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How do we view the prospects of quantum computers?

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Abstract: *This article briefly examines the concise history of quantum computers, the basic logic gates of quantum computer operation, compares the hardware and software algorithms of quantum computers with traditional computers, and uses the cybernetics model of quantum mechanics to analyze the mechanism of internal stability and structural stability extension of quantum states. It is concluded that quantum computers are quite fragile and error prone computing devices, and are unlikely to become widely used future computers.*
Keywords: *quantum computer, quantum logic, logic gate , structure stability*

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I. A Brief History of Quantum Computers

A quantum computer is a device that uses quantum logic for general computing. Unlike electronic computers (or traditional computers), quantum computing uses quantum bits to store data and operates on it using quantum algorithms. The antiparticle of Majorana fermions is its own property, which may be a key factor in making the manufacture of quantum computers a reality. [1] Quantum computers are sometimes excessively portrayed in public opinion as omnipotent or hundreds of millions of times faster, but whether such computers are powerful or not depends on the problem at hand. If there are already quantum algorithms proposed for solving the problem, but they are unable to be executed by traditional computers, then quantum computers can indeed achieve unprecedented speeds; If there were no problems with inventing algorithms, quantum computers would perform no differently or even worse than traditional computers. [2]

With the development of computer science, Stephen Wesner first proposed '*quantum mechanics based computing devices'* in 1969. The earliest articles on '*Information Processing Based on Quantum Mechanics'* were published by Alexander Holev (1973), Poplavskii (1975), Roman Ingarden (1976), and Yuri Manin (1980) [3] [4] [5] [6]. Stephen Wesner's article was published in 1983. A series of studies in the 1980s enriched the theory of quantum computers. In 1982, Richard Feynman proposed the idea of using quantum systems to achieve universal computing in a famous speech. Subsequently, in 1985, David Doss proposed the quantum Turing machine model [8]. One important starting point for studying quantum computers was to explore the computational limits of general-purpose computers. When using computers to simulate quantum phenomena, the amount of data becomes enormous due to the vast Hilbert space. The computation time required for a complete simulation becomes quite long, even unrealistic astronomical figures. Richard Feynman thought at the time that if a computer composed of quantum systems was used to simulate quantum phenomena, the computation time could be significantly reduced, thus giving birth to the concept of quantum computers. Semiconductors rely on controlling integrated circuits to record and manipulate information, while quantum computers aim to control the states of atoms or small molecules to record and manipulate information.

Quantum computers were mostly in a state of theoretical deduction in the 1980s. After Peter Shor proposed the quantum prime factorization algorithm in 1994 [9], he proved that quantum computers can compute discrete logarithms [10] at a much faster speed than traditional computers. Because quantum, unlike semiconductors, can only record 0s and 1s and can represent multiple states simultaneously. If semiconductors are compared to a single musical instrument, quantum computers are like symphony orchestras. One operation can handle multiple different situations. Therefore, a 40 bit quantum computer can solve problems that 1024 bit computers took decades to solve in a very short time. Due to its ability to crack RSA encryption algorithms commonly used in banks and networks, quantum computers have become a hot topic. In addition to theory, many scholars are also focusing on using various quantum systems to implement quantum computers.

It is generally believed that quantum computers are still in the research stage. However, on May 11, 2011, D-Wave Systems, a Canadian company, released a computing device called 'D-Wave One' that claimed to be the world's first commercial quantum computer, containing 128 qubits. Subsequently, countries such as the United States, China, and the Netherlands made significant progress in quantum computing. On May 16, 2023, China Bose Quantum released its self-developed 100 qubit coherent optical quantum computer, the 'Tiangong Quantum Brain'. It is said that the machine has 100 computational qubits, reaching the international leading level at that time. It can solve mathematical problems with up to 100 variables and has complete programmability. Its solving speed is 100 times faster than classical algorithms, and the higher the computational complexity of solving problems, the more obvious its quantum advantage. [13]

II. Comparison between quantum computers and classical computers

Although the working principle of semiconductors in computers is also based on quantum mechanics, they do not directly use the states of atoms and molecules as logic devices, but instead use integrated circuits as logic devices, and therefore cannot be called quantum computers. In classical computers, data can be represented by the high and low voltage, the conduction or cutoff of current, the direction of magnetic poles, etc. These are abstracted and represented by two logical values, 0 and 1 [14, p42]. The logic devices of quantum circuits are: (1) spin atoms, molecules, or atomic nuclei, with logical values represented by ± and operated by nuclear magnetic resonance; (2) Ion capture, whose logical values are the ground and excited states of electronic and molecular vibrations, is operated using laser lines; (3) Quantum dots, whose logical values are the ground and excited states of electrons, are operated using electromagnetic microwaves; (4) Photon: The logical value is Slit (up, down), and the operation method is photon beam splitter, etc. [14, p145].

The logic circuit of a classical computer consists of three basic logic gates: AND, OR, and NOT. Logic circuits are various combinations of basic logic gates. The operations of three logic gates can be listed as follows [14, p42-43]:

1. Truth value of logical product

A	B	A•B
0	0	0
0	1	0
1	0	0
1	1	1

2. Truth value of logical sum

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

3. Truth value of logical negation

A	$\bar{A}$
0	1
1	0

In quantum computers, the input state becomes the output state after a certain period of time. Because the Schrödinger equation has time reversal invariance, the basis of quantum computers used as quantum circuits for quantum states is reversible circuits. Obviously, in reversible quantum gates, in order to reproduce the input from the output, the number of output ports must be greater than the number of input ports. The basic characteristic of quantum computers is that they can produce the superposition of logical values 0 and 1 [14, p62]. The output quantum state is connected to the input quantum state using the unitary operator U:

output state vector=U × input state vector

The basic quantum logic gates are [14, p62-63]:

(1) Identity transformation, the transformation operator is $I=\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

(2) Not gate, the transformation operator is $X=\begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$

(3) Phase gate, the transformation operator is U (ϕ)= $\begin{bmatrix} 1 & 0 \\ 0 & e^{i\phi} \end{bmatrix}$

(4) Hadamard gates, whose two functions are equivalent to identity transformations, can be represented as matrices: H= $\frac{1}{\sqrt{2}}\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$

(5) Spin rotation operator.

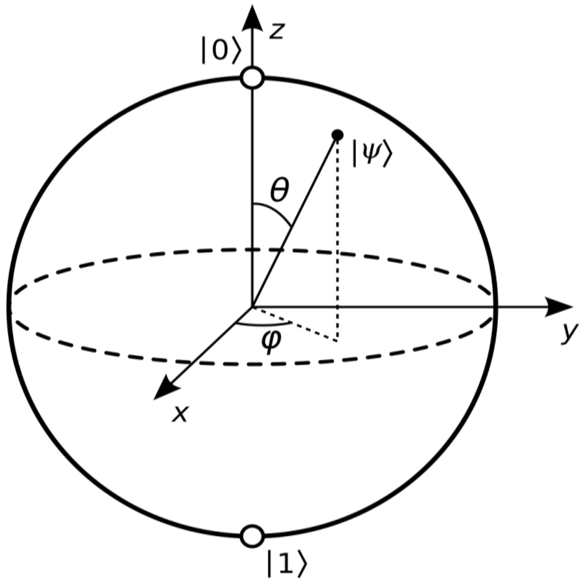

Figure.1 Bloch sphere representation of a qubit.

In the specific implementation of quantum computers, the current main technological routes can be summarized into six types: superconductivity, ion traps, optical quanta, neutral atoms, silicon spin, and topology. Quantum computers, like many computers, are composed of many hardware and software components. In terms of software, they include quantum algorithms, quantum coding, etc. In terms of hardware, they include quantum transistors, quantum memory, quantum effectors, etc. Quantum transistors break through the physical energy limits through the high-speed movement of electrons, thereby achieving the switching function of transistors. This type of transistor controls the switching speed very quickly, has much stronger computing power than ordinary chips, and has strong adaptability to the environmental conditions of use. Therefore, in the future development, transistors are an indispensable part of quantum computers. Quantum storage is a highly efficient storage device that can assign values to any computational information in a very short amount of time. It is an indispensable component of quantum computers and one of the most important parts of quantum computers. The effector of a quantum computer is a large control system that can control the operation of various components. These components occupy a major position in the development of quantum computers and play important applications [15].

Quantum computers have powerful quantum information processing capabilities, which can extract effective information from massive amounts of information and process it into new and useful information. The processing of quantum information first requires storage and processing of quantum computers, followed by quantum analysis of the given information. This method can accurately predict weather conditions, with a current accuracy rate of 75% for computer predictions. However, using quantum computers for prediction can further improve accuracy and make travel more convenient for people. Quantum computers use quantum logic with indefinite truth values, while traditional computers use binary logic that satisfies Boolean algebraic operations. The number of times quantum algorithms need to search for a specific object in an unordered database containing N data is on the order of $N^{1/2}$, while classical algorithms require N times.

Traditional computers are often attacked by viruses, which can directly cause them to crash and steal personal information. However, quantum computers, due to their unclonable quantum principles, do not have these problems. Users can safely access the internet without fear of personal information leakage when using quantum computers. On the other hand, quantum computers have powerful computing power and can analyze large amounts of different data simultaneously, so they can accurately analyze financial trends in finance and play a significant role in avoiding financial crises; It can also play a significant role in the research of biochemistry, simulating the composition of new drugs and developing drugs and chemical products more accurately, thus ensuring the cost and efficacy of drugs.

The research difficulties of quantum computers mainly focus on the following aspects. These difficulties are intertwined, requiring interdisciplinary cooperation and innovation in the research and development of quantum computing, involving multiple fields such as physics, computer science, materials science, and electronic engineering

1. Preparation and manipulation of quantum bits

Quantum bits are the fundamental unit of quantum computing, which require stability, controllability, and long coherence time.

It is very difficult to achieve high-quality qubits because they are highly sensitive to environmental interference and prone to noise and errors.

2. Error correction and fault tolerance mechanism

Due to the susceptibility of quantum bits to noise, quantum computing requires efficient error correction mechanisms to ensure the accuracy of calculations.

Classical computers handle errors through repetition and error correction codes, but quantum error correction requires more complex methods such as surface codes.

3. Maintenance of quantum entanglement

Quantum entanglement is the core resource of quantum computing, and maintaining the stability of quantum entangled states is very difficult because the entanglement between quantum states is easily disrupted by thermal noise and other interferences in the environment.

4. Selection of physical implementation

At present, there are various physical systems that can be used to achieve quantum computing, such as superconducting circuits, ion traps, topological quantum computing, photon quantum computing, etc. Each implementation method has its unique advantages and challenges, and choosing a suitable physical system and improving it is key.

5. Scale and integration

To achieve practical quantum computing, thousands or even millions of quantum bits need to be integrated together and effectively controlled and communicated. There are still significant bottlenecks in large-scale integration and interconnection of existing technologies.

III. Quantum Computers from the Perspective of Cybernetics

In 1959, Mario Bunge proposed to use feedback mechanism to understand closed class lines in Feynman diagrams, and believe that the eigenstates that appear in the quantum evolution process are the result of the boundary conditions being continuously reorganized and adjusted by the scattering process[16].In 1976, Jin Guantao deemed that the process of obtaining micro world information relies on controlled experiments, which means obtaining information through the action of macro objects (or instruments) on them (specific control effects). Therefore, the interaction between macroscopic objects and microscopic states must be included in the theoretical composition.[17,p473] That is to say, in understanding the microcosm, we understand its internal structure through the iterative process of input-output, i.e. control-observation. [17,p474] Mario Bunge expressed a similar viewpoint on quantum measurement in 2006: *“The measured object, the measuring apparatus,and the recording device(whether observer or automated) are interconnected but distinguishable. ”* [18,p70] *“And, since measuring instruments are set up and handled by experimenters, one can speak of the object-apparatus-observer supersystem. However, contrary to Copenhagen dogma, this is not an indivisible whole: connection does not entail indistinguishability . ”* [18, p70]

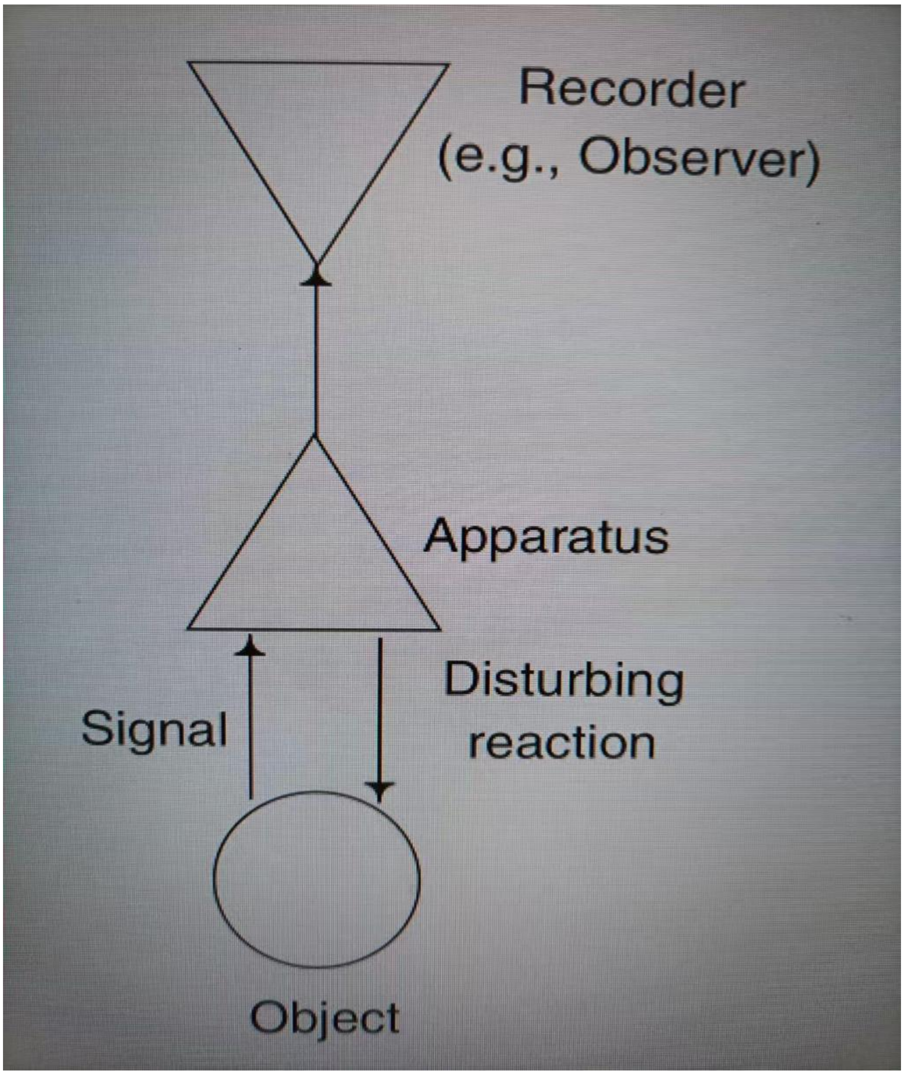

Figure.2 Mario Bunge on quantum measurement [18,p70]

Rene Thom believed that the modern scientific spirit urgently feels the need to understand the internal regulatory mechanisms of stability in things. He also pointed out sharply that quantum mechanics demonstrated the magical effects of Mach spacetime at a distance, and Einstein demanded a return to a scientific attitude that had precise requirements for locality.[19,p159-165] In Thom's view, catastrophe theory is essentially a localized theory that can eliminate the non local, long-range, and quasi magical characteristics of concepts such as complexity, order, organization, information, and cryptogram.[19,p152-153] In quantum mechanics, the intrinsic wave function form that constitutes the dynamical system is structurally stable, and the energy state essentially depends on the topological properties of its configuration. The square of the quantum wave function not only has probabilistic properties, but also reflects the extreme curvature of the normalized hyper-surface. The entropy structure of thermodynamic systems can also be explained as being proportional to the total curvature of the dynamic field.[20] According to Rene Thom, quantum information not only has a representation of probability distribution, but also has the curvature and topological complexity of eigenfunctions.

Since 1994, some Chinese physicists represented by Zhao Guoqiu have proposed the curvature interpretation of quantum mechanics, believing that the radius of the phase circle formed by the de Broglie wavelength represents the curvature radius of the quantum wave packet, while the Compton wavelength gives the spatial range occupied by particles. Regions smaller than the Compton wavelength belong to the space-like regions described by the relativistic quantum field, in which causal conditions fail.[21]Within an atom, the steady-state orbital radius gives the curvature radius of the electromagnetic gauge field strength, similar to the equal round radius in the Ptolemaic system; And quantum curvature gives the curvature of quantum standing waves, similar to the epicycle curvature of the Ptolemaic system. The number of nodes in a standing wave represents the number of quantum divisions of a stationary orbit. These are all related to the geometric shapes and topological numbers of the electron clouds. On January 6, 2025, Physical Review A published a paper discussing the curvature of quantum evolution from other perspectives, stating that the evolution path of quantum states is not the shortest and therefore not geodesic, exhibiting a certain degree of curvature.[22]

Because Thom's seven basic catastrophe modes only involve the abrupt jumps of point attractors on high-dimensional potential energy surfaces, while quantum eigenstates involve periodic or quasi periodic attractors similar to harmonic oscillators, Thom's catastrophe theory cannot directly explain quantum transitions. We need to develop bifurcation and catastrophe modes of various attractors similar to those mentioned in Synergetics to study quantum phenomena.The chaotic attractors that appear in classical dynamics do not correspond to quantum chaos phenomena in quantum mechanics. The absence of point attractors and chaotic attractors in quantum mechanics precisely demonstrates the exclusion of infinitely precise quantum information and the unpredictability of details in chaotic phenomena in quantum mechanics.

The quantum linear superposition states are equivalent to several eigenstates that have not yet interacted with each other, that is, functional coupling has not yet occurred. The subsequent decoherence dissipation process is a process of quantum eigenstates forming a new global internal steady state through coupling, which means that the irreversible changes and unclonability of quantum states. Although quantum bits involved in quantum computers are the internal steady state of a carrier, information distortion is almost inevitable if various interferences and dissipation are not controlled under certain conditions.

The Schrödinger equation has a disguised linear form, and the linear superposition of quantum states, as shown by the scattering matrix, represents particles from the distant past entering the distant future after scattering, while the close range Hamiltonians of interactions are often nonlinear. Although quantum statistics is different from classical statistics, we have introduced concepts such as thermodynamic entropy to represent quantum entanglement entropy, and the concepts of control theory and information theory have entered the core of quantum information science. In future explorations, the internalization of self-organizing theories such as dissipative structures, catastrophe theory, and synergetics into quantum science will guide the creation of new theoretical paradigms for the second quantum revolution.

Jin Guantao once pointed out that due to various interferences everywhere, the organization growth formed by the continuous coupling of the internal stability of subsystems is not unlimited, and there is a limit to organization development[23]. As an operating system organized by humans, although computers differ greatly from the self-organizing systems that exist in nature, including biological tissues, the philosophical argument that there is a capacity limit in organizational evolution also applies to analyzing the limitations of computer development, especially quantum computers. The carrier of quantum information is much more fragile than that of classical information, and the technical cost of preparing and maintaining quantum coherent states far exceeds that of preparing and storing classical information. Therefore, errors in quantum computing are prone to occur, and the difficulty of error correction is often difficult to estimate. This is equivalent to Jin Guantao's so-called mechanism of structural distortion and functional alienation limiting the development limit of quantum computers.

IV. Conclusion

According to Moore's Law, the speed of computer microprocessors doubles every eighteen months, and the number of integrated components per unit area (or volume) increases accordingly. It can be foreseen that in the near future, chip components will reach the limit scale where they can operate in a classical way. Therefore, breaking through this scale limit is a major scientific problem facing contemporary information science. The study of quantum information is to fully utilize the research results of the fundamental principles of quantum physics, leverage the powerful role of quantum coherence, explore the possibility of computing, encoding, and information transmission in a completely new way, and provide new concepts, ideas, and paths for breaking through the limits of chips. However, when analyzing the hardware and software of quantum information and quantum computing from the perspective of structural stability, we should also recognize the organizational capacity limitations of the development of quantum information technology.

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