lloyd recently published a paper where he describes the *ultimate laptop* [9]. This machine is a computer with mass of 1 kg and a volume of 1 lt, operating at the fundamental limits of speed and memory “fixed” by physics. The proposed machine performs $2mc^2/\pi\hbar = 4.4258 \times 10^{50}$ logical operations per second on $\approx 10^{31}$ bits. To an external observer, the ultimate laptop appears to operate at $\approx 10^9$ degrees Kelvin. Also, Ng [13] argues that in some sense black holes may be regarded as the ultimate simple computers. In particular, if ν is the number of

³Thorne in his lucid account on the nature of black holes points out that “. . . free will is a terribly difficult thing for physicists to deal with. We usually try to avoid it. It just confuses issues that otherwise might be lucid” [18, p. 507].

operations per unit time and I the number of bits of information in the memory space of a black hole, then $I\nu^2 \lesssim t_p^{-2}$. However, it is really an exaggeration to say that a black hole does actually compute something. In general, given some device S , only conscious, intelligent beings may attach to it the power to perform computation. For example, our fingers may be used to count, but this is not the reason they are there. In other words, computing devices are manufactured devices and computation does not occur in Nature.

4 Conclusions

We have presented our ideas regarding the possibility to construct a computer simulation of the Universe. We believe this is not possible at all. However, it is possible and it does make sense to create computer simulations of closed, controlled systems.

References

- [1] AVERY, J. *Information Theory and Evolution*. World Scientific, Singapore, 2003.
- [2] BOSTROM, N. Are You Living in a Computer Simulation? *Philosophical Quarterly* 53, 211 (2003), 243–255.
- [3] CAMPBELL, D. T. Variation and Selective Retention in Socio-Cultural Evolution. In *Social Change in Developing Areas: A Reinterpretation of Evolutionary Theory*, H. R. Barringer, G. I. Blanksten, and R. W. Mack, Eds. Schenkman Publishing Company, Cambridge, MA, 1965, pp. 19–49.
- [4] GOLD, E. M. Limiting Recursion. *The Journal of Symbolic Logic* 30, 1 (1965), 28–48.
- [5] HAMEROFF, S. R., AND PENROSE, R. Orchestrated Objective Reduction of Quantum Coherence in Brain Microtubules: The “Orch OR” Model of Consciousness. In *Toward a Science of Consciousness — The First Tucson Discussions and Debates*, A. W. K. Stuart R. Hameroff and A. C. Scott, Eds. MIT Press, Cambridge, MA, 1996, pp. 507–540.
- [6] HAYES, B. Debugging the Universe. *International Journal of Theoretical Physics* 42, 2 (2003), 277–295.
- [7] KUGEL, P. Thinking may be more than computing. *Cognition* 22 (1986), 137–198.
- [8] LIEU, R., AND HILLMAN, L. W. The Phase Coherence of Light from Extragalactic Sources: Direct Evidence against First-Order Planck-Scale Fluctuations in Time and Space. *The Astrophysical Journal Letters* 585, 2 (2003), 77–80.
- [9] LLOYD, S. Ultimate Physical Limits to Computation. *Nature* 406 (2000), 1047–1054.
- [10] LUCAS, J. R. Minds, Machines and Gödel. *Philosophy* 36 (1961), 112–127.
- [11] MARGOLUS, N. Looking at Nature as a Computer. *International Journal of Theoretical Physics* 42, 2 (2003), 309–327.
- [12] MEINHARDT, H. *The Algorithmic Beauty of Sea Shells*, 3rd ed. Springer-Verlag, Berlin, 2003.
- [13] NG, Y. J. From Computation to Black Holes and Space-Time Foam. *Physical Review Letters* 86, 14 (2001), 2946–2949.

- [14] NG, Y. J., CHRISTIANSEN, W., AND VAN DAM, H. Probing Plank-scale physics with Extragalactic Sources? Available as [astro-ph/0302372](#), 2002.
- [15] PANKSEPP, J. Biological Psychiatry Sketched—Past, Present, and Future. In *Textbook of Biological Psychiatry*, J. Panksepp, Ed. John Wiley & Sons, Inc., New York, NY, 2003, pp. 3–32.
- [16] PUTNAM, H. Trial and Error Predicates and the Solution to a Problem of Mostowski. *The Journal of Symbolic Logic* 30, 1 (1965), 49–57.
- [17] SEARL, J. *The Rediscovery of the Mind*. MIT Press, Cambridge, MA, 1994.
- [18] THORNE, K. S. *Black Holes & Time Warps*. W.W. Norton & Company, Inc., New York, 1994.
- [19] WEED, L. E. *The Structure of Thinking: A Process-Oriented Account of Mind*. Imprint Academic, Exeter, UK, 2003.
- [20] WEGNER, P. Interactive foundations of computing. *Theoretical Computer Science* 192 (1998), 315–351.
- [21] WEINBERG, S. Is the Universe a Computer? *The New York Review of Books* 49, 16 (2002), 43–47.
- [22] WOLFRAM, S. *A New Kind of Science*. Wolfram Media, Inc., Champaign, IL, USA, 2002.
- [23] ZUSE, K. *Rechnender Raum*. Friedrich Vieweg & Sohn, Braunschweig, Germany, 1969. English translation available as [ftp://ftp.idsia.ch/pub/juergen/zuserechnenderraum.pdf](#).