Article

Quanta, Computations, and Extended Everett Concept

Alexander D. Panov

ABSTRACT

In the Extended Everett Concept, proposed by M.B. Mensky, is assumed, that numerous quantum alternatives that are included in a superposition of many-world Everett universe, are available for the analysis to consciousness, being in some threshold states like sleep or meditation. Since this possibility is in the direct contradiction to no-cloning theorem of quantum mechanics, the question arises how this can be. The proposed solution is based on an analogy with the 'miracle of cloning of states', which can be implemented for an observer living in the quantum world, simulated on a classical computer. The basis of the hypothesis is the algorithmic solvability of the quantum theory.

Key Words: Extended Everett Concept, many-world interpretation of quantum mechanics, quantum alternatives, no-cloning theorem, computability

NeuroQuantology 2013; 1: 116-122

1. Introduction

Many world interpretation of quantum mechanics and Extended Everett Concept

The Many-worlds interpretation of quantum mechanics (Everett, 1957; Everett *et al.*, 1973) admits many different shades of interpretation, but perhaps one of the most radical extensions of the concept is the Extended Everett Concept (ECC), proposed and developed over the recent years by M. B. Mensky (Menskii 2005; Mensky, 2007a; 2007b; 2007c; 2009; 2011; 2012). The role of consciousness of the observer is treated in a special way in the concept of ECC. The essence of the concept of ECC can be represented by three main items:

1. The question of how consciousness selects one of many possible quantum alternatives included in the coherent superposition of the Everett's quantum universe, the ECC concept provides a very radical answer: consciousness *is* the separation of classic alternatives between each other (that results in that if one of these alternatives is perceived, the other are not perceived). Thus, the question about the selection of an alternative is a tautological question.

2. From the item 1, it follows that the absence of waking consciousness means no separation of quantum alternatives, and therefore one can not exclude that all quantum alternatives are available for analysis simultaneously if consciousness is in a threshold state such as sleep or meditation.

3. It is possible that the mind can be active in the selection of the preferred alternative for him, using information on all quantum multiverse alternatives that are available to consciousness, in accordance with the item 2.

In this article, the item 2 of the ECC concept is the most interesting for us. The question is, how the information about the quantum alternatives, representing the quantum universe, may become available to consciousness, without destroying the overall coherent quantum state of the universe? What, in principle, could be a mechanism to access these quantum alternatives?

Corresponding author: Alexander D. Panov
Address: Skobeltsyn Institite of Nuclear Physics, Moscow State Unuversity, Russian Federation.
✉ panovenator@gmail.com

Received Feb 2, 2013. Accepted March 14, 2013.
*e*ISSN 1303-5150

The problem is that the availability of such information on the quantum alternatives is in a direct contradiction with the no-cloning theorem of quantum states in quantum mechanics (Zurek, 1982; Dieks, 1982). Indeed, in the ECC concept it comes to getting information about the quantum state (the state of Everett's quantum universe) without destroying this state. If quantum mechanics is allowed getting of such information, at least for the most simple states like states of two-level systems, then such information could be stored and, subsequently, it would be possible to create an unlimited number of copies of a quantum state with the use of this information. It is directly prohibited by the no-cloning theorem. What can there be a mechanism to access of consciousness to the quantum alternatives of the many-world Everett's universe, if quantum mechanics expressly prohibits such access? One of the possibilities is related to the concept of computability of the quantum theory.

2. Computability of the quantum theory

Among the various computational problems there exist algorithmically solvable and algorithmically unsolvable problems. There are many clearly stated but algorithmically unsolvable problems. For example, Yuri Matiysevich proved the algorithmic unsolvability of general Diophantine equations (the Hilbert's Tenth Problem) (Matiysevich, 1993), many other algorithmically unsolvable problems are also known. It is important that the mathematical problems that arise in the context of the quantum theory, do not belong to the category of algorithmically unsolvable problems. All these problems are algorithmically solvable, so the quantum theory could be called a computable theory.

Indeed, the states of quantum systems are represented by vectors in a Hilbert space (more precisely – projectors to these vectors). A vector in a Hilbert space is well understood object, which in principle can be represented in a computer with any desired accuracy, even if the Hilbert space of a quantum system is infinite-dimensional. In principle, the situation is very similar to the representation of ordinary continuous classical fields in the computer with any required precision.

An evolution of quatum states in the quantum theory is a unitary transformation of the states – the vectors of the Hilbert space. From a formal point of view, a unitary transformation is either a multiplication of a unitary matrix representing the transformation to a column vector representing the state of the system, or a result of the solution of an initial Cauchy problem for a system of linear differential equations. Nothing is impossible in these operations for a usual computer.

Finally, the third and final component of the quantum theory is a quantum measurement. A measurement is characterized by the probabilities of obtaining at the output of the measuring procedures of various values of the observed variables. The probabilities themselves are determined by the Born - von Neumann projection postulate. To calculate the probabilities one does not need to calculate anything more complex than a scalar product of vectors in a Hilbert space. This, again, is an algorithmic procedure which is easy to perform on a computer. These probabilities can not only be calculated, but, if necessary, they even could be simulated with the use of a random number generators to simulate the probabilistic behavior of the measurement output.

Thus, formally speaking, all the calculations necessary to predict the behavior of quantum systems, can be carried out with the use of an ordinary classical computer – a finite state machine. Moreover, we can not only "predict" the behavior of a quantum system, but also to simulate the development of a quantum system in time step-by-step with any disired precision. Philosophically speaking, the quantum reality allows a comprehensive view in classical computing systems – computers. More precisely, we can talk about isomorphism of fragments of quantum reality and computer models of these fragments of reality. Thus, the quantum dynamics simulated in a computer looks as some emergent behavior of more "fundamental" pure classical system – a classical finite state machine programmed to solve the quantum problem. This fact proves the theoretical possibility that there is some "hidden" classical dynamics in the basis of the quantum behavior, and this classical dynamics is reminiscent a computational process. We emphasize that this conclusion is not contrary to Bell's theorem about hidden *local* variables (Bell, 1966; 1987), because the structure of the finite state machine does not satisfy the requirements of the locality, which are assumed in the derivation of Bell's inequalities.

3. The miracle of cloning in a simulated quantum reality

The possibility of an isomorphism of fragments of quantum reality and the corresponding classical computer models can be formulated in the form of a paradox. Suppose that one could accurately simulate such a large fragment of quantum reality in a classical computer that it may include a consciousness observer. If the simulation is accurate enough, such a virtual observer can not see that he lives in the virtual rather than a real world. But now we, in the computer simulation, begin to make copies of certain quantum states of the system, which is able to explore the virtual observer. For us (“programmers”) it is not a problem, since the computer model of quantum states is just a classic chain of bits. Observer, however, is familiar with the no-cloning theorem, and it has to interpret the “clone phenomenon” occurring in his eyes, as a miracle.

The paradox can be further enhanced. For such a quantum cloning an active intervention of the “programmer” is not required. Simulation program itself can have such routines that, from time to time, implement cloning some simulated quantum states, depending on some conditions. Such applications may be implemented, as well, as some parallel computational processes, which track the progress of the main simulation of the quantum dynamics, and sometimes interfere with this process by cloning quantum states. Such parallelism does not violate the structure of the system, as the structure of the finite state machine. Moreover, this additional cloning subsystem can be programmed so that it will keep track of the state of the consciousness of the virtual observer, and to clone quatum states in response to his “request”. Nothing is impossible in such a track, because, in the computer implementation, the consciousness of the observer is nothing more than a chain of bits that may be read out. If the observer exhibits a strong enough desire (above a certain threshold) to make the cloning of some of the quantum state, the subsystem can carry out the cloning. The observer subjectively will have an impression that the miracle of cloning occurs in response to his “prayer”.

The solution to this paradox can be found in the following direction. In fact, it is fundamentally impossible to create quite plausible model of a fragment of quantum reality, including the observer, using a *classical* computer, because of the excessively high dimensional quantum problem. A suitable computer simply can not be placed inside the cosmological event horizon, and this restriction is absolutely fundamental. Here is a simple example. To use the Shor's quantum algorithm (Shor, 1997) to decompose into prime factors of 1000-digit binary number (a common task for future quantum computers), a quantum computer requires memory only a few thousand quantum cells – qubits. That is, a computer will consist of several thousand two-level quantum systems, and the whole system will not be too complicated quantum system. At the same time, a classical computer requires about 2^{1000} of complex numbers to represent the state of the quantum computer memory – and this is many orders of magnitude greater than the amount of information that can be stored in all ordinary matter in the visible universe (~10^{90} bits (Gurevich, 2012). Therefore, the actual classical computer simulators of quantum computing – which actually exist (Julia-Diaz, 2005) – can only work with a very low-dimensional systems. Thus, it is fundamentally impossible to simulate with a classical computer even relatively simple quantum systems, like 1000-qubit quantum computer (actually, even 100-qubit quantum computer). Especially, it is impossible to simulate an observer in the quantum world, which is a resolution of the formulated paradox.

4. Classical combinatorial information as a fundamental level of reality

Despite the fact that it is fundamentally impossible to carry out a complete simulation of a rather complex quantum system on a classical computer, the conclusion that quantum behavior can in principle be purely emergent and may include in the basis of it some classical dynamics, is very important. A possibility to simulate simple quantum systems by means of classical computers is a clear proof of this fact. This situation is by no means trivial. If the quantum physics contained the need to address something like solution of Diophantine equations of general form, such evidence would not be valid.

We now return to the Everett's quantum multiverse which contains, as we know, conscious observers among other things. In light of the above, the idea that all such quantum multiverse can be a simulation in a classical supercomputer must seem completely absurd, since the scale of such a supercomputer would have to exceed any time-space areas that can provide the Universe on an unimaginable number of orders, even in the form of the Multiverse of the inflationary cosmology. However, let's not jump to conclusions.

Any classical computers implement some information processing. Under the information we refers here, roughly speaking, simply an ordered chain of bits. It is assumed that there must exist some material information-carrying medium, states of which encode these bits.[2] This corresponds to the definition of the *physical* information (Gurevich, 2012): “Information is heterogeneity, stable for some definite time”. It is suggested in this definition, that there exists some substrate on which the inhomogeneities one can speak. This material information-carrying medium, substrate, is represented by some physical objects in the ordinary sense, which are located in real space-time, inevitably occupy a finite volume and has a finite mass-energy, causing excessively large amounts of information necessary for the representation of complex quantum systems can not be placed in any available (even in principle) amount of space.

However, one can imagine an information of completely different type. We have in mind a purely combinatorial structure that exists “by itself”, on a very fundamental level, without being embedded into any space-time, without any information-carrying medium. Concepts such as mass and energy are completely irrelevant to such a fundamental entity. This information is not encoded by states of some material bodies, and it is appropriate to call it as the *fundamental combinatorial information*.

This information is somewhat reminiscent of the combinatorial information encoding objects in the world of mathematics. For example, in the world of mathematics there is objectively the infinite decimal expansion of π number. Not all of the digits of the expansion are already known, but they can be calculated, and whoever calculate and whatever method he may do – the result is the same. These numbers exist objectively. However, if we try to imagine the information relevant to all this expansion, being represented physically in some real physical medium, we are immediately confronted with the problem of the cosmological horizon of computability (see the end of the previous section). So, where are there all these numbers? They exist by a purely combinatorial fundamental way, but, still, they exist quite objectively.

The information of fundamental mathematics, however, is only not quite accurate analogy of the fundamental combinatorial information in question. Common feature in fundamental combinatorial information and information of mathematical objects is that they, for their (objective) existence, require no space and no energy. Common feature is also the fact that both types of information are in a sense, classical. That is, in the sense, that there are ways to “read” the information without corruption of it. For example, studying the structure of the expansion of π, we have no influence on the structure of this expansion. Hereinafter we will use the abbreviation: CFCI (Classical Fundamental Combinatorial Information). The *difference* between the information of mathematics and CFCI is that CFCI can encode all the real quantum dynamics of our material world, while the fundamental mathematical objects, such as the π number, is not directly related to any real dynamics. We can say that the level of CFCI is something intermediate between the level of purely mathematical objects and the level of the real physical world. Or, what is even more interesting, CFCI, perhaps, is in some sense prior to both of them, being for them a common root.

Now, nothing prevents us to assume that the Everett's quantum many-world universe is only emergent structure in relation to the

---

[2] In the more general case, the information can be encoded by a more complex way, for example, by the levels of the magnetization in the magnetic recording of analog sound, but these details do not play a role in our consideration. Ultimately, these analog values can easily be re-converted to a digital record from any desired accuracy, and that was actually done in the development of digital audio recording techniques.

fundamental classical dynamics of CFCI just as quantum dynamics appears in an emergent way in a simulation on a classical computer. Indeed, first, we do know from the computability of the quantum theory that the quantum behavior can be emergent with respect to classical processes of more fundamental level (may be the result of a classical simulation). Second, despite the unimaginably vast amounts of CFCI needed to represent the state of the quantum universe of Everett, along with all the conscious observers in it, the question of "location" of the information is no longer relevant, as this information is a purely combinatorial structure and does not require any space and energy to organize.

Entire quantum world, all of Everett's quantum universe, in this model are in a certain sense, "Matrix" in relation to the classical dynamics of CFCI. But, however, it is not necessary to think that Someone built for us that "universal" computer, that implements this classical simulation of the quantum universe. This maybe just the nature of things. Moreover, this classical fundamental process does not have to be similar to a computer program in the literal sense. The existence of a real classical software simulators for quantum processes only proves that quantum behavior can be *some* emergent manifestation of a classical dynamics, nothing more.

5. Prevision of quantum alternatives by consciousness in the context of classical combinatorial information

In the classical model of the CFCI it is clear what mechanism might be of getting by a mind the knowledge about the quantum alternatives of Everett's multiverse, without destroying the quantum coherence of the alternatives, and to bypass the prohibition of the no-cloning theorem. This mechanism may be quite similar to the mechanism of the "miracle of cloning" in a simulated quantum reality, which was described in the Section 3. It is enough to assume that in the threshold states like sleep or meditation, a consciousness allows access to the degrees of freedom of CFCI, which encodes the quantum dynamics of the real world. By the classical nature of the CFCI information, it (in principle) can be "read out" by a consciousness without dectroying this information, in complete analogy with the way the chain of bits can be read out from a classical computer which is simulating a quantum problem. In the future, the information obtained can be used by the mind (explicitly or unconsciously) to their advantage. Of course, this process violates not only unitary, but even ordinary linearity of a quantum behavior. However, as M. B. Mensky proved in his works (Menskii, 2005; Mensky, 2007a; 2007b; 2007c; 2009; 2011; 2012), the receipt of such information by each individual consciousness is not in the sense of Popper's falsifiability, so this non-unitary and non-linearity does not contradict the conventional unitary and linear dynamics of the "laboratory" quantum mechanics.

One note about how consciousness can get information about the future is still required, since it is clear from the above mechanism that exactly the current state of the multiverse may be "read" without perturbation of this state. The subtlety here is what exactly is to be understood by the current state of the multiverse in the context of Everett's many-worlds interpretation.

If we would like to be completely consistent, it should be clearly understood that the many-worlds interpretation of Everett is in fact a quantum cosmology. If we discuss the quantum superposition of worlds, we come to the cosmological level of consideration, and this level is quantum, by construction. That is, we find ourselves in quantum cosmology. This has been understood for a long time (Tipler, 1986). Meanwhile, at a fundamental level, quantum cosmology provides a timeless picture of the quantum universe (DeWitt, 1967; Hartle and Hawking, 1983). The state of the universe is described by a superposition of space-like layers, where each of layer has an amplitude with which it belongs to this superposition, but there is no time order in this set of spatial layers. The time appears by an effective way in the later stages of the interpretation of such a timeless pattern, in the form of correlations of certain degrees of freedom, which are present in the wave function of the universe as its arguments. Some degree of freedom then, by agreement, one can declare a clock, and for other degrees of freedom, this "clock" will show the time due correlations. Thus, at a fundamental level of quantum cosmology, there exists no "current" state of the quantum universe, since there is no concept of time and there is no dynamical evolution in the time. Meanwhile, the picture of the quantum superposition of spatial layers in quantum cosmology – is exactly the quantum many-world picture of the universe in terms of Everett. In it, each such layer is an “instant” state of the entire classical universe. The picture of the universe in quantum cosmology is, in fact, the Everett's many-world picture. The splitting of the universe to the branches by measurements of quantum states, which is located in the center of attention in the context of the many-worlds interpretation, corresponds to a tree-like structure of the static timeless quantum universe in the exact picture of quantum cosmology.

CFCI information, by its very fundamental sense, must encode the states of quantum cosmology. That is, the space-like layers and the corresponding amplitudes should have emergent origin in CFCI. Incidentally, this implies that the very CFCI should have a timeless nature, so the classical process that underlies the entire quantum dynamics, is not really a process in the usual sense of the word. This is also a timeless phenomenon. Therefore, if the mind has access to the level of CFCI, it does not have access to the “current” state of the quantum universe, but to a very timeless picture, in other words – to all states of the universe at all times. Therefore, the ability of consciousness to the prediction of the future, if the access to CFCI really is possible, looks completely natural.

Note that it would be wrong to conclude that if the mind is capable of prevision, then, in the same way, by obtaining a timeless CFCI, it must necessarily be capable of “retrovision” as well. The ability to predict is a useful to an organism for survival, so it must be maintained by the natural selection, and may just be *the* result of the natural selection. On the contrary, the ability to “retrovision” does provide nothing particularly useful for an organism, therefore, natural selection will not support it. This also applies to some other forms of “quantum clairvoyance”. However, this does not mean that such phenomena do not exist at all, at least as a rare exception.

“An argument from evolution” allows us to understand also one additional important thing. It seems that the mechanism of connection of consciousness with the level of CFCI must be incredibly complicated and unclear. What could cause or design such a mechanism, if laboratory tests so far do not give any sign of the existence of a communication between the quantum level of reality and the level of reality of CFCI? But evolution gives us examples of other incredibly complicated and sophisticated systems, the complexity and perfection of which is far beyond the limits of any modern understanding. For example, how the genetic code, which contains just a few gigabytes of data, which encode not so large number of proteins, is transformed into a sophisticated phenotype of an adult organism? Where and how “stored” the program of this transformation? And what is the origin of the genetic code itself? Creation by the evolution of a communication between the quantum levels of reality and the levels of CFCI does not seem absolutely impossible against the background of these “evolutionary miracles”.

The proposed picture may seem very surprising, implausible or even completely insane. Maybe, the capability of consciousness to come into contact with fundamental combinatorial degrees of freedom, and to store the information, contained in it, in mental images, is the especially surprising item. However, from a purely logical point of view, there is nothing impossible in it. And all of this is due to the undoubted fact that the quantum mechanics is a computable theory.

Acknowledgement

I am grateful to M.B. Mensky for discussion and comments on the article.

References

Everett H. Relative stat formulation of quantum mechanics. Rev of Moder Physics 1957; 29: 454–462.

Everett H, Wheeler JA, DeWitt BS, Cooper LN, Vechten van D, Graham N. The Many-World Interpretation of Quantum Mechanics. Princeton Univ. Press, Princeton, New Jersey, 1973.

Menskii MB. Concept of consciousness in the context of quantum mechanics. Physics Uspekhi 2005; 48: 389–409.

Mensky MB. Reality in quantum mechanics, extended everett concept, and consciousness. Optics and Spectroscopy 2007a; 103: 461–467.

Mensky MB. Postcorrection and mathematical model of life in extended Everett's concept. Eprint: arXiv:0712.3609. 2007b.

Mensky MB. Quantum features of consciousness, computers and brain. eprint: arXiv:0910.4300. 2009.

Mensky MB. Postcorrection and mathematical model of life in extended Everett’s concept. NeuroQuantology 2007c; 5: 363-376.

Mensky MB. Mathematical models of subjective preferences in quantum concept of consciousness. NeuroQuantology 2011; 9: 614-620.

Mensky MB. Synchronicities of Carl Jung Interpreted in Quantum Concept of Consciousness. NeuroQuantology 2012; 10: 468-481.

Zurek W. A single quantum cannot be cloned. Nature 1982; 299: 802–803.

Dieks D. Communication by EPR devices. Phys Lett A 1982; 92: 271–272.

Matiysevich Y. Hilbert's Tenth Problem. The MIT Press, Cambridge, London, 1993.

Bell JS. On the problem of hidden variables in quantum mechanics. Rev Mod Phys. 1966; 38: 447.

Bell JS. Speakable and unspeakable in quantum mechanics. Cambridge University Press, New Yorkü, 1987.

Shor P. Polynomial-time algorithms for prime factorization and discrete logarithms on a quantum computer. SIAM Jour Comp 1997; 26: 1484–1509.

Gurevich I. Some works on physical informatics. Lambert Academic Publishing, 2012.

Juliá-Díaz B, Burdis JM, and Tabakin F. Qdensity – a Mathematica quantum computer simulation. eprint: arXiv:quant-ph/0508101. 2005.

Tipler FJ. The many-world interpretation of quantum mechanics in quantum cosmology. In Penrose R and Isham CJ, editors, Quantum concepts in space and time. Clarendon press, Oxford, 1986; pages 204–214.

DeWitt BS. Quantum theory of gravity. I. The canonical theory. Phys Rev 1967; 160: 1113–1148.

Hartle JB and Hawking SW. Wave function of the universe. Phys Rev D 1983; 28: 2960–2965.