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Information Processing and Quantum Computation in Brain Microtubules

P. K. Sethy[1], S. Sinha[2]
[1]Department of Physics, Kirori Mal College, University of Delhi, Delhi, India
[2]School of Natural Sciences, University of California, Merced, CA, USA

ABSTRACT

In this paper, we attempt to understand the complex processes using the quantum computing techniques in the multidimensional universe having observable super-gravity effects in general, brain in specific using a simple quantum model of mind. Brain process the information through the neurons. The microtubules being an integral part of the neurons do perform the computation in the brain and also help in the transfer of information. We discuss the implications of assuming that consciousness is generated by the sub-neuronal process. The electric signal processing in different communication channels is discussed from a different perspective. We discuss the implications by assuming that the consciousness is generated by the microtubules as sub-neuronal processors.

Keywords : Neuron, Microtubules, Entanglement, Cytoskeleton.

I. INTRODUCTION

The processes that occur around us in daily life is well described by classical physics. The classical physics has certain limitation and thus could not explain some observed phenomena. A probabilistic mechanics was formulated to explain such phenomena i.e. the birth of quantum mechanics. Imagine you are observing a bank robbery. The bank robber is pointing a gun at the terrified teller. By looking at the teller you can tell whether the gun has gone off or not. If the teller is alive and unharmed, you can be sure the gun has not fired. The death of the teller would confirm that the gun has fired. This is elementary detective work. Otherwise one can say that by examining the state of the gun whether it has fired or not, one can conclude the state of the teller I.e. either the teller is alive or dead. Therefore, one can safely infer from the above that there exists a direct correlation between the states of the teller and the gun. 'The state of the teller implies whether 'gun is fired or not-fired. We assume that the robber only shoots to kill and he never misses. Such states and the correlation among them is best described by Schrodinger's cat experiment. Imagine an atom which might undergo a radioactive decay in a certain time, or it might not. We might expect that with respect to the decay, there are only two possible states here: 'decayed', and 'not decayed', just as we had two states, 'fired' and 'not fired' for the gun or 'alive' and 'dead' for the teller. However, in the quantum mechanical world, it is also possible for the atom to be in a combined state 'decayed-not decayed' in which it is neither one nor the other but somewhere in between. The combined state is obtained through the superposition of the two probable states. This is a very peculiar and unique feature of quantum mechanics whose counterpart is not found in classical mechanics. There exists a strong correlation among the probable/possible states. Quantum mechanically there are more correlations between the atoms than we would expect classically. This kind of correlation in quantum world is called 'entanglement' Schrodinger having realized the surprising aspect of the correlation, coined this term 'Entanglement' which was earlier known in German as Verschrankung'. It is so surprising and strange to imagine that the condition for gun firing is determined by the atom not the robber. Lets say, if the decay of atom initiates a trigger which eventually results in the gun firing. If the atom doesn't decay, then the gun would not fire. But what does it mean if the atom is in the superposition state 'decayed-not decayed'? Then can it be correlated to the gun in a superposition state 'fired-not fired'? And what about the poor teller, who is now dead and alive at the same time? The problem is that in the everyday world we are not used to seeing anything like a 'dead-live' cat, or a 'dead-live' teller, but in principle, if we expect quantum mechanics to be able to explain all such strange states. Where does the strange quantum world stop and the ordinary classical world begin? These are problems which have now been debated for decades, and a number of different 'interpretations' of the quantum theory have been suggested. The problem was brought into focus by a famous paper in 1935 by Einstein, Podolsky and Rosen, who argued that the strange behaviour of entanglement meant that quantum mechanics is yet to mature itself to describe such strange things. This produced a famous debate between Einstein and Niels Bohr, who argued that quantum mechanics was complete, and that Einstein's problems arose because he tried to interpret the theory too literally. However in 1964, John Bell pointed out that for certain experiments classical hidden variable theories made different predictions from quantum mechanics. In fact he published a theorem which quantified just how much more strongly quantum particles were correlated than would be classically expected, even if hidden variables were taken into account. A number of experiments were performed, and the result is almost universally accepted to be fully in favour of quantum mechanics. Therefore the theory is yet to be formulated to describe the concepts of correlation and entanglement. The only kind of hidden variables not ruled out by the Bell tests would be 'nonlocal', meaning they would be able to act instantaneously across a distance.

The quantum theory attains maturity by succeeding in explaining the processes convincingly and its application in other physical systems were explored extensively, giving rise to many other theories such as quantum information theory. In the early nineties , quantum information theory expanded its horizon and eventually the concepts like quantum teleportation and quantum entanglement were discussed with all seriousness in a scientific temperament rather than considering it as merely a puzzle.

II. Quantum Model of the Mind

In recent years, many papers have addressed the problem of developing a theory of mind[8,9,11-16,18,19,21,22]. A quantum model of the mind considering the cytoskeleton of neuron cells as the principal component that produces states of mind or consciousness[9,11]. the microtubules (MTs) perform a kind of quantum computation through the tubulins. Microtubules are hollow cylinders whose exterior surface cross-section diameter measures 25 nm with 13 arrays of protein dimers (tubulins). The interior of the cylinder contains ordered water molecules which implies the existence of an electric dipole moment and an electric field. The MTs represent a dipole due to individual dipolar charges of each tubulin monomer. The microtubule dipole produces a fast growth at the plusend towards the cell periphery and a slow growth at the minus end. The MT polarity is closely connected with its functional behavior which can be regulated by phosphorylation and dephosphorylation of microtubule associated protein(MAP)[14-15,23-26]. Tubulins are proteins which form the walls of the MTs. They claim that the tubulins work like a cellular automata performing that kind of computation. In this way, the walls of the MT could be able to store and process information by using combinations of the two possible states (α and β) of the tubulins. The MT interior works as an electromagnetic wave guide, filled with water in an organized collective state, transmitting information through the brain. A gelatinous state of water in brain cells, which was observed[22] could boost these communication effects. Each tubulin has an electric dipole moment p due to an asymmetric charge distribution[14-16,23-26]. The microtubule is thus a lattice of oriented dipoles that can be in random phase, ferroelectric (parallel-aligned) and an intermediate weakly ferroelectric phase like a spin-glass phase. It is natural to consider the electric field of each tubulin as the information transport medium. Therefore, the tubulin dimers would be considered the information unit in the brain and the MT sub-processors of the neuron cells. Therefore, to know how MTs process information and allow communication inside the brain is a fundamental point to understand the mind functions. Guanosine triphosphate molecules (GTP) are bound to both tubulins in the heterodimer. After polymerization, when the heterodimer is attached to the microtubule, the GTP bound to the βtubulin is hydrolyzed to the guanosine disphosphate (GDP). On the other hand, the GTP molecule of the a-tubulin is not hydrolyzed. The microtubules present a calm dynamic instability which are their principal feature [14-16]. Many models of conformation (and polarity energy) of the microtubular protofilament were developed. These models describe the behavior of the pulses generated by the free energy in the GTP hydrolysis. The pulses propagate along the MTs using the elastic coupling or the electric field propagation between tubulin dimers [13,14-16,23,24]. The overall effect of the surrounding dipoles on a site n can be modelled by the double-well quartic potential

$$V_n = \frac{a}{2}u_n^2 + \frac{b}{4}u_n^4 \quad \ldots\ldots\ldots\ldots\ldots\ (1)$$

where u_n represents the dimer conformational change on the nth proto filament axis coupled to the dipole moment. a depends on the temperature T_c is the critical temperature and b is a positive parameter that does not depend on the temperature [14,16]. In the next section, we reconsider this model taking into account the information theory, which allows us to calculate the storage and transference of information along the MT. We assume that the information is mediated by the electric field and propagates in the cellular medium. This propagation of energy can provide a communication channel.

The Shannon entropy of a random variable X is defined as[28]

$$\langle I(x)\rangle = -\sum_i p(x_i)\log p(x_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where p(xi) is the probability of the outcome xi. This definition describes the amount of physical resources required on average to store the information being produced by a source, in such a way that at a later time the information can be restored completely.

If we want to send a message X through a noisy channel, that message might be subjected to a loss of information. To correlate a sent message X with a received message Y we have to calculate the mutual information I(X : Y) between them. The mutual information concept gives us how much knowledge we obtain from a message X given that we have received Y. It is defined as[28]

$$\langle I(x:y)\rangle = \langle I(x)\rangle - \langle I(x|y)\rangle = \langle I(y)\rangle - \langle I(y|x)\rangle \; \ldots\ldots (3)$$

And

$$\langle I(x|y)\rangle = -\sum_i \sum_k p(x_i, y_k) \log p(x_i \mid y_k) \; \ldots\ldots\ldots (4)$$

Where $p(x_i \mid y_k) = p(y_k, x_i) / p(y_k) \; \ldots\ldots (5)$

Nevertheless, by using a binary code to send a message M, compressed by procedure C that minimizes the use of bits in that codification, any receiver of M, using a decoding procedure D, must to be able to get all information associated to M. Consider a symmetric memoryless channel1 N with a binary input Ain and a binary output A_{out}. For n uses of the channel, the procedure C encodes the input message M such that $C^n : \{1,\ldots , 2^{nR}\} \rightarrow A_{in}$ and D decodes the output such that $Dn : \{1,\ldots , 2^{nR}\} \rightarrow A_{out}$, where R is the rate of the code (the number of data bits carried per bit transmitted)[29]. Therefore, if X is the encoded message M through the procedure C, Y the received message, and D is the decoding procedure for Y, then

probability of error =

$$p(C^n.D^n) = \max p(D^n(y)) \neq M \mid X = C^n(M) \; \ldots (6)$$

The principal problem of the information theory is to determine the maximum rate R for a reliable communication through a channel. When $p(C^n \cdot D^n) \rightarrow 0$ for $n \rightarrow \infty$, the rate R is said achievable. According to Shannon's theorem, given a noisy channel N, its capacity Ω(N) is defined to be the supremum over all achievable rates for this channel. That is,

$$\Omega(N) = \max_{p(x_i)}(\langle I(X:Y)\rangle) \; \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where the maximum is taken over all input distributions $p(x_i)$ of the random variable X, for one use of the channel, and Y is the corresponding induced random variable at the output of the channel.

Eq. (7) allows us to calculate the transference of information among many physical systems. The transfer of energy may include the transfer of electrostatic energy, energy of low frequency oscillating fields, energy of light, energy of vibrations etc. The chemical bonds, the excited electron states do contribute to the enrgy of the molecule.. A common measure of the interaction leading to cooperative behavior is the information transference. The information gets transferred to the systems through the electromagnetic field.

The charge separation of the MTs is wide enough to store information[14]. Dynamical coupling allows the information to be stored in the form of mechanical energy and chemical events. Changes in the opposite direction can be favorable to the SG phase over the Fphase. This change could switch from the growth mode to operational behavior. Our focus is this operational mode. Information processing is performed by considering the highly specialized nature of the functional proteins on the microtubules[8,9,11-13]. The tubulins have a net dipole moment and thus are sensitive to external electric fields. Some papers use physical models such as spin net to describe the behavior of the dipole moment net[14,15]. Tubulins are alligned in the same direction at low temperature (˜ 200 K). In this case, the system is in the ferro eletric phase. At high temperatures (˜ 400 K), the polarity of the tubulins are randomly oriented and therefore the system is in the paraelectric phase. The key point is to know whether is there a phase transition from the disorder (Fphase) to order (Pphase). After this transition a new state can emerge which is known as spin-glass phase (SG). This transition is determined by the critical temperature Tc, which is estimated by some theoretical models[15,16].

III. CONCLUSION

The present work considers microtubules as a classical subneuronal information processor[8,9,11-15]. Using information theory, one can calculate the information capacity of the microtubules. It is estimated that the favorable conditions for storage and information processing are found at temperatures close to the human body. These results corroborate the possibility of communication among the domains (where each energy level corresponds to some kind of symbol). This communication is mediated by the dipole electric field, and this interaction is necessary to describe some processing or computing on MT. Through this communication, each domain (or symbol) presents some dependence with another. Therefore, the diamers are equipped to store and process information. Besides, from the information theory point of view, the formation of domains creates some redundancy for storage or representation of these symbols. This redundancy is important for error correction and information protection. However, some points still need further investigations. (1) The direction of the propagation of the information under the influence of the environment is an interesting point to be analyzed, (2) There is some water ordination inside MTs which could increase the quantum processes in MTs. These points deserve to be analyzed using the information theory point of view.

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