International Journal of Engineering & Technology, 7 (4.31) (2018) 348-351

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

An Empirical Research on the Performance Analysis between Silicon and Quantum Computers

M. Aisar M.M.I[1], S.S.M.Fauzi*[2], H. Baharin[3], W.A.W.M. Sobri[4], A.J. Suali[5], R.A.JM. Gining[6], M.N.F.Jamaluddin[7], Mohd Helmy Abdul Wahab[8]

[1]Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, Malaysia.
[2]Institute of Visual Informatics, Universiti Kebangsaan Malaysia, Malaysia.
[3]Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn, Malaysia.
**Corresponding author E-mail: shukorsanim@uitm.edu.my*

Abstract

This paper reports a preliminary study that compares the computational capabilities of silicon computers with quantum computers. Three types of programming control statements, *for*, *while*, and *if-else* were executed on a silicon computer and in Google Quantum Playground. Each control statements were executed five times or more in both computers and completion times were recorded. Average completion time was then calculated. The results show that silicon computers performed better that Google Quantum Playground.

Keywords: *Quantum Computing; Silicon Computer; Performance Analyses; Virtual Quantum Computer; Physical Silicon Computer.*

1. Introduction

The aim of this study is to gauge the processing capabilities of quantum computing, specifically, a GPU-accelerated quantum computer with a simple IDE interface provided by Google called Quantum Computing Playground, in comparison to silicon computers. The scope of the comparison is in execution of algorithm control statement. It was expected that quantum computers would outperform silicon computers in this aspect.

Quantum computers is seen as the future of computing technology, which is predicted to replace silicon computing [3][4], due to their nature of using quantum mechanics to make them significantly faster, far exceeding performance limit of silicon computers today [5][6].

Computers' processing power will increase twofold every two years and carry on indefinitely [2]. Since the late 1990's silicon computers have become ubiquitous, evolving and existing in many forms such as personal computers, workstations, minicomputers, mainframes, and supercomputers. Quantum computers is changing the paradigm of computing because they are fundamentally structurally different from silicon computers which requires a complete paradigm shift from the current understanding of computer technology [1][7][8].

One of the main challenges to achieving the full potential of quantum computing is actually an engineering problem. In order for the current quantum computing systems to be stable, it has to rely on absolute zero cooling and heavy shielding, which can be very costly. Without these, the system is instable and minor interference can affect quantum computing processes and calculations. However, promising advances are being made in solving this problem.

This rest of this paper is organized as follows: In the next section the methods used in the study is discussed. Presentation of the results comes after that and it is followed by the discussion of the results. The paper ends with a conclusion section.

2. Related Works

This section summarizes related work in performance comparison between quantum computers and silicon computers. Previous studies have made comparison between the two types of computers in terms of measurement of speed, inner workings observations, in chaotic simulations, and Travelling Salesman Benchmark through Ant Colony Optimization. These are aspects of processing capabilities which can be measured, however the results depend on the type of algorithm executed in the tests. It is safe to assume that there is a need for a stable performance benchmark in comparing quantum and silicon computers. However, this may only be achieved if quantum computers have reached stability.

Several experiments to test the capabilities of quantum computing against silicon computers were proposed at D-Wave, the leading commercial quantum computers developer [9], one of which used the Travelling Salesman Problem (TSP) as the benchmark. The quantum computer used in the experiment was equipped with 512 qubits, albeit only 439 were functioning. The silicon computer meanwhile, used a cluster of seven Intel Xeon E5-2609 processors running at 2.4 GHz. In TSP, a hypothetical salesperson is selling his or her goods to multiple cities. The problem is in making the salesperson trip efficient by visiting every city once using the shortest possible route. Reaching an optimum solution to TSP is not simple and can take an extended amount of time. In the experiment conducted at D-Wave, the silicon computer took 30 minutes to solve the TSP using the best available software at that time. Meanwhile, quantum computer only took less than half of a second to solve the same problem. The experiment demonstrated that quantum computer can be about 3,600 times faster than silicon computers in solving the TSP.

Research shows that the efficiency of The Ant Colony Optimization (ACO) is improved by using a novel self-organizing Ant Colony Optimization algorithm based on Quantum mechanism for

Traveling salesman problem (TQACO). [10]. ACO is a metaheuristic based on ants' capability to find the shortest paths from the nest to food location. Using swarm intelligent, ants are able to do this by depositing pheromone trails of the ground which allows other ants to find the food source and determine its quantity and quality. The efficiency of the ACO is improved significantly in convergence rate and solution quality by using quantum self-organizing operators.

Despite quantum machines offering the possibility of performing certain computations significantly better than silicon machines, the definition of measurement of quantum speedup is still being debated, hence there is no clear evidence of quantum-based speedup over current silicon-based technologies [11].

3. Methodology

The study conducted has four phases: experimental preparation, coding preparation, testing, and evaluation.

3.1. Experimental Preparation

In the preparation phase, programming codes to be used in quantum and silicon computers were chosen. Similar algorithm was used for both computers. QScript was used to write the algorithm in the quantum computer, while C was used for the silicon computer. QScript and C are quite similar. Limitations for the algorithm are set up in this phase.

3.2. Coding Preparation

In this phase, algorithms for both languages is standardized by setting up the guidelines for experiment. The experiment used simple calculation algorithms executed repeatedly using three types of control statements, which are, *for*, *while* and *if-else* which was coded in both QScript and C.

3.3. Testing and Evaluation

The prepared algorithms from the experimental design phase were executed on both the quantum and silicon computer programming environments in this phase. For the quantum computer, the program algorithms were executed online via QScript on the Google Quantum Playground. Meanwhile, for the silicon computer, the algorithms were executed using C-Free 5.0 and also using an online C compiler. All three experiments were repeated for five time or more on both types of computer, as will be shown in the sults section.

4. Results

In this section, the findings from the three experiments performed using quantum computer and physical silicon computer are discussed.

4.1. For *loop* Experiment

The outcomes of the loop experiments performed on silicon computer are illustrated in figure 1. Also, figure 2 shows the various outcomes for the loop experiments performed on quantum computers.

The outcomes of both virtual as well as physical computers were anticipated to exhibit different completion time's degrees primary because of the internet literacy. Nevertheless, there was a little inconsistency in the second reputation since the completion time recorded was one second faster as compared to the silicon computer. Nevertheless, the same incident never repeated again. Moreover, virtual silicon computer had an average of three seconds completion time as compared to that of physical computer. It should be noted that the two silicon computers completed the experiments in a matter of only seconds. On the other hand, the quantum computer produced inconsistent outcomes. Its time of completion ranged from 14.83 mins (fasted) to 21.25 mins (slowest completion time). The experiment performed with the quantum machine was completed in terms of minutes.

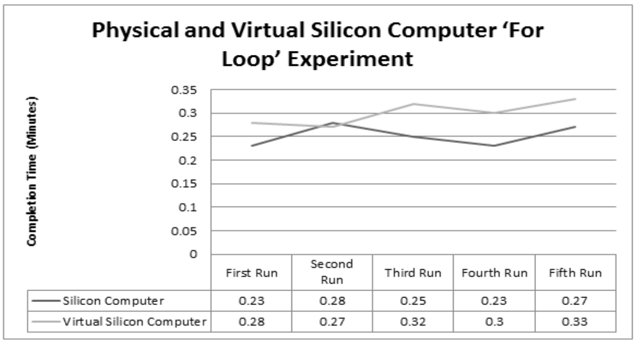

Fig. 1: First Experiment on the Virtual and Physical Silicon Computer

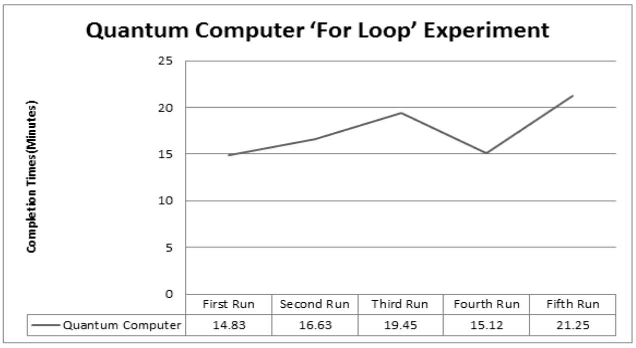

Fig. 2: First Experiment on Quantum Computer

4.2. The *while* Experiment

The *while* experiments' results that were performed on silicon computers is illustrated in figure 3. Figure 4 also exhibits *while* experiments' results that were performed on the quantum computer. Both virtual silicon and physical silicon computer's results were the same *for loop* experiments in terms of their completion times. Only a difference of approximately three seconds was exhibited between the experiments and this is as a result of internet latency. Dissimilar to the initial experiment, no anomalies were recorded about the silicon computers' completion times, and these experiments were conducted in a matter of seconds. Sluggish completion times were recorded on the second experiment on quantum computer. These completion times were ranging between 14.1 minutes and 17.85 minutes. The *for loop* experiment's results were slower as compared to the completion times, since the *while* experiment never executed the additional processing requirements as per the *for loop* experiment's layered approach that necessitates for loops within loops. The experiment performed with the quantum machine was completed in terms of minutes.

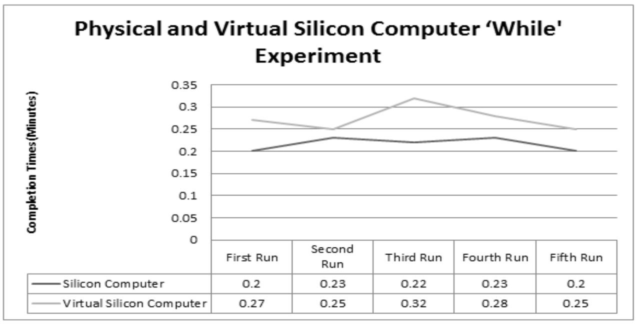

Fig. 3: Second Experiment on the Virtual and Physical Silicon Computer

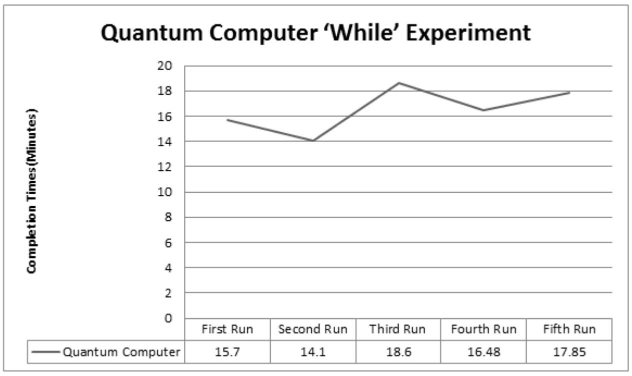

Fig. 4: Second Experiment on Quantum Computer

4.3. If-else Experiment

If-else experiments were performed on silicon computers and the results are illustrated in figure 5. Also, *while if-else* experimental results from the quantum computer are illustrated in figure 6. On average, completion times for both the *while* experiment and physical silicon computer are the same. Nevertheless, virtual silicon computer exhibited the highest completion time difference for the three experiments performed. The average difference for the virtual silicon computer was 4 seconds. It took the silicon machines a few seconds to complete the experiments. Of all the three experiments conducted, the quantum computer recorded the lowest average completion time of 20.45 minutes, whereas *if-else* experiments recorded the fastest time of 16.35 minutes. It was unexpected that physical silicon computer exhibited the same average completion time to that of *while* experiment as well as recording the slowest completion times for the virtual silicon computers. Such differences may be as a result of unanticipated interferences on the internet connection when the experiment is on-going. The experiment performed with the quantum machine was completed in terms of minutes.

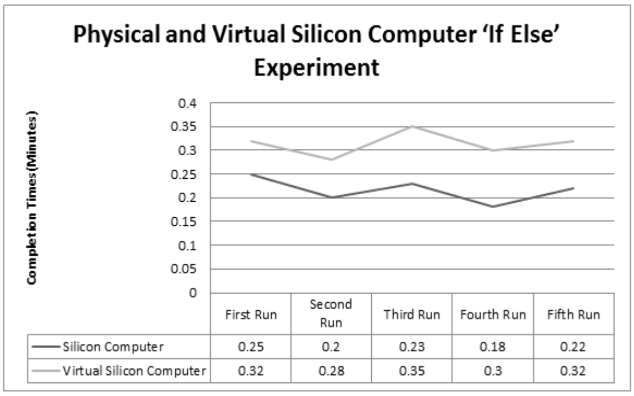

Fig. 5: Third Experiment on the Virtual and Physical Silicon Computer

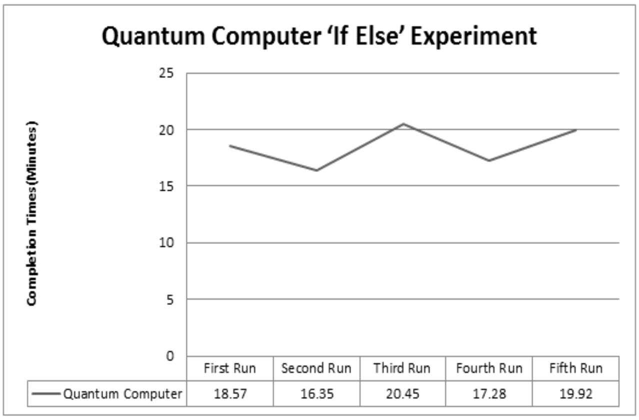

Fig. 6: Third Experiment on Quantum Computer

5. Discussion

The three experiments were performed in both virtual and physical computer setting as well as virtual quantum computer setting. Quantum machine's virtual capability is estimated at a processing of 22 qubits with approximately 2.2 qubits best effort basis for every user while its usage is maximum. On the other hand, silicon computer processor conducts with the statistics that follows: CPU @ 2.60 GHz, Intel® Core™ i7-4720HQ.In terms of processing, it is assumed that a virtual silicon machine is of a server grade quality. Based on the quantum machine's bare minimum processing capability when compared between physical as well as virtual silicon machines, the presumption is that silicon machines will perform better than quantum machines in terms of the experiments' completion times, however the study's results proved otherwise.

Both physical and virtual silicon machines were in a position to compile, perform as well as complete within a few seconds simple control statement algorithms. Both machines recorded a slight difference in completion time of between 3 and 4 seconds. This was most likely as a result of latency between program algorithm execution and display of the outcomes. On overage, the three experiments had a completion time ranging between 11 seconds and 20 seconds in both physical and virtual environments.

On the other hand, quantum machine was available only in a virtual environment and it was capable of compiling, executing as well as completing basic control statement algorithms in a matter of minutes. For the three experiments, the average completion times ranged between 14 minutes and 21 minutes. The study's results may have been influenced by a plethora of variables, however all the variables arise from the quantum machine itself. This research employed a virtual quantum computer that was publicly hosted by Google, also referred to as "*Google's quantum playground.*" Definitely, the internet's latency affected the availability as well as results of only one compiler executing the *QScript*, which was more likely to affect the experiments. Studies conducted previously to analyze the quantum computers' performance may have used various computers that are designed to execute as well as complete customized algorithms. On the other hand, *QScript* is one of the compilers that is given to the public in order to experiment *Google Quantum Playground's* limitations.

The stop watch played a crucial role in recording accurate results while executing *QScript* algorithms because during the research, no time comparison functions were available. However, *Google's Quantum Playground* continues to improve and there is a more likelihood to witness better results as time goes by because it is regularly getting updates on the *QScript's* architecture as well as minimum qubit challenges for each user on an appropriate effort basis. Presently, using a quantum machine is considered a better alternative, however one of the main deterrence to using this machines is the high pricing of its physical units.

6. Study Limitations

This research has various limitations. To start with, one of the main limitation is the absence of the physical quantum computer, as well as over reliance on publicly shared virtual quantum machines, which are hosted on Google and functions on the best-effort-basis, while using a single *QScript compiler* experiment.

The use of *Google's Quantum Playground* in this research as the other alternative quantum machine is another limitation to this research. It was lucky that there was a global quantum computer to be used by the public. Nevertheless, quantum computer recorded the highest performance capability at 22 qubits.

Lastly, the compiler of the quantum computer that is offered by the *Google's Quantum Playground, also referred to as QScript compiler* was another limitation. Irrespective of the computer's hardware power, all computers are limited based on their software utilization. The conclusion that reviews this paper's main points does not duplicate the paper's abstract as the conclusion. The conclusion may elaborate the significance of the research or propose various extensions and applications.

7. Conclusion

This research was conducted to explore the similarities and differences between new quantum computers and current silicon computers in terms of their performance capabilities. Initially, the research predictions were that silicon computers will be surpassed by the quantum computers without any great efforts. Based on the results from various experiments, this prediction was completely the opposite of the research findings. In each of the experiment conducted, quantum computer recorded a sluggish performance, together with several gap in the completion times as compared to silicon computer. Even though the research's predictions were not achieved, the current findings contribute significant new knowledge to the society. Also, this research involved a simple performance analysis in order to explore the new capabilities of the future quantum computers (next-generation quantum computers). At the moment, it is apparent that quantum computers may still not be the desired holy-grail of technology in various computing aspects, however no one knows what is in store for tomorrow.

References

[1] Bell, G. "Bell's Law for the birth and death of computer classes: A theory of the computer's evolution". *IEEE Solid-State Circuits Society Newsletter*, *13*(4), 8-19, 2008.

[2] Schaller, R. R. "Moore's law: past, present and future". *IEEE spectrum*, *34*(6), 52-59, 1997.

[3] Ladd, T. D., Jelezko, F., Laflamme, R., Nakamura, Y., Monroe, C., & O'Brien, J. L. "Quantum computers". *Nature*, *464*(7285), 45-53, 2010.

[4] N.A. "D-Wave Systems Breaks the 1000 Qubit Quantum Computing Barrier". Retrieved December 31, 2016, from http://www.dwavesys.com/press-releases/d-wave-systems-breaks-1000-qubit-quantum-computing-barrier.

[5] Nielsen, M. A., & Chuang, I. (2002). Quantum computation and quantum information.

[6] Georgescu, I. M., Ashhab, S., & Nori, F. (2014). Quantum simulation. *Reviews of Modern Physics*, *86*(1), 153.

[7] Bell, G. (2008). Bell's law for the birth and death of computer classes: A theory of the computer's evolution. *IEEE Solid-State Circuits Society Newsletter*, *13*(4), 8-19.

[8] Dongarra, J., Sterling, T., Simon, H., & Strohmaier, E. (2005). High-performance computing: clusters, constellations, MPPs, and future directions. *Computing in Science & Engineering*, *7*(2), 51-59.

[9] Rooney Peter. 'Amherst Prof Devises First Head-To-Head Speed Test With Conventional Computing, And The Quantum Computer Wins - Amherst College'. N.p., 2015.

[10] Xiaoming You; Xingwai Miao; Sheng Liu, "Quantum computing-based Ant Colony Optimization algorithm for TSP," Power Electronics and Intelligent Transportation System (PEITS), 2009 2nd International Conference on , vol.3, no., pp.359-362

[11] Ronnow, T. F. et al. 'Defining and Detecting Quantum Speedup'. *Science* 345.6195 (2014): 420-424.