Chapter 16
Computational Space, Time and Quantum Mechanics

Michael Nicolaidis
TIMA Laboratory (CNRS, Grenoble INP, UJF), France

ABSTRACT

The author starts this article by introducing an ultimate limit of knowledge: as observers that are part of the universe we have no access on information concerning the fundamental nature of the elementary entities (particles) composing the universe but only on information concerning their behaviour. Then, th authors use this limit to develop a vision of the universe in which the behaviour of particles is the result of a computation-like process (not in the restricted sense of Turing machine) performed by meta-objects and in which space and time are also engendered by this computation. In this vision, the structure of space-time (e.g. Galilean, Lorentzian, ...) is determined by the form of the laws of interactions, important philosophical questions related with the space-time structure of special relativity are resolved, the contradiction between the non-locality of quantum systems and the reversal of the temporal order of events (encountered in special relativity when we change inertial frames) is conciliated, and the "paradoxes" related with the "strange" behaviour of quantum systems (non-determinism, quantum superposition, non-locality) are resolved.

INTRODUCTION

In this article we present a computational vision of the universe aimed at resolving the paradoxes of modern physics. The computational universe idea introduced by Konrad Zuse (Zuse, 1969, Zuse, 1970) and further developed by Jurgen Schmidhuber (Schmidhuber, 1997), considers that the universe can be engendered by a computation. However, to be convincing, such an approach should explain:

1. Why we perceive a real space and time in our every-days life if the world is the result of a computation?

DOI: 10.4018/978-1-61692-014-2.ch016

2. How space and time could emerge from a computation and why we could not distinguish them from a space and a time that would be primary ingredients of the universe?
3. How a relativistic 4D space-time could emerge in a computational universe?
4. What could be a computational model of quantum systems?

Since several millennia we consider that our universe is composed of objects immersed in a veritable space and evolving with the flow of a veritable time (merged in space-time according to relativity). Thus, in this vision, objects, space and time are primary ingredients of the universe. But, is this vision compatible with the behaviour of our world as it is described by modern physics? Several questions concerning the non-determinism, the state superposition and the non-locality of quantum systems, and the structure of space-time described by special relativity, seem to indicate the opposite.

Non-locality of quantum systems raises an important philosophical question concerning the nature of space. In entangled particles, a measurement performed on the one impacts instantaneously the state of the other, whatever is their distance. But, the essence of space is to separate objects. The extent of this separation is referred as distance. The essence of this separation is to take time for two distant objects to interact. The more distant are two objects the more time they need to interact. So, the instantaneous "communication" between distant entangled particles annihilates the very essence of a veritable space, that is, the existence of a veritable separation between distant objects.

Quantum superposition also raises important philosophical questions. What exactly this superposition means? For instance what is this state where an object can be simultaneously on infinite number of space positions?

The nature of space-time described by special relativity raises also several philosophical questions. We imagine time to flow from past to future through the present. But in relativity there is not clear distinction between past, present, and future. This question raises a fundamental dilemma, as expressed with clarity in the foundation text of the International Conference on the Nature and Ontology of Spacetime (Space-Time conference web site, 2004):

"A 3D world requires not only a relativization of existence, but also a pre-relativistic division of events into past, present, and future. Therefore, it appears that such a world view may not be consistent with relativity. However, the alternative view – reality is a 4D world with time entirely given as the fourth dimension – implies that there is (1) no objective time flow (since all events of spacetime are equally existent), (2) absolute determinism (at the macro scale), and (3) no free will. It is precisely these consequences of the 4D world view that make most physicists and philosophers agree that a world view leading to such implications must be undoubtedly wrong. But so far, after so many years of debate, no one has succeeded in formulating a view that avoids the above dilemma and is compatible with relativity."

Yet another quote (Lusanna, Pauri, 2006) reveals the importance of this question for the philosophy of science: "the conventional nature of the definition of distant simultaneity that follows from the analysis of the basic structure of causal influences in SR seems to conflict with every possible notion of /3-dimensional reality / of objects and processes which stands at the basis of our phenomenological experience since it entails that no observer- and frame-independent notions of simultaneity and instantaneous 3-space be possible. There is, therefore, a deep contrast between the formal inter-subjective unification of space and time in the scientific relativistic image, on the one hand, and the ontological diversity of time and space within the subjectivity of experience, on the other. This appears to be the most

Related Content