On a Possible Future of Computationalism

Jozef Kelemen

Institute of Computer Science, Silesian University, Opava, Czech Republic
and
College of Management, Bratislava, Slovakia
kelemen@fpf.slu.cz

Abstract: Computationalism is traditionally considered in the context of the cognitive science as perhaps the dominant contemporary approach to understanding cognition and cognitive phenomena. In this position it plays the crucial role in present day not only in cognitive science, but also in the field of cognitive psychology, artificial intelligence and also in an important part of advanced cognitive robotics. However, it is possible to treat computationalism in a most general context of present day science and engineering, in a broader meaning as it is usual according the prevailing tradition. From this perspective, computationalism consists in application of concepts and methods formulated in the field of theoretical computer science for understanding and (re)construction of phenomena appearing in much more broader fields of science, including natural sciences (like biology, chemistry, physics, astronomy), but also economy, and some branches of social sciences up to the art (esp. in the area of new media).

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1 Introduction

Computationalism is traditionally considered in the context of the cognitive science as perhaps the dominant contemporary approach to understanding cognition and cognitive phenomena. In this position it plays the crucial role in present day not only in cognitive science, but also in the field of cognitive psychology, artificial intelligence and also in an important part of advanced cognitive robotics.

The central doctrine of the *traditional computationalism* considerd as the basic paradigm for the study of cognition consists in the view that, according (Giunti, 1996, p. 71), *cognition essentially is a matter of the computations that a cognitive system performs in certain situations. The main thesis I am going to defend is that computationalism is only consistent with symbolic modeling or, more generally, with any other type of computational modeling. In particular, those scientific* *explanations of cognition which are based on (i) an important class of connectionist models or (ii) nonconnectionist continuous models cannot be computational, for these models are not the kind of system which can perform computations in the sense of standard computation theory.*

Illustrative examples of such approach might be found in the systems developed in traditional Artificial Intelligence (different knowledge-based systems, robot control systems based on symbolic representation of the robots environments inside their robots memories, etc.) Having the set of notions and scientific rules formulated and discovered during the 50 years of the existence of theoretical computer science research based crutially on the concept of the Turing machine proposed in 1936, and on the acceptance of the so called *Church-Turing hypostese* on the equivalence of the Turing machine and each other imaginable computing device, we try to explain the nature of phenomena of the (human) intelligence (usually, esp. in artificial intelligence and in advanced robotics, at the level which provides the real base for engineering (re)production of them).

An alternative position to the traditional computationalism emerged in cognitive science during the 80ties of the past century. It was the *connectionism*. While traditional computationalism stresses the sequential nature of the processes considering them as traditional (algorithmic style, or Turing-type) computations performed by traditional (von Neumann type) computers, connectionism, roughly speaking, stresses the multiprocessor-based architecture of systems and emphasizes the architectural principle of multiple nodes layered into certain strata. Traditional examples of such architectural principle are (artificial) neuronal networks.

2 A Slump in the Traditional Computationalism?

However, it is possible to treat *computationalism* in another, in a most general context of present day science and engineering as it is usual according the prevailing tradition. In this *broader meaning* computationalism consists in a broad conceptual framework for, and in a suitcase of specific methodologies of applications of concepts and methods originated and rigorously formulated in theoretical computer science for understanding some aspects of, and of (re)construction of (some fragments of) phenomena appearing in much more broader fields of science as those related to cognition and mind. As parts of these fields we recognize (some branches of) natural sciences, like biology, chemistry, physics, astronomy, but also at least a subfield of economy, and some branches of social sciences, and also arts (e.g. some sub-area of area of the field of the new media, computer art, robotic art, etc.).

Both the traditional computationalism or the connectionism have, as the present day state-of-the-art in science and engineering signalize that, some problems how to react to the many new situation appearing in numerous fields of science and engineering. In (Kelemen, 2003) we have emphasized the R. Brooks appeal formulated during his plenary talk for the *8th International Conference on Artificial Life* (Sydney, Australia, December 11, 2002) which focused our attention towards a need of a new understanding of computing and computability, in other word to reconsidering the actual form of computationalism and push our understanding of computation closer to the present-day requirements. Earlier, in *Nature* (p. 410), R. Brooks wrote:

'*We have become very good at modeling fluids, materials, planetary dynamics, nuclear explosions and all manner of physical systems. Put some parameters into the program, let it crank, and out come accurate predictions of the physical character of modeled system. But we are not good at modeling living systems, at small or large scales. Something is wrong. What is wrong? There are a number of possibilities: (1) we might just be getting a few parameters wrong; (2) we might be building models that are below some complexity threshold; (3) perhaps it is still a lack of computing power; and (4) we might be missing something fundamental and currently unimaginable in our models of biology*.'

An important and general lesson from the fields like artificial intelligence, advanced robotics, artificial life, and cognitive science is that the Turing machine universality as a mathematical concept which states that all kinds of computers are equally good devices for performing computational tasks might be misleading in situations, when we consider machines embedded in their real physical environments. The fact that an active agent is embedded in its dynamically changing environment may cause two fundamental consequences:

(1) *The input-output relation*, required when we consider processes as Turing machine computations, seems to be an unrealistic requirement, because of the environment dynamics, and the fact that real agents are at least in some extent open systems functioning in this environment.

(2) *The potentially infinite tape* of the Turing machine as a computing device cannot be required as a part of any real physical system.

The matter is discussed in more details in (Sloman, 2002) or in (Kelemen, 2004) and (Kelemen, 2005a, 2005b), where we will provide a particular example of how at least some of computationally relevant questions concerning embodied agents may be approached from the position of a well-elaborated theoretical (formalized) computational perspective.

There are no physical counterpart in many systems, including, might be surprisingly, also the real computers, to the Turing machines potentially infinite memory (the tape of the Turing machine). All kind of physical machines have the limitation of their behavior, in their *performance*, but some of them, esp. the human brains, have a kind of *competence* to ‘imagine’ the infinity (of natural numbers for instance) in some constructive way (by adding the number 1 to the ‘greatest’ natural number, for instance).

In the core of the two above-mentioned understanding of computationalism, there exists the conviction in

(1) the power of symbolic representation, and in

(2) the approximation of a large scale of processes as computational processes, so as processes which transform structures created form symbols into the structures of the same type.

The second important for the new understanding of computation point is the discovery of the power of *emergence*. Emergence is, roughly speaking, ‘... *a product of coupled, context-dependent interactions. Technically these interactions, and the resulting system, are nonlinear: The behavior of the overall system cannot be obtained by summing the behaviors of its constituent parts... However, we can reduce the behavior of the whole to the lawful behavior of its parts, if we take nonlinear interactions into account*’ (Holland, 1998, pp. 121-122).

Especially *interactions* of relatively simple computing entities are very appealing for re-consideration of the form of ‘computation’ performed by societies of such agents, or much complicated systems set up from them, and for drawing perhaps new boundaries between what we consider as computable and what as non-computable.

In present day theoretical computer science there are numerous efforts to demonstrate that the notion of computation might be enlarged beyond the traditional boundaries of the Turing-computability. In (Burgin, Klinger, 2004) it is proposed to call algorithms and automata that are more powerful than Turing machines as *super-recursive*, and computations that cannot be realized or simulated by Turing machines as *hyper-computations*.

In (Kelemen, 2006) we have illustrated how from randomly interacting computationally active entities emerge some level of robot consciousness. In (Kelemen 2005b) such type of entities and their societies are related to the computational power of embodiment, and in (Kelemen, 2005c) the situation is discussed in the context of special type of societies which members communicate very freely an randomly – in collection called herds in the mentioned above article.

3 How to Cope with Limits?

In (Kelemen, 2005a, 2005b) we have illustrated, using na interesting in this context result by D. Watjen – published in (Watjen, 2003) – on the theoretically well-defined generative power of a specific type of grammar like generative systems, in so called teams working in eco-grammar systems (Csuhaj-Varju et al., 1994). Watjen has proved that there exists formalized (formal grammar like, esp. special type of eco-grammar) systems set up from decentralized components with higher computational power as Turing machines have.

We have expressed our conviction that there are no principal reasons to reject the hypothesis that it is possible to construct real robots as certain kind of implementations of these formalized systems. If we include into the functioning of such robots the activation of their functional modules according a non-recursive (in Turing sense) computation, the behavior of the agents might be non-recursive.

We suppose that this situation may appear if some of the functional parts of the robots are swich on or off on the base of the random behavior of the robots environments, for instance. So we exclude the situations when a computer simulation of randomness are included into the functional architecture of robots. Rather, we suppose the randomness appearing in the environment, a randomness which follows from the ontology of robots situated in their environments.

Conclusions

The just mentioned, so called *ontological randomness*, might be caused by different reasons – by imprecise work of sensors and actuators of robots, by erroneous behavior of their herdwired or software parts, so by the general couse of their embodiment, by nondeterminism of the behavior of the environment, by lack of resources necessary for executing the required computations, so by their finitary nature, etc. All these influences may be reflected in the specific behavior of the robots and we cannot reject the *hypothesis* that just these kind of irregularities cause also the phenomenon called robot cunsciousness. It is also possible, that the organic, effective, and rigous enough inclusion of this type of randomness, caused in fact by the embodiment of computing systems, and by their finitatry nature, as well, can contribute to our new understanding of computing machineries, and computing as well. If this possiblitity turn to reality, than we will have at hand the required new model for rigorous formal study and understanding of a new type of computationalism.

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