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New Metaphor of Human Brain under Quantum Information Theory

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Abstract: The flourishing development of quantum information theory has gradually caused quantum computer from theoretical conception to practice; the deepening of brain science research has caused the limitations of analogy between human brain and classic computer to be increasingly prominent. Under this background, the analogy between quantum computer and human brain will make quantum computer become a new metaphor of human brain, and point out that this new metaphor opens up a new way for the theoretical narrative of analogy research between computer and human brain.
Keywords: Quantum information theory; quantum computer; human brain; classical computer.

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1. INTRODUCTION OF QUANTUM INFORMATION THEORY

Quantum information theory is an independent discipline formed by combining quantum mechanics with classical information theory, including quantum communication and quantum computing [1]. In short, the research on quantum information theory is information transfer and logic operations which take quantum state as information carrier [2].

The classical information takes bits as the information unit, and the bit is essentially a system containing two states, such as yes or no, true or false, with or without, represented by 0 or 1, and the classic bits are only stored as 0 or 1 at the same time; the unit of quantum information is a quantum bit, the quantum bit is based on the quantum state of a quantum object (such as atom and photon), due to the superposition property of the quantum state, one quantum bit can simultaneously save two numbers 0 and 1, two quantum bit, two quantum bit can save 4 numbers, and so on, N quantum bit can save 2N numbers.

After information quantization, the characteristics of quantum mechanics become the physical basis of quantum information, including: quantum entanglement, quantum no-cloning, quantum superposition and coherence. Quantum entanglement [3] describes the "ghostly" strong correlation in different subsystems of one system, particles in a pair of entangled states like a pair of telepathic twins, when the state of one changes, the other one will immediately feel that no matter how far the distance between the two is, the non-localized effect revealed by the entangled state is usually called the super-distance, and it is fascinating. Quantum entanglement is the catalyst of quantum information theory, Einstein first noticed the quantum entanglement in 1935, in the same year, Schrödinger [4] used the term "entangled state" in his later paper called "Caradox" for the first time, since then, quantum entanglement has been the popular vocabulary in physics, which has led to a lot of research, and quantum information science has been born and flourished. Quantum dense coding (transfer classical bits with quantum channel), quantum teleportation (use classically aided methods to transfer unknown quantum states), quantum code (use quantum states as key and transmit information through quantum channels), quantum algorithms, quantum computers and quantum game theory are the main problems in quantum information research.

Quantum teleportation is one of the most eye-catching researches in the field of quantum information; quantum teleportation with the aid of classical communication, information can be transmitted through quantum channels, achieve accurate reproduction of different points in space, Thereby achieving the purpose of transferring objects. It likes a scene in a science fiction movie, astronauts walk into the conveyer, a beam of light flashes, and instantly he appears in the receiver of another distant galaxy. Of course, there is always a distance between reality and science fiction, quantum teleportation can't transmit matter, only transmit information, and the state of the transport object is inevitably destroyed, exact copy of the transmitted object is obtained, but the teleportation has opened the human endless imagination. From 1997, the experimental group led by Salinger of the University of Innsbruck in Austria realized the invisible state of photon for the first time, by 2015, the research team led by Pan Jianwei of the University of Science and Technology of China successfully realized the teleportation of multi-free quantum system for the first time in the world, and this will provide a solid foundation for extensible quantum computing and quantum communication networks.

With the progress of quantum communication research, quantum algorithm and quantum computer have also made great advances. Because all the data of the memory can be operated at the same time, the quantum computer implements a calculation; it is equivalent to the classical computer with 2N processors to perform parallel operations [5], and it shows that the quantum computer has extremely powerful computing power. In 2000, a team led by IBM's Isaac L. Chuang succeeded in developing a quantum computer with five atoms, two years later, a seven-atom quantum computer was developed. In 2011, Canadian quantum computing company D-Wave officially released the world's first commercial quantum computer "D-Wave One", Google and aviation giant Lockheed Martin purchased this quantum computer. Although there are commercial quantum computers, the application of quantum computers still has enormous obstacles. First of all, quantum computers need to cooperate with quantum algorithms to exert the powerful power of quantum computing, secondly, the operating environment of quantum computers is very harsh; the operating stability of D-Wave quantum computers needs to be kept near absolute zero; however, it is certain that the computing potential of quantum computers far surpasses that of classical computers.

In order to exploit the enormous parallel processing power of quantum computer, it is necessary to find effective algorithm suitable for this quantum computing. In 1992, the quantum algorithm proposed by Deutsch-Josza first demonstrated the effectiveness of quantum parallel acceleration. In 1994, the factorization algorithm found by Shor [6] was effectively used for factorization, which immediately caused a sensation, because this algorithm can be used to decode the commercial code system currently in use at present, such as RSA public key system widely used in e-banking, the Internet and so on. Due to the powerful computing power generated by quantum parallel computing, factoring a 400-bit cipher number, it takes ten billions of years to use the fastest supercomputer for factorization with 400 code numbers, and if the Shor algorithm is used, only need a few hours or even minutes. Another widely used quantum algorithm can solve finding a specific project in an unclassified project, which is called as the quantum search algorithm, also called as the Grover algorithm, it was discovered by Grover [7] in 1996, the search speed of this algorithm is amazing. For example, to find someone's phone number from 1 million phone numbers, using the classic method to search for average 500,000 times to find the desired number with 1/2 probability, and using the Grove algorithm 1000 times to get the correct answer with 1/2 probability.

In recent years, the research results of quantum communication and quantum computing have begun to enter into the field of practice, which will bring revolutionary changes to communication technology and computer technology [8].

2. ANALOGY AND DEBATE BETWEEN HUMAN BRAIN AND CLASSICAL COMPUTER

Since the 1950s, with the rise of cognitive psychology, influenced by cybernetics, classical information theory, and computer science, the idea of information processing has become the study of cognitive psychology and even the mainstream of psychology for a long time, and guide psychology to explore the internal mechanisms of psychological processes. The so-called information processing viewpoint is to compare the human brain with the classic computer, and regard the human brain as an information processing system similar to a computer [9]. This analogy is functional, there are many similarities between the human brain and the classical computer in functional structure and process, and it does not involve the material structure of the two. Newell and Simon, the pioneers of information processing, believe that people and computers can be described by information processing systems; information processing systems operation symbols, symbols are patterns, such as languages, marks, tokens, etc., the function of symbols is to represent, mark or indicate external things in the world [10].

However, the idea of information processing centered on the analogy between the human brain and the classic computer has received a lot of criticism since it rose. One type of criticism comes from the biological, social, and cultural characteristics of human beings, which are vastly different from classical computers. Norman, the representative of this kind of viewpoint, thinks that it is not enough to regard people as a symbolic system, human beings are organic living organisms, have a biological basis and evolution history, human beings are still social creatures, and they interact with other individuals and the environment. Therefore, people have psychological phenomena such as emotions, needs, motivations, and personalities that computers cannot describe and simulate, and it leads to functional differences between people and computers. For example, relatively speaking, the human brain is slow to operate, easily affected by emotions and motivations, easy to make mistakes, computer operations are fast and accurate, and almost impossible to make mistakes; information stored in the human brain is often fuzzy, approximate, and information saved in the computer is exhaustive and rigorous; it is easier for the human brain to discover new problems and absorb new knowledge, which is difficult for computers. Therefore, the relationship between the two seems not to be analogous, but to complement each other.

Another type of criticism directly points to the difference between the processing of the human brain and the classical computer, which is the basis of the information processing perspective, the information processing method of modern computer is generated from modern control theory, and regards information processing as a series of continuous information processing processes, namely the series processing method. In short, the series processing is to handle one event at a time, and the events handled each time are connected in some way to realize the processing of information. The daily experience of human beings clearly shows that the human brain can handle different information or events at the same time, although this parallel processing method of the human brain does not negate the series processing, it shows that the human brain is compared to the classic computer based on series processing, and it has a lot of limitations. The difference between the two in the information processing process is also reflected in the information representation mode, all the information is in units of bits for the classic computer, namely a string composed of 0 or 1, and carry out digital processing, and the human except the ability to handle discrete data, it seems to have the ability to handle continuous quantities, namely analog processing.

In general, the analogy between the human brain and the classical computer is based on the approximate functionality of the two, but its limitations are also very obvious, and with the deep research on the human brain, the difference between the two is more prominent.

3. WILL QUANTUM COMPUTER BECOME A NEW METAPHOR FOR HUMAN BRAIN

Since the concept of quantum computer was introduced in the 1980s, quantum computers have become a new research hotspot in the computer field with its powerful computing potential. Moreover, along with the continuous development of brain science research, the difference between the classic computer and the human brain is increasingly prominent in function and processing method, the analogy between the two seems to have lost the scientific significance, that is to say, the classic computer is difficult to simulate the operation of the human brain, so can a quantum computer as a new generation of computers, whether it can take on the role of classic computer, and give a new analogy to the brain and computer? The answer is yes. The physical carrier of a quantum computer is a direct quantum object, for example, if two atoms satisfy a specific condition in a molecule,, specifically, the atom's nuclear spin is 1/2, then 2 quantum bit computer can be designed, if there are four conditions are met, 4 quantum bit computer can be designed, if there are N, an N-bit computer can be designed, and the quantum state of object can be controlled by nuclear magnetic resonance or ion trap. Quantum computer can be regarded as a quantum mechanical system, and its operation process is actually the unitary transformation of quantum state, and obeys the basic principles of quantum mechanics. The unitary transformation is a transformation process of quantum states characterized by different representations; this is similar to the transformation between physical states represented by different coordinate systems, for example, the position and velocity of an object can be expressed in rectangular coordinates and can also be expressed in polar coordinates, the state of the objects represented in the two coordinate systems can be converted to each other, this transformation is similar to the unitary transformation, and the representation is similar to the role of the coordinate system. The quantum mechanical architecture of quantum computer provides material basis for simulating the operation of the brain, recent research simulates the evolution of quantum systems, and it is likely to become a major use of quantum computers [11], of course, there is a long way to go to truly simulate brain operations., and there is no evidence that quantum computers can simulate the emotions, motivations, personalities that people experience and so on, but quantum computers surpass classic computers in at least two ways, and make them more suitable for becoming new metaphor of brains.

The first is the natural probabilistic nature of quantum systems. The statistical interpretation of the wave function proposed by Born, the wave function is a description of the quantum state, and it shows the probabilistic nature of the physical quantity measurement results of the quantum system. This kind of probabilistic nature seems to more conform to the way the human brain works; it does not want to explore the probabilistic nature of its operating mechanism from the microscopic structure of the brain, because there are too many unknown parts and too many arguments that failed to reach an agreement in this type of research, here I just want to draw on the phenomena that we often encounter in our daily life. Recognition of Chinese characters can be a starting point for this problem; I believe most people have encountered this phenomenon, you stare at a Chinese character you know all the time, you will find that the more you look at the word, the less it looks like it. If the classic computer uses 0 and 1 to represent all the information, this phenomenon that does not look more like it should not happen, because all the information has been identified, the information is in a certain state, so how many times should you look at it, you should see the same information. However, it is different in the quantum system, the problem of the probability distribution of all identifiable states, when always looking at a Chinese character, it's actually a measure of quantum states, because the probability distribution of the quantum state itself cannot guarantee the correct recognition every time, so there will be a phenomenon that the recognition of the word is not the same in the process of multiple recognition.

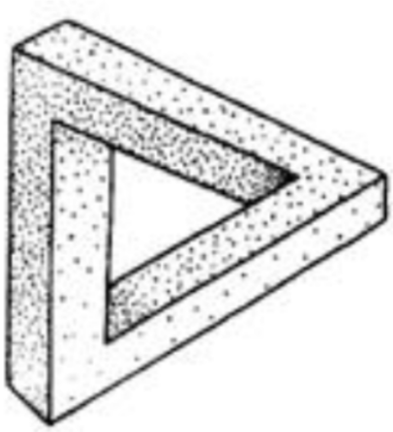

Fig 1. impossible triangle

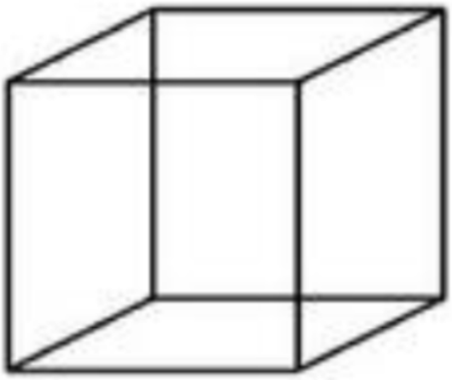

Fig 2. Necker cube

Another example is the impossible triangle, as shown in Fig.1. From the Euclidean geometry, the impossibility is that the same point cannot be in two different positions at the same time, but from the quantum theory, here a particle is equivalent to a point in space, can simultaneously distributed throughout the universe. This image is identifiable for the human brain, in this sense, the human brain may follow the theory of quantum mechanics, and it is likely that quantum computer can simulate this part function of the human brain. Necker cube, as shown in Fig.2, when people recognize the two states of the Necker cube, you keep staring at the image and will find that the result of the image recognition will automatically convert between the two states, this seems can also be explained by the probabilistic nature of the quantum system. From this point of view, the quantum probability properties represented by quantum computer may make it better to be close to the operation way the human brain.

The second is the ultra-powerful computing power of quantum computers. The human brain is a super-large parallel computing system, whose operation speed is 10 orders of magnitude faster than the fastest "Tianhe II" supercomputer; however, due to the energy consumption limit of classical computer, its computing speed is difficult to increase, on the other hand, although parallel computer with multiple chips have long been used, even parallel computer read information from memory and then conduct operations on different chips, this is essentially different from the quantum computer's simultaneous manipulation of all the data in memory. Therefore, only the computing power and processing methods of quantum computer can best match the human brain under the current knowledge level. Of course, most of the descriptions of the brain's computing power and processing methods come from the theoretical derivation of the researchers, and there is less experimental evidence, here we still have to go back to the experience of daily life, and find evidence of the comparability of quantum computers for the human brain. Nowadays, the floating-decimal arithmetic speed of the ordinary home computer is more than 100 million / second, and the size of the hard disk storage is about 1000 GB, many people use the search function provided by the operating system to find the desired file or folder, but I am afraid that few people pay attention to the searching time, in fact, it takes not short time to search a file in a storage space about 1000 GB, it is often necessary to use minutes as the time unit for the search. It is estimated that the human brain's capacity is on the 103 to 106 GB order of magnitude, as the capacity increases, the searching time will increase exponentially, so even the fastest classic computer want to complete the search, it takes a lot of time, however, for a normal ordinary person, it takes only eyewink to find the name of an acquaintance or identify a familiar face, if only calculate the brain computing process, the time will be shorter, it can be said that the computing speed of searching human brain is far faster than that of a classic computer, therefore, it is necessary to quantum computers that truly achieve parallel computing.

Quantum computers give new meaning to metaphor between human brain and computer with its amazing computing power and natural probabilistic nature, more importantly, the non-locality shown by quantum entanglement in quantum information theory ruthlessly crush the continuous illusion of time and space in the classical world, that is to say, the discrete data processing method used by computers is a more realistic description of the real world, the center of the metaphor of computer and human brain is no longer stay whether the computer is similar to the human brain, but extends to operation mode of computers and human brains, and which is more realistic, it opens up a new way for the theoretical narrative of analogy research between computers and human brains. Thus, the metaphor of quantum computer and human brain is no longer a partial function simulation of computer as human brain, and it is the similarity of the description, calculation, search and analysis way of the real world by computer and human brain based on quantum information.

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