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First Report on Quantum Computational Logic in Biological Networks

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Abstract

It is argued in this paper that biological networks may behave as quantum computers. Thus biological networks process information both in classical and quantum fashion. The quantum computational logic in biological networks is discussed. The logic of the quantum information processing can be described by L_q which differs from classical logic in the sense that quantum truth is probabilistic and many valued (fuzzy). The metalanguage of L_q is QML (Quantum metalanguage). It is also emphasized that in biological networks the information is processed by a system which is not just quantum but quantum computational.

Keywords: Networks, information processing, metalanguage, quantum, computing

Report on Quantum Computational Logic in Biological Networks

The biological networks compute. Their computer language consists of laws of physics and their biological and chemical consequences. The question that needs to be addressed is that whether biological networks are nothing more than a digital computer. The answer is probably No. The problem with identifying the biological networks as a classical digital computer is that the biological networks are apparently more computationally powerful. “Two computing machines have the same computational power if each can simulate the other efficiently” [1]. A conventional digital computer seems unable to simulate the biological networks efficiently. The problem with such simulations is though they are possible, they are actually inefficient. The biological networks are basically quantum mechanical and it is difficult for conventional digital computers to simulate quantum mechanical systems. It has been estimated that in order to simulate a tiny piece of matter consisting, for example, of a few hundred atoms for a fraction of second, a conventional computer would need more memory than the total number of atoms in the universe and would take more time to complete the task than the current age of the universe. Even the most primitive biological networks are more than 100 atoms. Thus the conventional computers would be inefficient in simulating even the simplest of biological networks. Therefore it follows that computational power of conventional digital computers is much less than that of biological networks. Though classical computers can be useful for capturing certain aspects of biological networks, there is no known way for conventional digital computers to perform a full dynamical simulation of biological networks without using practically unavailable vast amount of resources. Seth Lloyd has shown that quantum computers can simulate any system that obeys the known laws of physics in a straightforward and efficient way. The principle of simulation is as follows: First the state of every piece of a quantum system such as atom electron etc. is mapped on to the state of some small set of qubits known as quantum register. Since the register is itself quantum mechanical, it is capable of storing the quantum information contained in the original system on just a few qubits. The natural dynamics of the quantum system can be simulated using simple quantum logic operations which are -interactions between quantum bits. These arguments are extension of the arguments originally proposed by Seth Lloyd for universe to biological networks [1].

Thus the biological networks possibly employ both the classical information processing and quantum information processing. The logic of quantum information processing by the biochemical pathways is coextensive with the logic of classical information processing. The logic of the quantum information processing can be described by Lq, the logic of quantum information [2]. In Lq propositions are configured in qubits, (quantum analogue of classical bits) which are linear superposition of classical bits. Lq differs from the classical logic in the sense that the classical truth is single valued and deterministic while quantum truth is probabilistic and many valued (fuzzy). The metalanguage of Lq is a quantum metalanguage (QML) [2]. In this paper we will use physical interpretations of assertions in QML as field states configured by a dissipative quantum field theory (DQFT). The metalinguistic of information processing by biological networks should be well modelled by QML (in conjunction with classical language notation).

Pessa and Zizzi have proposed that by employing a dissipative thermofield elaboration of QFT (DQFT) based on a doubling mechanism [3], it is possible to obtain a generalization of quantum theory which considers typically dynamical processes of the biological world. An important question is what definable kind of logic can be used for biological networks. It was once believed that for a classical physicist and a quantum physicist, classical logic and quantum logic are enough respectively. However quantum information is processed by a system which is not just a quantum system, but is a ***computational quantum system***. Thus besides quantum features, computational features should be taken into account by the associated logic. It is notable that quantum computational logics proposed by [4] have only semantics but no deductive calculus. Zizzi has introduced quantum computational logic comprising both semantics and syntax. It is imperative that the physical interpretation of quantum logical coherence should consider concepts of quantum coherence both in non-relativistic quantum mechanics (QM) and relativistic quantum field theory (QFT) [2].

In relativistic quantum field theory coherent states are eigen states of the annihilation operator whereas Quantum coherence in non-relativistic quantum mechanics is a property of pure states, whose linear superposition is also a pure state. It has been suggested [5] that Quantum metalanguage must be interpreted in QFT, whereas Quantum object language(QOL) containing quantum coherent propositions can be interpreted in non-relativistic quantum mechanics. QML can be envisaged as a quantum control on the quantum robot [6].

Conceptually reality grows from the discipline of ontology. However the concept of reality is very different from the perspective of physicist (classical and quantum) and a mathematical logician (particularly a constructivist), for a physicist, the real is measurable. In quantum physics, a measurable physical quantity is described by a hermitian operator. For a classical logician, in most of the cases truth and reality are the same. This correlation was stated by [7] in his semantic theory of truth.

For a constructivist logician, what is true is what can be proven. Constructivist logics in general are very weak and are therefore not constrained by Goedel's theorems (particularly Goedel's first incompleteness theorem). In quantum logic [8] a logical entity bearing a truth value, i.e. a proposition, corresponds to an observable (a projector). The quantum measurement is performed by a projector producing an event with a specific probability. In this version of quantum logic, there is a tight relationship between classical reality and the truth which is coextensive with the "event". Therefore, though the standard approach fits into the context of quantum logic, its concept of truth is classical; in other words, access to the truth occurs outside the quantum system. This is somewhat different from the semantic content, which is the classical output of the quantum measurement.

In the "quantum computational" logics [4] the quantum superposed state plays the role of single atomic proposition. Thus quantum information encoded by a qubit can detect the semantic content of proposition. In such logics the one to one correspondence between the proposition and the corresponding internal physical truth of the quantum system is lost.

Generally the term "metalanguage" which by convention is denoted by M, means a language which "talks" about another language, an object language denoted as L. The role played by M is very important in the context of biological networks since it describes the control system of a given network. It is notable, however, that in the case of a quantum system, the action of metalanguage, M (acting as quantum control) cannot be performed through the usual projective measurements since these would destroy typical quantum superposition. Thus one should perform the so called "weak measurements" [9] which permit measurement without disturbing the superpositions of the quantum system. Weak measurements correspond to a quantum state called the "Generalized Coherent State" (GCS) [10] which is generalization of the "coherent state" [11] which refers to a special type of quantum state referring to a single resonant mode of light. It should be noted that that coherent states are most classical among quantum states and describe maximum degree of phase correlated coherence.

The meta-logical description of GCS requires a Quantum Meta Language (QML) which controls the quantum logic, Lq [2]. The Lq is founded upon some species of constructivist logic like Basic Logic (BL) [12] and has in addition its own typically quantum features. For instance, the truth values emerging from the proposition of Lq are both probabilistic and fuzzy. There is also a logical connective namely that of quantum superposition, which is the quantum analogue of classical "and". Assertions originating in the new QML are labelled by number called the assertion degree which is physically described as probability amplitude. GCS is described as an ensemble of assertions having the same assertion degree [13].

It has been proposed in this paper that biological networks may behave as quantum computers and process the information in both classical and quantum fashion. The quantum information has been discussed in terms of Lq-logic of the quantum system and the quantum meta language (QML).

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