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Quantum Computers for Optimization the Performance

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Abstract

Computers decrease human work and concentrate on enhancing the performance to advance the technology. Various methods have been developed to enhance the performance of computers. Performance of computer is based on computer architecture, while computer architecture differs in various devices, such as microcomputers, minicomputers, mainframes, laptops, tablets, and mobile phones. While each device has its own architecture, the majority of these systems are built on Boolean algebra. In this study, a few basic concepts used in quantum computing are discussed. It is known that quantum computers do not possess any transistor and chip while being roughly 100 times faster than a common classic silicon computer. Scientists believe that quantum computers are the next generation of the classic computers.

Keywords: Quantum computer, Qubits technology, Computer architecture;

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1. Introduction

Recent computer architectures are founded on von Neumann architecture [1], as shown in figure 1. The central impression of the von Neumann architecture is to distribute the computer into specific fragments: memory, bus system, Arithmetic Logic Unit (ALU), input and output (IO), Control Unit (CU). ALU is capable of applying various processes on its input registers, such as addition, subtraction, multiplication, and division and permit the evaluation with the input registers. Along with CU, ALU is the base of the central processing unit (CPU), while CU manages the ALU by sending commands, together with the bus system, that allows the reading of fresh commands and information from the bus into the CPU and sending the results to the bus. The memory and IO component are connected to the bus in order to receive or stock the data and respond to exterior inputs through retrieving the bus. In order to fulfill a task in a von Neumann architecture, the CU retrieves the task from memory into the CPU, where it would be decrypted and performed. The outcome of the implementation can be obtained from the IO interface or in the memory. For instance, in order to multiply two numbers, both numbers should be loaded into the CPU and stacked in registers of the ALU, known as accumulator A and accumulator B. Then, ALU executes the multiplication and sends the outcome to the registers, in order to be utilized for extra processing or to be stored into the memory. The reminder of the paper is structured as follows. Section 2 presents and examines the previous studies relevant to the development of computer design and architecture. The computer architectures limitations has been explained in Section 3. The discussion emphasizes on single CPU architecture, multiple CPU architecture, and special architectures, respectively. Next, section 4 elaborates the concept of quantum computers followed by explaining the characteristics of quantum computers and comparing between the classical computing and the quantum computing. Section 5 summarizes the conclusion of the paper.

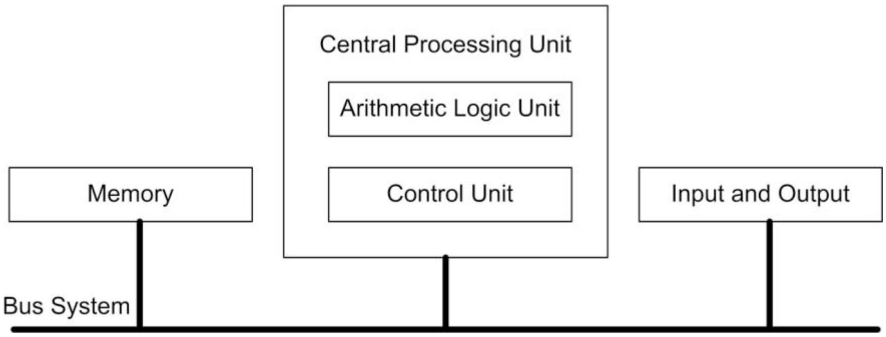

Figure 1: The von Neumann computer architecture

2. Literature review

In a study by [2], the challenges confronted by computer architecture were reported, where the author clearly discussed the single core processors and multi-core processors. In another study [3], RP3 and RP3 were introduced as a parallel research project regarding the multi-core processors from IBM. The author provided an idea to accommodate 512 modern microprocessors. Furthermore, software models were introduced in [4] in order to authorize the offered hardware. The study evaluated the operation and association of the proposed project via straightforward scalar simulations in order to replicate computing device processes by performing task commands via an interpreter. Moreover, product architecture with five zones of executive significance: product alteration, product diversity, element adjustment, product presentation, and product expansion organization was proposed in [5]. In addition, tile computing paradigm as a new method in the design of multi-core microprocessors was proposed in [6]. The components were developed in two-dimensional grids and several forms of cores, memory components, and interconnection networks while architectures used data flow and control flow performance control. In another study [7], a software architecture for previous, current, and upcoming systems was introduced. Based on the previous and current, the study proposed the upcoming software architecture. Moreover, another study [8] focused on software architecture advances and design of industrial-scale software-intensive processors and software development system. It must be mentioned that none of the stated studies focused on the topic of quantum computers.

3. Computer Architectures limitations

Countless varieties of systems have been established through history of contemporary computing machineries. The formerly outsized processors, the descendants of the current systems in the challenging business are stated as mainframe computers. The designation belongs to the time when the computer took up the whole large border or mounting frame, extending from the ground to the ceiling. A range of multiple processor chips to solo processor chips are currently available. Altogether, these designs possess drawbacks such as parameters, memory, retrieving, and etc. Different types of architectures have been discussed below along with their limitations.

3.1. Single CPU architecture

Almost all of the general-purpose computers execute tasks on a single CPU. This architecture is the descendant of the original Von Neumann architecture [1], which was established for the EDVAC and EDSAC in 1940. On the other hand, Harvard architecture, as another computer system established by Howard Aiken, was utilized in Mark- I and Mark- II system as shown in figure 2. Similarly, Princeton architecture was developed and achieved higher performance advantage by possessing distinct cache storage for commands and information.

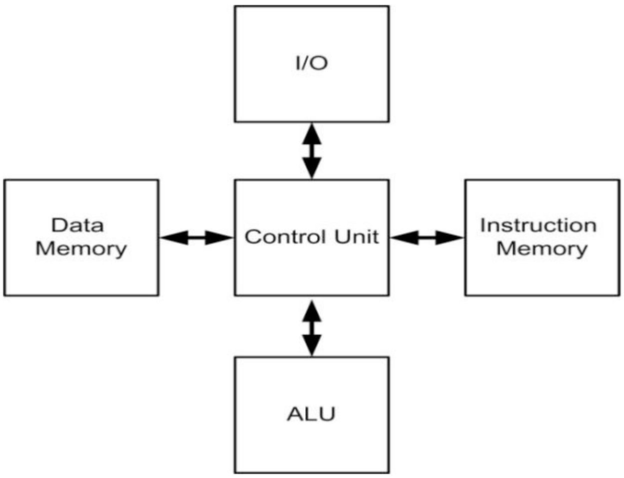

Figure 2: Havard model

3.2. Multiple CPU architecture

In computer systems, simultaneous processing is task execution which contains division of instructions and data between several CPUs in order to execute a task in a shorter time as shown in figure 3. In the primary computers, solely one task could be executed. A software-intensive task that required one hour to be executed and a tape copying task that required one hour to be performed would have taken two hours to be executed. The initial method of simultaneous processing permitted the included implementation of both tasks at the same time. The machine would initiate the I/O process, and while waiting for the process to finish, it would run the task. Hence, the entire implementation time would be around one hour for the two jobs.

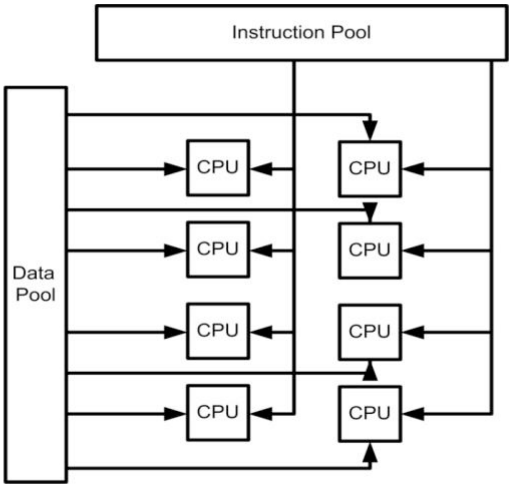

Figure 3: Multiple CPU architecture

3.3. Special Architectures

Current and upcoming computer systems could not be simply categorized as Princeton, Harvard, or parallel systems. The distinctiveness of these architectures indicates that they could be utilized in special-purpose systems other than common computing applications. These distinctive architectures comprise fuzzy logic architectures, which function on values with a likelihood of being true or false other than binary values 1 and 0, artificial neural networks, which are designed based on the human brain and nervous systems, dataflow systems, which evade the consecutive programming utilized in Von Neumann machines. Currently, scholars are attempting to make novel computing devices established on quantum physics instead of Boolean algebra [9, 10]. This machinery, if demonstrated to be applicable, would utilize quantum properties to execute infinite calculations in parallel. These quantum mainframes would be exceptionally more effective than present supercomputers.

4. Quantum Computer

The immense quantities of processing capability produced by computer manufacturers have not been capable of meeting the demand for speed and processing capability so far [11, 12]. An American computer engineer known as Howard Aiken stated in 1947 that a handful of electronic digital computers would fulfill the computing requirements of the United States, while others have stated comparable forecasts about the quantity of computing capacity that would fulfill the developing technological requirements [13 -15]. Indubitably, Aiken did not consider the massive quantities of information produced by scientific exploration, the propagation of PCs, or the appearance of the Internet, which raised the requirement of computing capability. According to the Moore's Law, the quantity of transistors on a microprocessor carry on to be two folded every 18 months, while by the year 2030 the circuits on a microprocessor will be measured on an atomic scale. The quantum computer is one of the keystones of modern physics, where it administrates the performance and features of substance in a structural way, specifically on the microscopic scale of atoms, see figure 4. Therefore, what are currently known as traditional computers, are obeying the instructions of quantum systems. Nevertheless, they are not quantum systems since their data management can be impeccably defined in traditional data concept. Actually, quantum mechanics are not required to clarify the way in which zeros and ones (bits) in a traditional computer progress, since the architecture of traditional computers does not utilize one of the utmost essential properties of quantum mechanics known as the prospect of superposition. During the execution of a task on a traditional computer, each bit obtains the quantity of one or zero. However, quantum systems permit the superposition of zeros and ones, known as quantum-bits (qubits), which are simultaneously in the state of one and zero. Computing devices which utilize this opportunity, and all the important properties of quantum mechanics, are referred to as quantum computers [16, 17]. Due to the fact that they possess a supplementary ability, they are however as effective as traditional computers. Consequently, any task which could be resolved on a traditional computer could be executed via a quantum system too. The opposite is accurate as well due to the fact that dynamics of quantum computers are administrated by linear differential equations that could be resolved by traditional computers as well. Hence, traditional and quantum computers may theoretically imitate each other.

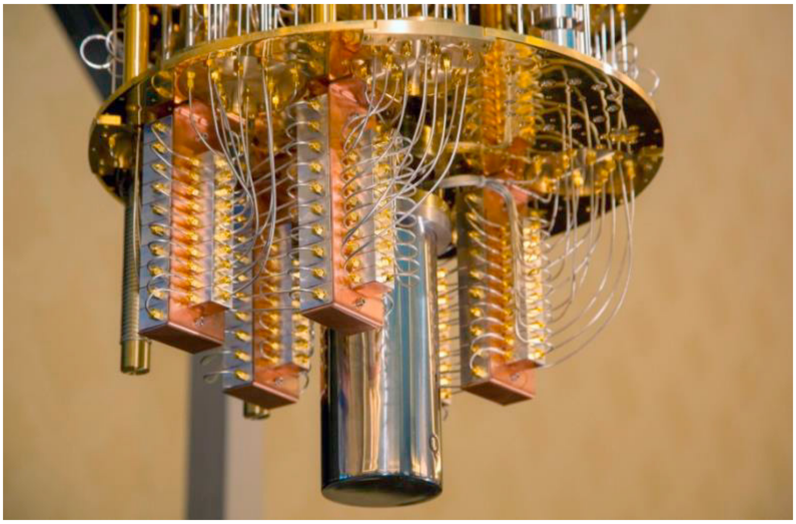

Figure 4: Quantum computer [18]

4.1. Characteristics of Quantum Computer:

1. *Quantum computers moderate the difficulty of various computational programs.*

Quantum computers are able to resolve various varieties of tasks quicker than any (current or upcoming) traditional computers. The boundary among easy and complicated tasks is not the same for quantum computers and their traditional counterparts. Here, "simple" indicates that the duration of problem solving raises polynomially with the extent of the data, while "challenging" tasks are those that the needed time raises exponentially. Therefore, a challenging task for any traditional computer is known to be simple for quantum computers.

2. *Quantum systems are able to proficiently simulate other quantum systems.*

Nature offers various interesting quantum marvels such as Bose-Einstein condensation, magnetism, and superconductivity. While all features of substance are defined and can be theoretically explained from the rules of quantum systems, scientists often have problems in grasping these laws comprehensively and to predict them by beginning from essential laws and initial theories. This is for the reason that the sum of factors required to define a particle quantum system rises exponentially with the sum of particles. Therefore, evaluating a theoretic system for the performance of thirty particles with investigational certainty is not conceivable by means of numerical simulation of the theoretic design on a traditional computer without implementation of major generalizations. Through considering the stated challenge of emulating quantum systems on traditional computers, Richard Feynman reported that a traditional simulation characteristically suffers from an exponential reduction, while quantum computes are able to efficiently execute the emulation with manageable overhead [19]. As follows, a quantum system functioned as a quantum emulator may perhaps be utilized as a connection amid theoretic designs expressed on structural level and investigational data. Resembling the Shor's algorithm, a quantum emulator would produce a significant speedup in comparison to a traditional computer [20]. A significant variance amid these applications is the fact that a valuable Shor-algorithm system needs thousands of qubits, while a few tens of qubits will be possibly sufficient for the imitation of quantum computers.

3. Moore's law possesses physical restrictions

Aside from the processing capability of a quantum system, numerous banal arguments exist for including quantum mechanics into computer systems. In 1960s, Intel co-founder Gordon Moore witnessed significant advancement in the quantity of transistors on the integrated circuit and forecasted that this inclination would carry on [21]. Ever since, the density has been two folded almost every 18 months. In case that this inclination endures, by the year 2020 various parts of computer systems would be at the atomic dimension, where quantum properties are governing.

4. Even small quantum circuits may be advantageous

In addition to the quantum system with its stated properties, quantum data science produces various beneficial functions which might be simpler to comprehend. The greatest sample is quantum cryptography, which permits the transmission of data with "the safety of nature's laws" [22]. Nonetheless, small parts of a quantum system, i.e., small quantum circuits may be beneficial too. For example, they could be utilized in accuracy examinations (i.e. in atomic clocks) [23, 24]. The latter is essential in GPS, distant telescopes, and synchronizing networks [25]. Through development of quantum links amid the N relevant atoms in the atomic clock, the uncertainty of the clock could be theoretically decreased by a factor $\sqrt{N}$ with a quantum circuit. Moreover, small quantum circuits could be utilized in entanglement distillation. With the intention of distribution of entangled states over large distances, they should be sent via unavoidably noisy channels and loosing the entanglement. Luckily, several extremely entangled states out of countless dimly entangled ones could be distilled [26 -28].

4.2. Comparison between classical and quantum computing

The information of traditional computing is stored in bits, taking the distinct values of 0 and 1. Since storing one number takes 64 bits, storing of N numbers would take N times 64 bits. Computations are executed principally just as by hand. Consequently, the class of tasks which could be performed proficiently is similar to the class which could be calculated by hand. The word "proficiently" denotes the impression that the duration of calculation doesn't rise rapidly with the extent of the input. The information of quantum processing is recorded in qubits, while a qubit could be in positions categorized as $|0\}$ and $|1\}$, in addition to being in a superposition of these positions, $a|0\} + b|1\}$ and a and b are complex numbers. If the position of a qubit is deliberated as a vector, then the superposition of positions is just vector calculation, while for every additional qubit, twice as many values could be stored. For instance, with 3 qubits the coefficients for $|000\}$, $|001\}$, $|010\}$, $|011\}$, $|100\}$, $|101\}$, $|110\}$ and $|111\}$ could be obtained. Investigations are executed by unitary transformations on the state of the qubits. Along with the theory of superposition, this delivers potentials that are not obtainable by calculations performed by hand. This interprets into extra effective systems for a.o. searching, factoring, and imitation of quantum computers.

5. Conclusion

Computer systems have evolved over the last decades. Quantum systems, which are founded on quantum mechanics, differ from a digital computer and are capable of executing the processes faster than supercomputers. It is believed that the future of computer systems would be altered due to this new invention. This paper discussed the concepts of quantum computing to develop quantum-based computer systems. The paper also examined the relationships between the computer architecture and building quantum-based computers. Furthermore, we also describes the characteristics of quantum computers and explain how quantum-based computer differ from traditional computers. It has been argued that quantum computers are able to simply resolve applications that cannot be finalized with the aid of current systems. Developing a useful quantum system is just a matter of time, where it would be one of the major steps in science and could reform the applied computing systems.

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