Thinking Matter and Computational Skills

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ABSTRACT

Computational skills are what computing machines are good at: simulating the evolution of physical systems. Cognitive sciences often deal with tricky concepts like consciousness, mind, etc. In this paper I show that computability being strictly a mathematical concept not bound to any particular type of computing device, be it a TM or the brain, it is possible to use computational skills to interpret consciousness in terms of simulation, perception, computational reversibility, reducibility.

1. Introduction

Res cogitans. And *res extensa*.

Res: matter, that's what it ultimately is.

Matter and energy are two *modes* of the stuff that makes up the world as we know it and where we live in. The 'thinking', the '*cogitans*' is the product of that lump of matter that we call brain.

Thinking matter is living matter: in it matter and energy are closely entangled in a chain of chemical reactions.

Conscious thought is the product of the neural activity of the brain: an open, physical, dynamic, complex system that is at the origin of our cognition involving perception, language, reasoning, etc. How conscious thought (consciousness) emerges from the neural activity of the brain is the central issue of Artificial Intelligence and its investigation is necessarily entangled with the issues of what is intelligence, of whether someone has to be conscious to be deemed intelligent and of whether there can be cognition without consciousness.

I argue with Penrose (1989) that consciousness involves noncomputable ingredients: consciousness not intelligence. There are in fact several layers of intelligence: we can deem intelligent any dynamic complex system capable of adaptivity at its lowest level, some kind of unstructured reflex. The intelligence I am talking about is intelligence that transforms adaptivity from a simple reflex into a finalized, structured process a.k.a. technological development. This is adaptivity 'after' consciousness, this is Kurzweil's Law at work.

I argued that the string of emergences (life, adaptivity, thought, consciousness) implies the existence of a similar law at work through the whole of evolution: the word emergence itself is descriptive, not explicative, but it is nevertheless regularly used to establish as it were a line of development in the sense that an emergence seems to imply the next one.

Now that we have reached the stage of consciousness we are able through adaptivity at its highest level to draw on the history of past events to steer evolution to achieve further emergences: the century old 'training-of-the-mind' to achieve 'higher' consciousness levels (Baringa 2003; Stewart 2006) and the research areas of bionics and neuronics are examples.

The point that I am addressing in this paper is that although we cannot explain consciousness and adaptivity through computationalism, it is possible to interpret them in terms of computational skills.

In Vitiello's words: "…memorizing breaks time reversal symmetry. The brain dynamics is thus intrinsically irreversible…" or "…"after" having received some information, one cannot anymore behave as "before" receiving it." (Vitiello 1996) . The time's arrow is thus born in the brain in the act of knowing and makes the brain an irreversible computational machine. However, through consciousness, by remembering (Bennett 2003) the brain is capable of computational reversibility (we meet here the first computational skill) creating the necessary level of adaptivity that leads to new emergences.

2. Computationalism: the one-dimensional cognition

Contrary to what some people think, "*Penrose also revives, for some reason, the* ***long discredited*** (my emphasis) *idea that Goedel's work in mathematics somehow implies a special difficulty in achieving self-awareness in a physical system.*" (Gell-Mann1995) this is exactly the meaning of Goedel's theorems: since our formal systems are unable to capture all of mathematics, computationalism cannot be the whole picture. Penrose is not denying that some of the brain's capacities are computational in nature, Penrose is trying to find an answer to such "founding" questions as why is it that physical constraints that seem to limit all computing devices allow the brain to develop consciousness? Or, again and more fundamentally, what is there beyond Goedel that allows the mind "to see" non computable "truths"?

Neurological studies (Damasio 2000 and 2003) have done away with Cartesian dualism by showing that our intellectual faculties (the mind) are the product of the neural activity of the brain. However when we come to computationalism to explain the brain's neural activity we are confronted with the modern version of dualism: software and hardware.

Although computation is more than the algorithmic symbolic information processing activity of digital computers, all computational models will have to be tested on dychotomic, digital and structurally rigid machines while the brain itself, as far as its computing capabilities are concerned, is an integrated, analog and structurally flexible computing device.

The design of the data processing machine determines how we use and how we can use that machine: the fundamental design constraints of the underlying hardware are molding and constraining software. Therefore Turing-computability because of its rigid symbolic codification cannot explain processes of intrinsic emergence (thought, consciousness) where the continuous flow of information due to the interaction with the world requires ever new codifications (Licata's Thesis 2003). This is the whole point: because of its opening onto the world (Vitiello 1996) the brain has an edge on our computing machines that cannot possibly be made good even by computationalism beyond the Turing limit. Computationalism is missing the depth of consciousness, it is one-dimensional. Computationalism produces machines (artificial brains) without a mind. But although computationalism cannot explain the emergence of consciousness it can however interpret neural activity which is at the origin of consciousness. Neural activity entails consciousness in the sense that there cannot be consciousness without neural activity and therefore computationalism must be a part of the explanation.

This is why computational skills can be used to explain the emergence of consciousness.

3. Computational skills

Computability being strictly a mathematical concept not bound to any particular type of computing device, be it a TM or the brain, computational skills can be used to explain features of living matter. Of course this is admitting that the brain is endowed with some kind and some measure of computational power but, although computationalism cannot explain consciousness, it is possible to give a model of its emergence in terms of computational skills in the same sense as Edelman (2007) argues that consciousness is not caused by brain processes but is entailed by them.

Computational skills are what computing machines are good at: simulating explicitely each step in the evolution of a physical system to predict its behaviour. We have already met one, computational reversibility, we meet now another computational skill: reducibility. The effort is on devising computations that are more sophisticated than those that the physical system itself can perform, whereby "reducing" the number of steps in its evolution. There are two important cases where this is not possible: the first one is the evolution of a computer, itself a physical system, that can determine the outcome of its own evolution only explicitely following it through: no shortcuts are possible (Wolfram 1985). Such computational irreducibility occurs whenever a physical system can act as computing machine.

The second case happens when dealing with intractable quantum systems meaning by this that it is necessary to perform exponentially large amounts of computation in order to predict the outcome of its evolution.

This difficulty led Feynman to observe (Deutsch 1997) that if it requires so much computation to work out the evolution of a quantum experiment, then the very act of setting up such an experiment and measuring its outcome is tantamount to perform a complex computation.

What does this mean in the case of the brain, assuming that it can be considered a quantum system? The brain itself does not seem to be affected by this computational limitation. It means that if we consider the sensorial perceptions of the brain as the results of computations executed by dedicated computing (information processing) neural networks, the brain is simulating itself as experimental setup.

This is a definition of consciousness: the reflexive faculty of the brain as a computing machine to simulate itself as an experimental setup assessing reality through sensible perception: a metacomputation expanding computationalism to include mind and matter as dynamical elements of a unitary scenario.

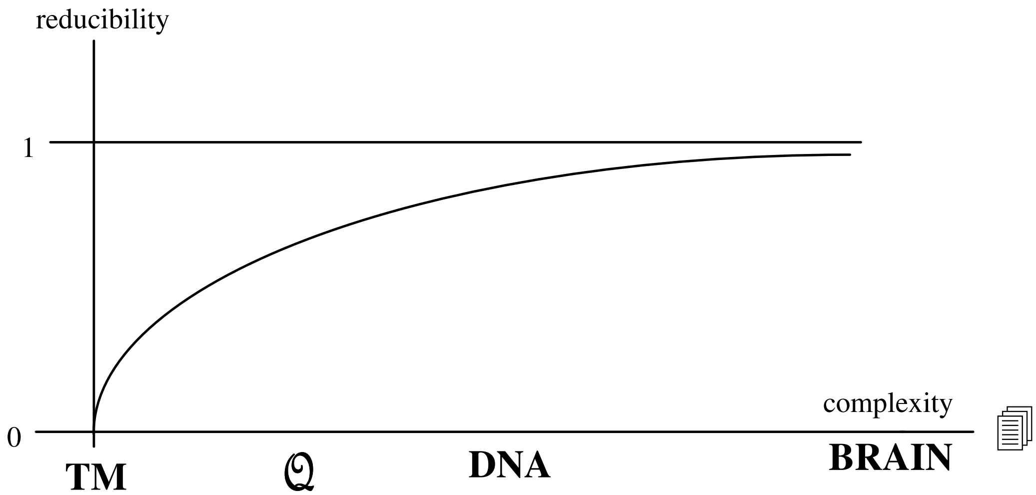
We meet here an interesting parallel with the concept of neural networks as a particular type of computer consisting of multiple assemblies of basic processors interconnected in an intricate structure. Siegelmann (1998) argues that examining these networks under various resource constraints reveals a continuum of computational devices that gives rise to a Church-Turing-like thesis applied to the field of analog computation that could be the point of departure for the development of supra-Turing computational theories.

It should however be remarked that the parallel stops here: the model that is proposed here is an open one. In this model I not only consider the elementary constituents of the brain (neurons, ganglia) in their computational activity, I include their functional activity (computational skills) embodied by their structure as networks. The structure and the function supply the dynamical knowledge of the system in agreement with the dissipative model of the brain as an open system interacting with its own image (Vitiello 1996).

Computational skills are how the brain's structures function and generate consciousness: if you dissect a brain you will find neurons, ganglia but not consciousness.

How does the brain as a physical system compare in this representation as a '*computing machine*' and as '*experimental setup*' assessing reality through sensible perception to other computing devices? How does neural structure mold and constrain the mind?

Let us look at the concept of complexity of a system as measured on a scale of reducibility: in the following drawing reducibility is on a scale from zero (no reducibility) to one (total reducibility) and complexity is on a scale from zero (no complexity) to infinity. I have tentatively plotted a few well known physical systems (existing or theoretically projected) on it.



TM is the Turing Machine: a deterministic computer can determine the result of its own evolution only following it step by step explicitely, no shortcuts are possible. A TM can therefore be assigned reducibility zero and, since what is irreducibile is at the lowest level of complexity, a TM has also complexity zero.
I put the **brain** at the other extremity assuming its complexity to be so large as to approach infinity. In the proposed model consciousness acts as a "short" between perception and its representation producing flashes of intuition which Bohm calls '*quantum jumps*' (Bohm 1989) or that could be explained in terms of the 'supertasks' advocated by Bringsjord in hypercomputing minds (Bringsjord & Arkoudas 2004). They are the indication of total reducibility beyond Goedel.
Somewhere in between I have put Deutch's Universal Quantum Machine **Q** (Deutsch 1985) and the DNA, which is also by the way capable of computational reversibility as pointed out by C.H. Bennet (2003). Computational reversibility in nature is a characteristic of living matter explaining adaptivity. Adaptivity at its highest level draws on the history of past events to advance evolution beyond consciousness: the century old 'training-of-the-mind' to achieve 'higher' consciousness levels and the new research areas of bionics and neuronics are examples.

4. Conclusions

Cognitive sciences often deal with very tricky concepts and terminology, the most difficult to catch is consciousness. I have therefore chosen in this paper to comment on things that you can physically describe: brain, neural networks. I object, for instance, to the use of expressions like "computing or even hypercomputing minds": in my view and for sake of clarity, if anything at all, it is the brain that is doing the computing! Further the use of computer skills defined by a terminology whose meaning is generally agreed upon - we all know what simulation, perception, computation, etc., mean - leads to a definition of consciousness that is in agreement with the dissipative model of the brain. I also comment on the limitations of computationalism even beyond the Turing limit but also stress the use of computationalism as a basis for the explanation of consciousness.

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