Nature from the bit and beyond

Sergio Miguel-Tomé

Abstract

Information and computation are two concepts that are being applied every day more and more in science. However, these concepts are sometimes misunderstood about what they imply by several physicists and several computer scientists. Information and computation are not mathematical concepts as computer scientists usually think and also they are deeper physical concepts than what physicists usually assume. For this reason, this essay is dedicated to explain why information and computation are physical concepts and why they are deeper concepts. Until now, computation and information are concepts derived in the epistemic scheme of energy but they could be taken as fundamental concepts allowing us to understand nature from a new perspective.

1 Introduction

Two of the concepts that have been more spread in science since the middle of last century are the concepts of information and computation. One of the fields, where these concepts have increased their use, has been physics. In 1990, Wheeler suggested that information is fundamental to the physics of the universe. However, I assist many times to a discussions about these concepts in terms that information and computation imply discreteness in nature against the view that claims about no computation in nature asserting that nature is continuous. The own John Wheeler saw two faced outlooks: decoherence and it from the bit[21] in these terms. The view identifying information and computation with discreteness in nature and no computational with a continuous nature is very common among physicist[19][20] but it is totally wrong. At same time, I see many computer scientists consider that information and computation are mathematical concepts, which is not a correct understanding of the matter. Many times I had to explain personally to my colleagues aspects of the concepts of information and computation which they unknown. So I would like to use this opportunity to write an essay mainly to show physicists that information and computation are concepts

much deeper of what they usually think and to show to people concerned about computer science that they are concepts not from the platonic kingdom of the mathematics but from the kingdom of nature[4]. Also, I want to discuss the possibility of create an epistemic scheme of information. At the moment, the notions of information and computation are defined from the epistemic scheme of energy. However, I consider that information and computation are concepts fundamental enough to create a new epistemic scheme that let explain nature.

This paper is structured as follows. In section 2 the history of the concepts of information and computation is shortly examined. Then, section 3 talks about information and computation as physical concepts. Afterwards, section 4 explains why information and computation are deep concepts. In section 5 I will discuss the possibility of create a new epistemic scheme with the concepts of information and computation. Finally, in section 6 the conclusions of this essay will be presented.

2 Information and computation in science

The first computational notion was the notion of algorithm. This notion has been developing from two different spheres that were connected with the work of Alan Turing. On the one hand, mathematicians were developing the concept. The first works reach Greeks with the Euclid's algorithm, for computing the greatest common divisor. The name of algorithm was born in honor to the Arab mathematician Al-Koarizmi of the 9-th century, due to his works in arithmetic using Hindu-Arabic numerals to find systematically solutions of linear and quadratic equations. Another important issue about algorithm began with attempts to solve the Entscheidungsproblem posed by David Hilbert in 1928. In 1936 Alan Turing gives a mathematical definition of algorithm with the now known Turing Machine and a definition of computer with the universal Turing machine. On the other hand, the interest about machines, which could do computations, was born also in the Hellenistic civilization with the astrolabe. We can mention some people who contributed to it. Raimond LLul in the 13th century developed a system of organizing concepts using devices such as trees, ladders, and wheels, what we know nowadays as classification system. Galileo Galilei with his compass. Blaise Pascal with his work on mechanical calculator. The works of Gottfried Wilhelm Leibniz in the 17th century about adding automatic multiplication and division to Pascal's calculator, and binary and his calculus ratiocinator influenced by Raimond LLul works. The work of Charles Babbage with the Difference Engine and the Analytical Engine and Ada Lovelace who cre-

ated the first programs. Finally, these two worlds, mathematics and physical machines, meet in the work of Alan Turing.

In the case of the concept of information much of the mathematics behind information theory were developed for the field of thermodynamics by Ludwig Boltzmann and Josiah Willard Gibbs, but it was the paper of Claude Elwood Shannon who, in a engineer context, invented the field of information theory. The work of Shannon, which was born with a technical orientation, fastly jumped to other fields. One of the fields was physics. One of the reasons was that Marian Smoluchowski pointed out that the key question about the problem of the Maxwell's demon was the information which has the demon. In 1929, Leo Szilar studied the relation between entropy and information[13], although he was not right in his conclusions. In the 50's, Leon Brioullin used the results of Shannon to continue researching the link between entropy and information[13]. Since then, the link between physics and information has increased strongly with the Landauer principle[11][2] and after the holographic principle[8][18]. Also the concept of computation jump to physic when Zuse Conrad proposed that the universe could works as a computer [10].

Since the theory of computation and theory of information became disciplines many scientific areas have incorporated the ideas of information and computation, as : cognitive psychology, biology or neuroscience.

3 Information and computation are physical concepts

Most of computer scientists think that a Turing Machine is the formal definition of algorithm. Henceforth, what can't be defined by a Turing Machine is not computable and also there is not an algorithm to calculate it. This is a terrible error due to forget a model of computation is also defined on a domain. It is true that Turing Machines, recursive functions and λ-calculus has the same limit of computation, but all these models of computation are defined on the naturals. So, Turing Machine is the definition of algorithm in the domain of Naturals but it is not the definition of algorithm on over domains. What people should understand is there are not an absolute definition of algorithm but a relative definition of algorithm that depends of the domain where the computational process are being executed. At this point, one could think that an algorithm or computational process is a mathematical concept, but it is totally wrong. The computational limit is a feature of the universe, so Turing-computation, supercomputation or hypercomputation are possible

values for a feature of nature[1]. Henceforth, only through experiments we can know which is the value of nature for the limit of computation. This idea could be strange for some readers but it is the same case of physics in which one wants to know what kind of geometry has the space. So, one should want to know which the computational limit of the nature is. In theoretical physics, one can calculate how will be the universe if some elements of nature would have different values[5], in the same way one can calculate which functions would be calculated if the nature would let one or other computational process, and the computational process are let by the nature depends of what domain is isomorph to the universe. Henceforth, computation and information are no mathematical concepts but physical concepts and mathematics allow us to create different mathematical models of computation. None say a quark is a mathematical concept because there are several models of the particle; we select through experiments the model, which better describe nature. The definition of algorithm or the limit of computation must not be taken as mathematical concepts, we must do experiments to know which are the values for our universe. I suppose that in the concept of quark none think it is a mathematical concept because already was born in physics. However, the computational limit or algorithm were born in the mathematics and it is not easy forget that. Why mathematics let us create models and one fix with nature is a different and mysterious issue[22].

4 Information and computation are deep physical concepts

Now that I have already explained why computer scientists should think about computation and information as physical concepts I want to make think to physicists about how deep are these concepts in physics. Many physicists argument that the universe is computational due to the discreteness and others say that is not computational because it is continuous. The same problem of computer scientist again, both think that the definition of computation is absolute and not relative to the domain. I do not if it is due to in the market there are only digital computers and people have identified computers with digital but in the 60's there were commercial analog computers[9]. I will show now some definitions which must let see to the reader that concepts of information and computation are not fixed to the

[1]I use supercomputation as quantum computation with the limit of a Turing Machine but improving the complexities, and hypercomputation as the quantum computation which would break the limit of a Turing Machine

discreteness of the nature, they are definable on different domains.

The entropy for the discrete case

$$H(X) = -\sum_{i=1}^{n} p_i log_2 p_i$$

also there is a version for the continuous case

$$H(X) = -\int_{-\infty}^{\infty} f(x) log_2 f(x) dx$$

The mutual information in the discrete case

$$I(x_i, x_j) = log_2 \frac{p(x_i, y_j)}{p(x_i p(y_j}$$

also there is a version for the continuous case

$$I(X, Y) = \int_{-\infty}^{\infty} f(x, y) log_2 \frac{f(x, y))}{f_1(x) f_2(y)} dxdy$$

So, information does not imply discreteness. But, what about the concept of computation? In the case of computation it is a little long to develop mathematically here but there are models of computations on the domain of the reals reals[16][3].

5 A new epistemic scheme

In the last section, it has been justified why the concepts of information and computation are physical and deeper than one could think initially, but how important are them? At the present, information and computation are concepts derived inside the epistemic scheme of energy, but I consider them concepts deep enough to take them as fundamentals. So, I want to encourage and I want to propose that they could be used to create a new epistemic scheme that develop theories to understand the nature. The epistemic scheme of information is not affected by questions of continuity or discreteness of space and time[12][1][17], because where those data have effect is selecting among the theories of the epistemic scheme. The data could decide the theory must have a notion of continuous or discrete information but they do not say the epistemic scheme of information is wrong.

5.1 Epistemic schemes

Physics have had until now two famous epistemic schemes. The first was developed by Newton to explain mechanics; it was the epistemic scheme of force. All explanations buzzes around the concept of force in the epistemic scheme of force: how forces are generated and what the forces generate. Since Newton, step by step a new concept was creating, the concept of energy. After hundreds years, the concept of energy was well established and a new epistemic scheme emerged where the fundamental concept was energy. Some people consider energy as a concept more fundamental than the concept of force, but it is not exactly in that way, because we are talking about different epistemic scheme, it is more correct to think that the epistemic scheme of energy is more powerful than the epistemic scheme of force because in the epistemic scheme of force there is nothing more essential than the concept of force. In the epistemic schemes even space and time can be understood from the fundamental concepts of the epistemic schemes. For example classical space can be understood as follows:

A place x_1 is further from the origin than other x_2 if one needs more energy to go to x_1 than to x_2 from the origin.

Something similar could be done for classical time easily. An epistemic scheme, or an epistemic paradigm, is a new framework that contains a set of theories among which the scientist look for which better describe nature through the scientific method. As the history of physics illustrates very well, it is not only the creation of a new theory but also the creation of a new epistemic scheme that let us go further in our knowledge of nature.

5.2 The model of communication

The important issue is which concepts are fundamental in the epistemic scheme of information. My proposal uses the model of communication of information theory. For this reason, before my proposal I am going to present the model of communication. The simplest model of communication which one can have const of three elements.

- Source: It is the element which sent the information.
- Sink: It is the element where the information will arrive
- Channel of communication: It is the element through the information conveys from the source to the sink.

5.3 The epistemic scheme of information

Up until now, information and computation have been interpreted and studied from the point of view of the epistemic scheme of energy[14][15], but they could be thought as fundamental concepts from which we would explain the nature. Some theories which take these concepts as fundamentals have been proposed[7][6][10]. However, that theories propose same concrete values for the information and computation and I want to focus on the role of these concepts as fundamentals for an epistemic scheme. As it was mentioned above, an epistemic scheme is a framework for theories so we define the concepts without fix the values for the concepts.

Initially, one think that the epistemic scheme of information is plausible because we have the concepts of information and computation. Information can treat with the physical state. Computation allow to describe the process which alter the physical states. However, there is a problem which one find when is going to build an epistemic scheme of information, there is not a relation between the theory of information and the theory of computation[2]. Sometimes the relation between information and computation is established as a computer use information to transform information. Nevertheless, this explanation about relation between the computational theory and the information theory is weak, because computational theory treats about how to calculate and information theory treats about how to move information from one point to another. For that reason, I want to propose a most important relation between information and computation that has not been signaled and if it has being I have not news of it and I call Principle of equivalence of information processing.

Definition 1 (Principle of equivalence of information processing(PEIP):)**.** *For each computational process exist a transmission channel with which the sink get the same information what is obtained at the end of the computational process when the information sent by the source through the transmission channel is the same which is input for the computational process, and vice versa*

The PEIP is the fundamental element which I propose as base for the epistemic scheme of information. The PEIP unify both theories. Before, they seemed two different worlds however using the principle of equivalence we can say something so surprising as the difference between computational theory and information theory is that computational theory is interesting in channels which modify the information in concrete way and information theory is

[2]Exist the algorithmic information theory but I do not see how it could be use for a epistemic scheme of information in physics

interested in computational processes which no alter the initial information. The reader has not to forget this is not a mathematical statement but a physical statement because information and computation have been defined as physical concepts.

Using the PEIP want to propose how some physical concepts can be translated to the epistemic scheme of information.

- Time. While the time is considered another dimension where situate events, in the epistemic scheme of information the time would be interpreted as a information channel trough the state of the universe is being send. A channel of information is a iterative computational process where each iteration is doing advancing the symbol through the channel of information. In this case we can see which symbol is in each point of the channel.

- Space. Space can no be interpreted alone, it must contain something which let it to be interpreted as a symbol-message.

- Physical state, it is a symbol-message which can be in a point of the information channel.

- The vacuum energy. The vacuum energy would be seen as the noise on the information channel.

5.4 Processing and Storing information

The epistemic scheme of information determines that there are two elements in the nature.

- The information which contains the nature.

- The laws which determine how that information is processing.

So, a change to the epistemic scheme of information at the same time has relevance about how understand the own science due to it determines that there are two research process about nature.

- The process of knowing the laws to process and store information of the universe

- The process of knowing what information contains the objects of the universe

The main goal of science will be achieve a unification of the different natural sciences. All natural phenomena should be explained in the same framework. A very special feature of the epistemic scheme of information is that information and computation are scalable concepts. We can speak of the information in the atomic level or of information in the genetic code of a human being. Henceforth in every scale of nature one must do the research processes of the epistemic scheme of information. If it would be achieved in every level we would have a unification of sociology, psychology, biology, chemistry and physics. Actually, there are many researches using the concepts of information and computation to try explaining phenomena in all that fields, but a physical theory of the nature based in information and computation must be the fundamental pillar upon which the unification of science can be built.

5.5 Beyond the bit

If one reader would ask me about if there is a possibility of bit from it, I should have to say I do not know. If we really achieve to develop an epistemic scheme of information it would be the third scientific epistemic scheme in the history of the humanity. Henceforth, none can deny the possibility of a fourth epistemic scheme. Also as computer engineer I know behind a bit there is a structure, so it could there be a more fundamental concepts that information and computation. However, if he asked me whether I have any idea for it, I would be very frank: no, I have not got any idea.

6 Conclusions

I have discussed the concepts of information and computation and it has being showed that they are not link to concrete values of nature but concepts to understand nature in a new way. It is really important to see that a new epistemic scheme is not a new theory but a framework were define theories. So, the concepts of information and computation are no the keys of a new theory of physics but they are the keys of a new kind of theories of physics, of a new epistemic scheme. Henceforth we are living a amazing moment in science the change of an epistemic scheme to another epistemic scheme. Wether information is discrete or continuous, wether computation is digital or analog are issues which must be researched to find a theory among all the possible theories of the epistemic scheme of information which describe nature, but information does not imply discreteness nor computation imply the nature is not analog.

From my point of view the big problem to create an epistemic scheme of information was the isolation between the theory of computation and the theory of information. While both aspect which describe every theory are needed to describe the physical reality there where no a clear way of connect conceptually both theories. I have proposed the PEIP as that link. A epistemic scheme of information based in the PEIP is a really powerful framework. For example one can easily think the next question:

Could be another symbol being transmitted by the channel of time?

The reader can try to translate the same question to the epistemic scheme of force and energy, and he will see it is not easy to express.

Also another very important issue is that the epistemic scheme of information not only can be applied to physics but also the rest of natural sciences. I see that the epistemic scheme of information could be a framework where all natural sciences could be unified. This is one of the great advantages of the epistemic scheme of information against the epistemic scheme of energy because the concepts of information and computation are scalable.

The epistemic scheme of information it is no only a hope to go further in physics but also and epistemic scheme to achieve one of the biggest challenges of the humans, the unification of science.

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