

Facing N-P Problems via Artificial Life: a Philosophical Appraisal

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Abstract. Life as an N-P problem is a philosophical, scientific and engineering concern. N-P problems can be understood and worked out via artificial life. However, these problems demand a new understanding of engineering, since engineering is basically a way of acting upon the world. Such a new engineering is known as non-conventional engineering or also as complex systems engineering. Bio-inspired systems are more flexible and allow a higher number of degrees of freedom. As a consequence, AL enlarges our understanding of living systems in general and can be taken as a step forwards in grasping the complexity of life.

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1 Life is an N-P problem

Generally speaking, life is an N-P problem. However, a feasible way for dealing with N-P problems and trying to solve them is via thinking, experimenting and working on and with AL. The workings and research on and with artificial life (AL) cover three main action domains, namely philosophy, science, and engineering. The first two deal with understanding and explaining phenomena, systems and dynamics exhibiting life –natural or artificial– whereas the third is mainly centered around building, optimizing, predicting and/or controlling engineering-like systems that behave as living beings, or having living features or characteristics. Two outcomes can be derived hereafter [1]: firstly, models and simulations for studying life (*scientific orientation*); secondly, artificial systems bearing biological properties and capabilities applicable to solving problems (*engineering orientation*).

In both cases, though, the role of computing is crucial in order to literally be able to *see* non-linearity in phenomena characterized by emergence, self-organization, growing, adaptation, evolution, and increasing complexity –in one word: life! However, we claim, many if not all examples of AL and its applications in other disciplines and sciences are systems imposing tremendous computational challenges – they are N-P systems.

2 Engineering life and AL

Unlike the techniques used in artificial intelligence, AL does not work uniquely on the existing computational paradigm (based on Von Neumann architecture). Rather, it *creates* in many cases new paradigms inspired by the forms of processing, architecture and dynamics of biological, social and evolutionary systems such as *evolutionary computation* (among others, J. Holland, J. Koza), *swarm intelligence* (E. Bonabeau, M. Dorigo, G. Theraulaz), *membrane computing* (Gh. Paun), *DNA computing* (L. Adleman), *artificial immune systems* or *immunological computation* (D. Dasgupta) and *cellular computing* (M. Sipper). These new *computational paradigms* belong to the so-called *non-conventional computing* and cross other paradigms from other areas and contexts such as physics and logics; such is notoriously the case of *quantum computation* (P. Benioff, S. Lloyd), *fuzzy systems* or also *hipercomputation* (foreseen somehow by A. Turing circa 1938 when working on the idea of non-computable tasks; in other words, tasks that are not carried out by a conventional Turing machine [2]).

The most generic example of the new computational paradigms arisen within the frame of AL has been pointed out by M. Sipper [3], related to cellular computing (CC). Here, most of the features and claims of AL, even philosophical ones, are gathered. The core of CC turns around principles such as simplicity, vast parallelism and locality:

- *Simplicity*: unlike current complex units, the processing unit in CC, called *cell*, can carry out very simple tasks.
- *Vast parallelism*: This principle is based on the interaction of large number of cells (around 10^x) that interact in order to carry out complex tasks at a high level that one single cell could not achieve (emergence). This is evidently a proposal quite different to those that we normally find within the frame of parallel computing and massive parallelism.
- *Locality*: The connectivity patterns –interaction- among cells are entirely local, and no single cell is able to see the whole system. In other words, it has to do with the absence of local control or with the implementation of distributed and local control techniques.

These three principles are strongly connected with each other and are necessary to create a CC; otherwise, if one of them is modified we converge to another type of computational paradigm (Fig. 1). Nonetheless, within every principle there are diverse degrees that are *eligible* according to the context of the problem one wishes to attack. The kind of cells (discrete or continuous), the scheme of connectivity (regular or irregular grid) and the dynamics in time (synchrony/asynchrony, discrete/continuous) are some of the configurable variables in CC [3].

However, the really important feature of CC and hitherto of the remaining computational paradigms of AL consists in that within the possible applications, among others, are the complete N-P problems, opening thus a wide horizon for the study of complex systems.

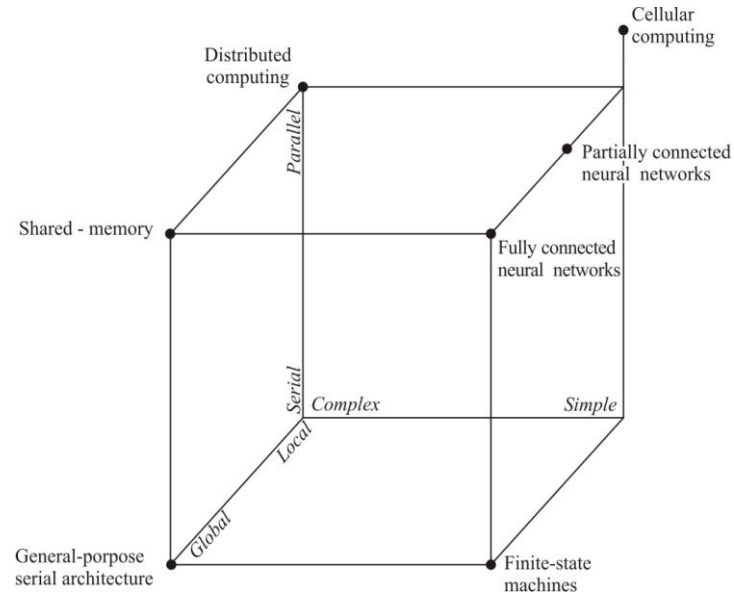


Fig. 1. Computing Cube. Adapted from Sipper [3]

3 About non-conventional engineering

Now, the majority of paradigms in non-conventional computation are inspired by natural systems –whether biological or not, and they are gathered under the generic name of *natural computing*. Here, as f. i. does Nunes de Castro [4] swarm intelligence or evolutionary computation are categorized as independent and parallel to artificial life; beyond such recognition, that can be debatable, what is really important consists in its underlying goals [4], namely i) to develop computation inspired on nature in order to solve complex problems; ii) to construct tools to synthesize behaviors, patterns, forms, and natural systems; and iii) to use natural materials in order to carry out computational tasks.

These underlying goals set out clearly that paradigms such as cellular computing or any other in AL or from natural computation in general are not applicable as such to any kind of problems set out by science, engineering and computation, for in many cases the conventional techniques and models are better suited and work better. In contrast, we only use those models and techniques that entail a large number of variables, non-linearity, multiple goals, N-P time, a space of solutions or, what is equivalent, more than one potential solution – whereas standard techniques provide a unique or singular solution.

M. Bedau et al. [5] and [6], have worked on the structuring of AL around fourteen open problems. Being as they are all in all relevant, these problems could make more sense if they were set as P or N-P problems. In any case, even if for the sake of agreement we can say that those are N-P problems it remains to be set whether any open problem is an N-P problem.

Here, we claim that AL is a most viable way to deal with “real” N-P problems of real life; hence its utility and significance.

In engineering in general, we have come to talk about *non-conventional engineering* or *complex systems engineering* [7] or also about a “new engineering” – three different ways referring to one and the same idea. Non-conventional engineering is rooted in the theory of non-linear dynamic systems, namely the sciences of complexity¹, and thereafter on the bio-inspired systems of AL. We strongly believe that AL can and must play a crucial role in the structuring of the frame of this new engineering, not only from the technical and engineering-like scope, but also from a philosophical, scientific, heuristic and methodological standpoint [9].

Such a new way of thinking on, and doing, engineering has made possible firstly moving away from the basic principles of classical engineering – namely centralized control, preprogramming, the search for a unique solution: optimality – towards more flexible and robust principles such as distributed and local control, emergent or bottom-up programming, a space of solutions, and secondly it has set out previously unforeseen research lines in order to implement features and characteristics of living systems, such as autonomy, adaptation, evolution, self-organization, self-synchronization, immunological response and metabolizing, among others.

4 P problems and N-P problems within the frame of AL

A problem to which any problem in P can be reduced is called P-hard; if it also belongs to P, is called P-complete. Thus, to show that a problem is P-hard, it is enough to reduce a P-complete problem to it. Similarly, a system is universal if it may simulate a universal Turing machine. If so, then the problem arises about the decidability or undecidability of the system, i.e. whether we can safely say whether the program stops or not and when, and also whether the program can be compressed. A system is P-hard, when it admits a P-hard problem.

Any P problem, whether P-hard or P-complete, assesses and presupposes at the same time a polynomial time. Polynomial time is critical to living organisms as circadian cycles, or also at the scale of developmental biology. The critical case is the study of apoptosis and, hence, the biological clock [10]. ALife systems however not always “die”. They just vanish in simulated programs. What is it for an AL system to die? It is conspicuous to notice that artificial organisms may die, as they do indeed, but the program does not! Inversely, an AL-organism is born as the program creates it, but the very process of giving birth and developing on the evolution of an AL system is the very success of the program! The program can be different as it happens: artificial chemistry, swarm intelligence, and the like.

This idea could lead us back to the belief of a “programmer of the universe”, a dream that has already been dreamt. The reply to the belief can be positive if we think of conventional engineering, but it can be negative if we take into consideration non-

¹ For example, the thermodynamics of non-equilibrium, the theory (or science) of chaos, fractals, the theory of bifurcations, self-organized criticality, and the science of complex networks. See Maldonado [8].

conventional engineering, i. e., artificial chemistry, and the very possibility of programs that create other programs [11] and [12].

What can be thought of as a kind of biological clock within AL-systems, is simply a matter of programming. The question arises: can we really talk about N-P problems in the frame of AL? So far the answer clearly seems to be: no. If so, then AL is at most a P-complete problem; no more, no less.

The implications of such an acknowledgement are twofold: on the one hand, AL is susceptible only of P-treatments; hence, N-P problems are a patrimony of carbon-based life, not to talk about human systems. On the other hand, we could figure out as a question of possibilities N-P problems for AL. If so, the best chance comes from engineering AL in that direction.

As a consequence, three big axes are useful as references when working with or studying AL, namely the philosophical significance, the scientific endeavor and the engineering featuring of AL. As for the N-P problems, we want to assess that engineering AL is most useful to deal, understand and try to solve them. Nonetheless the road remains open and not fully experienced or crossed. Just some steps, although steady, have been done so far.

The crux of the studies on life, whether natural or artificial, is about the meaning of life. To be sure, any scientific answer to this question crosses necessarily throughout the fields of N-P problems. Living systems live by solving P problems, but when solving these kind of problems, they happen to encounter N-P; for instance, problems of optimization. Hence, the most basic form of appearance of N-P problems is via problems of optimization, but N-P problems do not, alas, reduce to questions concerning optimization.

Therefore, it can be useful to introduce a sort of phenomenology of N-P problems. Simulation via swarm intelligence or artificial chemistry allows us to truly “see” N-P times.

An N-P time should not be taken as a physical stance, namely quantitatively, i.e. as a large or big span of time. Such would be indeed a Newtonian understanding of time – as a “mass” or “force”. Grasping N-P time in such a way is misleading and it can simply be taken as a limit as in mathematics.

5 N-P time and complexity

An N-P time is, accordingly to complex science, rather a quite surprised time, unexpected in principle and unforeseeable. This opens up the door to the Greek notion of *kairós*, but it can be better grasped as Nietzsche put it: *unzeitmässige (Betrachtungen)*. Here we get a hint for further exploring of N-P time as different from a classical mechanical background (as an extensive – long span). Computationally speaking this leads us necessarily to quantum computing a most intriguing and passionate field underlying, to be sure, complex theory.

Life in general, and ALife in particular, obeys from time to time these kinds of N-P- times, and they emerge unexpectedly, as it happens. Several accounts of such phenomena have been recounted by Ch. Langton [13], [14] and [15], T. Ray [16] and [17], or J. Conway [18], among others. We can experience those accounts not just as

physical phenomena, but also as temporal or time happenings not assailable to, or as, a P time.

N-P time has been conceived in terms of its computability and, thereafter, its complexity (computational complexity) [19]. The question remains whether AL can bring new insights on a broader scope on computational complexity. This, we recall, is at the same time a scientific, a philosophical and an engineering challenge and endeavor that remains, so far, still open.

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