THE BASICS OF QUANTUM COMPUTING

Bandara H.M.S.H.
Academic Supevisor: V.A. Martinovich, PhD, Associate Professor

Quantum computing is an emerging field in physics that has the potential to revolutionize classical computing [1]. In contrast to conventional computing systems, which operate with binary digits known as bits to store and manipulate information, quantum computers rely upon quantum bits, often referred to as qubits [2]. Qubits can exist in multiple states simultaneously, which allows quantum computers to perform certain calculations much faster than classical computers.

The theoretical foundations of quantum computing are based on the principles of quantum mechanics. In classical mechanics, objects are described by their position and velocity, but in quantum mechanics, objects are described by their wave function, which represents the probability of finding the object in a particular state [2]. The wave function exhibits the property of superposition, whereby the object it describes is capable of existing in several distinct states simultaneously.

The science of quantum computing employs qubits as a means of information representation [2]. A qubit can exist in two states, which are usually denoted as 0 and 1, but it can also exist in a superposition of these states. This means that a qubit can represent both 0 and 1 at the same time, which allows quantum computers to perform certain calculations much faster than classical computers.

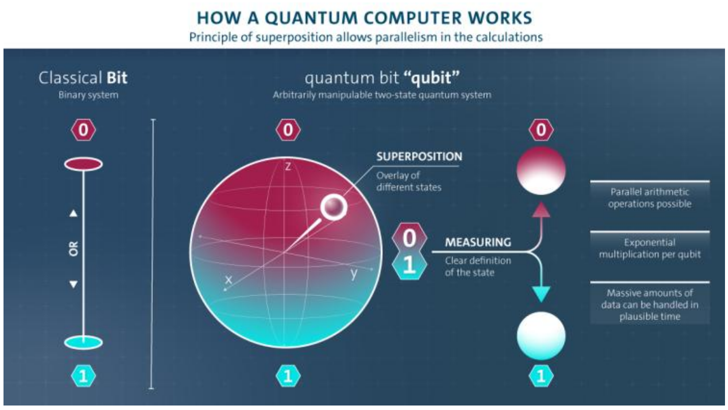

Fig. 1. How a Quantum Computer Works.
Source: Adapted from [9]

Quantum computing employs various types of qubits, such as superconducting qubits, trapped ion qubits, and topological qubits. Superconducting qubits constitute the most commonly employed species of qubits, comprising of superconducting substances that facilitate electrical conduction in the absence of resistance. The utilization of trapped ion qubits is based on the confinement of ions within an electric field and their subsequent manipulation through laser mechanisms. The notion of topological qubits denotes a recently developed qubit type that exhibits greater resilience to errors in comparison to other conventional qubits.

The quantum gate is widely recognized as a vital operation within the field of quantum computing. In the domain of quantum computing, a quantum gate denotes a unitary operator that operates on a single or multiple qubits, thereby achieving a distinct computational task [3]. There exist numerous variations of quantum gates, however, several types carry significant importance, namely the Hadamard gate, the CNOT gate, and the phase gate.

The employment of the Hadamard gate facilitates the creation of a superposition of states in a given qubit. It takes a qubit that is in the state 0 and puts it into a superposition of the states 0 and 1. Similarly, it takes a qubit that is in the state 1 and puts it into a superposition of the states 0 and 1. The CNOT gate has been employed for the purpose of entangling a pair of qubits. Entanglement is a phenomenon in which two qubits become correlated in such a way that the state of one qubit depends on the state of the other qubit [4]. The phase gate is used to change the phase of a qubit. This operation is important for quantum algorithms such as the quantum Fourier transform.

Shor's algorithm is widely recognized as one of the most eminent quantum algorithms employed for the purpose of factoring large numbers [2]. Factoring large numbers is a difficult problem for classical computers, but it is easy for quantum computers [5]. Shor's algorithm uses the quantum Fourier transform to find the period of a function, which can be used to factor a large number into its prime factors.

Quantum cryptography represents a pivotal application of quantum computing [6]. Quantum cryptography deploys the fundamental principles of quantum mechanics to guarantee secure communication channels between a pair of entities. The most famous quantum cryptography protocol is the BB84 protocol, which uses the properties of entangled qubits to ensure that the communication is secure.

Quantum computing has the potential to solve complex problems that are beyond the capabilities of classical computers [7]. One such problem is simulating quantum systems. Simulating quantum systems is important in many areas of physics, such as condensed matter physics and quantum chemistry [4]. However, simulating quantum systems is a difficult problem for classical computers, as the number of variables that need to be considered increases exponentially with the size of the system. Quantum computing, in contrast, possesses the ability to execute simulations of quantum systems in a significantly more efficient manner. This capability stands to offer noteworthy advances in these respective disciplines.

Fig. 2. An IBM quantum computer that uses superconducting qubits.
Source: Adapted from [10]

Another significant application of quantum computing is the field of machine learning [7]. Machine Learning is an interdisciplinary field of study, primarily centered around Computer Science, that aims to develop algorithms and statistical models capable of training computers to detect and analyze patterns in complex datasets. Quantum machine learning is an emerging field that combines quantum computing with machine learning. The utilization of quantum machine learning algorithms has the ability to address challenges that surpass the capacity of conventional machine learning algorithms, specifically in areas such as image recognition and natural language processing.

Despite the potential of quantum computing, there are still many challenges that need to be overcome [1]. Decoherence presents a formidable challenge of significant magnitude [5]. The phenomenon of decoherence is characterized by the entanglement of a qubit's quantum state with its surrounding environment, precipitating the collapse of said state. The phenomenon of decoherence represents a formidable impediment to the development of quantum computers of significant scale, as it imposes restrictions on the feasible usage of qubits in such computing systems [5].

Another challenge is the problem of error correction [1]. Quantum computing systems are vulnerable to errors as a result of the adverse effects of decoherence and other pertinent factors. The process of error correction in quantum computation involves identifying and rectifying errors [5]. However, error correction is a difficult problem, as it requires additional qubits and operations to be performed, which increases the complexity of the quantum computation [1].

In conclusion, quantum computing is an exciting field in physics that has the potential to revolutionize conventional computing . The utilization of qubits, capable of existing in a superposition of states, renders quantum computers highly efficient at performing specific computations in comparison to classical computers. Quantum gates are used to perform specific operations on qubits, and there are many different types of quantum gates [3]. Quantum algorithms such as Shor's algorithm and quantum cryptography protocols such as the BB84 protocol are important applications of quantum computing [6]. Despite significant advances in the field, there remain numerous formidable challenges to be addressed, including decoherence and error correction. As scholarly investigations into the realm of quantum computing persist, a surge of groundbreaking advances in this domain is anticipated [8].

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ПЕРВИЧНЫЕ ФОТОПРОЦЕССЫ ФОТОСИНТЕЗА

Домашевич Е.

Научный руководитель – Зенькевич Э.И., докт. физ.-мат.н., профессор

Фотосинтез является единственным процессом на Земле, который идет с накоплением свободной энергии и протекает вопреки закону возрастания энтропии. Природа в ходе эволюции задолго до ученых разработала основные пути формирования структур и механизмы их взаимодействия, которые активно используются в современных нанотехнологиях. В 2017 году исполнилось 200 лет со дня открытия хлорофилла Жозефом Кавенту и