Parallelism Evaluation of Quantum Computing Comparing with Classical Computation Systems

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IBM quantum computation technology

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Abstract— **A present computer has faced many statuses that cannot manipulate it, even with parallelism in the processors. A quantum computer has shown which can deal with many issues that classical computers need years to complete. This paper will compare classical computers with quantum computers in many aspects with an experiment to show how a quantum computation proceeds with the tasks.**

Keywords— *Qubit, Quantum, Superposition, Interference*

I. INTRODUCTION

As a big revolution of the technology that has shown up, since the first digital computing machine if we consider the first digital computer of the idea of Charles Babbage and German engineer Konard in 1941, it passes throw many generations starting from gears then relays to the valves then turn to transistors and then turn to the integrated circuit then chip and so on.

Depending Gordon Moore in 1965 says that the number of atoms needed to represent a bit of memory will be decreased exponentially.

As well, the power of computer processing will double every 18 months, which means that someday, each bit will be represented by a physical element that will be smaller than the atom. For the time being, the size of the transistor is around five nanometers. Like Samsung, if we take a silicon atom size, which is 0.2 nanometer, that means the transistor is bigger than the silicon atom approximately 25 times. Hence it is going smaller and smaller by the time. But we cannot make any transistor smaller than the atom. We need at least one atom at least. There are researches concerning in 1 atom-transistor. But what is the next, by the technology of the computers we have now we cannot go smaller than an atom? So, new technology has been beginning "Quantum Computers" as researchers they called it emerging technology

II. METHODOLOGY

A quantum computation works with different situations and environments than classical computers. We will discuss an experiment on a real-world quantum computer on a cloud platform of IBM. We will use python to show how are the behavior of Qbit and how are the quantum computers behave with a Qubit.

III. QUANTUM COMPUTER SYSTEMS

A. Superposition State

In classical computers, an electrical signal as voltages will represent either 0 or 1, which it considers as the states of the bits, which will represent the information. Hence n bits can represent 2n states. But in quantum technology, the alternative of the classical bit is "qubit." Qubit has two states system. For example, rather than uses voltage as classical computers do, we can consider an electron called qubit to be a voltage. The main idea is to use the spinning of electron direction to be as a high and low in classical computers, Hence electron spinning down and spinning up, which can produce high or low, 0 and 1. But we can go. Furthermore, we can use a photon as a qubit as well. In this case, we can use the polarization, which is either vertical or horizontal, to represent 0 or 1. A quantum computer can do all processes, which classical computers do, but the main difference is that a qubit can represent 0 and 1 at the same time, which is a superposition expression. Another different characteristic of quantum computers than classical computers is that the quantum computer has the possibility of parallel computation. Hence a qubit can represent both two states at the same time, as well two qubits can represent four states at the same time. For example, if we use two qubits as input, we can get four operations of 4 inputs with one computation process. A classical computer handles 2 bits as 2 bits with 2 bits operations, so the parallel in the quantum computer will be in the whole system, not as the classical computer just in processing.

B. Interference

A classical computer does not depend on the probabilities. It takes as input an explicit state of bits, then manipulates those bits and gives the output also as an explicit output of bits. Whilst the quantum computers take an implicit input of qubit, then measure those qubits and manipulate it as probabilities and give output as implicit output.

C. Memory and Storage

Classical computer stores a bit even 0's or 1's depending on encoding methodologies. Those bits are still fixed at any time, even if we do not want to use them.

IV. EINSTEIN'S SPOOKY ACTION AT A DISTANCE

Spooky action at a distance, it's a term first used was by Einstein in his letter to Max Born in 1947, which is the ability

of two objects to share the same state and action once the action has happened to one of them. Hence, the same principle will be applied to the atom, which means that if we separate two atoms from each other by a distance, and we measure both two atoms at the same time, we will find that both two atoms have the same states. A quantum computer will shift features than our expectation if we consider that. Whereas in a classical computer we always use media in between entities, such as cables or even signal in wireless mode to carry the data, that media as well have tolerance while it carries the data, but in action at a distance, tolerance will be null.

V. Quantum computer real implementation

can provide a quantum computer and make it available to any user on the internet. In this real implementation, we will take quantum-computing IBM. We can implement the circuit by IBM itself or even by getting a token and use any editor.

A. Environment of implementation

- Python 3.8
- Library and third-party: NumPy – Matplotlib – Qiskit-IBM-provider.
- Workspace: Jupyter lab

- Getting the token online: From quantum-computing IBM, we need to make a new account and then get the token, which will be used in the Jupiter lab. That token will allow the code we will write in the Jupyter lab to be connected and executed on the computer machines of IBM. That token is considered as API, So after taking that token, we will provide it in the jupyter lab.

B. Experiment

1) Create a circuit: we will define the actual circuit. because we need to start at a qubit level, which equivalent to classical computer a bit level. We will use two-qubit and two classical bits.

2) Now we are going to do a not gate of qubit zero. By default, those bits are going to store as zero. Which means qubit at the beginning we have (0,0), then after not gate it will be (1,0).

3) Now we will apply a controller, not a gate, it flips the second qubit if and only if in case the first qubit is equal to 1. So, the circuit will be (1,1)

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5) Now we take our measurement of qubits, which means we need to know the actual value. If qubit in superposition, it will be collapse and turn to the value. Because before and after measuring, we do not know what is the value of the qubit. So we will specify the actual qubit register and how it is going to map to the classical bit register, so we will feed [1,0] at the first parameter and as well feed [1,0] to the next parameter. That will make a direct representation of qubits to the classical bits. It means that after we take our

measurement, the value of qubit-0 is what we are going to return for classical bit-0 and the same thing for qubit-1 to classical bit-1, And then we will draw the circuit. We can see the first X which is Not gated and the second X which is controller Not gate, So the result of the measurement is giving us a high or 1's for both qubit-0 and qubit-1 as we mentioned (1,1) as Figure 1.
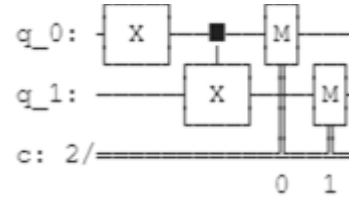

Figure 1 – Qbit circuit initial state

6) Now we need to implement that circuit on a quantum computer, So we need to import IBMQ from the qiskit library, then we have to feed the token of the online IBM quantum computer into the object. I will hide the token by X's because of security issues. Then we need to load that token to an online IBM quantum computer. After the token has loaded, a confirmation message showing.

7) Now we need to choose the provider in the online IBM quantum, so we will define a provider and search IBMQ how long the queue for each provider we need to wait. We can see a list IBMQ with its location and the queue of users who intend to use it, and the number of qubit of each one

8) As we have a list of all available machines, to where we are in the queue, we will need to import job monitor from qiskit. tool.monitor library and define a variable that will be as a backend or API, and we will provide the name of the selected machine we need. After success to get the connection between the IBMQ and our editor, a successful message will be coming

9) Now we need to draw a plot, with import plot histogram from qiskit.visualization, as well style from matplotlib , this plot will measure that circuit which we have already made it in the previous section which is (1,1). Hence the plot shows that the value of both two-qubit is (1,1) with probabilities rate of 0.848, as we can see others probabilities as (0,0) => 0.010, (0,1) => 0.074, (1,0) => 0.068. Whereas the measurement has taken the biggest ratio of probabilities shown in Figure 2
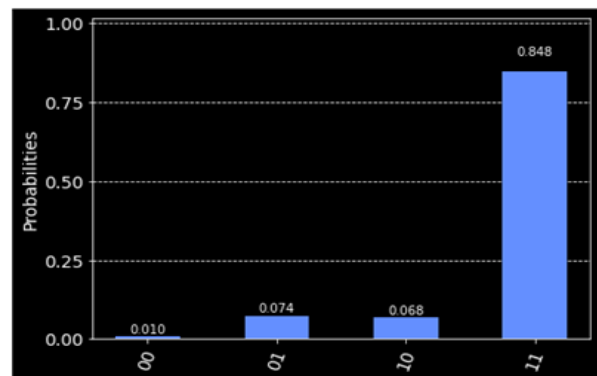

Figure2 Qbit status measure

10)   we have started by flipping with X, But now we will use a handmard gate. It put whatever qubits you pass and put it in superposition, which means the qubit with no measurement it may 0 or May 1. It shows how the qubits in superposition, It shows that it may be either (0,0) or (1,1) because the probabilities are almost equal to 0.490 and 0.406 as shown in Figure 3.
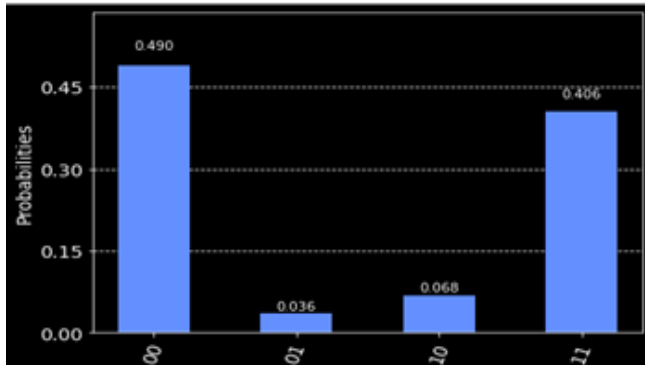

Figure3 – Qubit status measure in superposition.

VI. MEMORY

A quantum computer encodes Data to either 0's or 1's, but it uses different techniques or can use many different techniques, not as classical computers do. Classical computers use an absence or presence of the electrical charges to represent the bits states. Which is 0's will be represented by the absence of electrical charges, and 1's represents as electrical charges presence. In contrast, a quantum computer does represent the states of either 0's or 1's with the electrons spin UP or spin DOWN, which it can produce 0 for the DOWN and 1 for the UP. There are also different ways to represent the state of the bit in a quantum computer. With that, we can see that a quantum computer and a classical computer are similar in the idea of the bit states, but both got different from each other in how each one will represent its bit states. So, based on that, a quantum computer will get a smaller component than a classical computer but still yet needs more extra tools as measurement tools, which will increase the cost.

VII. PARALLELISM

Since 1967, there were arguments about the parallel processors, hence Gene Amdahl's law, that law has disappointed designers to exploit the parallelism till the Gustafson-Barsis Law has been founded. They were successes applying parallel computing to be used. Still, yet classical computer processors varying of using the parallelism depending on classes of parallelism in the application as Data-link parallelism or Task-level parallelism or even on classes of architecture parallelism as Instruction-level parallelism (ILP), Vector architectures/Graphic processor units (GPUs), thread-level parallelism or Request-level parallelism. We can also have a look at Flynn's Taxonomy, which either single instruction stream - single data stream (SISD), single instruction stream – multiple data stream (SIMD), multiple instruction streams – single data stream (MISD), or multiple instruction streams – multiple data streams (MIMD). We can see the idea of parallelism in classical computer have limited to several instruction or data, which can enter into the processors and getting manipulated but we can know each one state, even if we need to change the state, we need more time to convert that state to be another state. In quantum computers, if we consider the same principle of parallelism, we can find the parallelism is not located in the processing stage but the qubits themselves. By another hand, it is located in the whole computing process. Qubits are either 0 or 1 at the same time, which allowing to take a probability at the same time. As we can see in the previous experiment, we have found that the qubit in superposition has approximately the same result, may 0 or 1.

VIII. RESULTS

IX. We have found the way of how quantum computation will be done its processing and how a quantum computer works differently than classical computers.

X. CONCLUSION

XI. We conclude that quantum computers do their jobs of processing in a different way than classical computers. We have shown that the parallelism concept of quantum computers is different from its located in classical computers. Hence, classical computer parallelism needs a special algorithm, which also needs to be developed periodically to improve papalism. In contrast, a quantum computation processing the tasks naturally without any human intervention. It depends on the natural physical behavior of the electron itself

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