Journal of Physics:
Conference Series

PAPER • OPEN ACCESS

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To cite this article: M.M.I M. Aisar *et al* 2018 *J. Phys.: Conf. Ser.* **1049** 012005

IOP Conf. Series: Journal of Physics: Conf. Series **1049** (2018) 012005 doi:10.1088/1742-6596/1049/1/012005

Performance Analysis between Quantum Computers and Silicon Computers: A Preliminary Investigation

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Abstract. The purpose of this study was to perform a preliminary investigation on the performance between a high-performance silicon computer and a quantum computer in terms of programming control statements. The study hypothesizes that the quantum computer would outperform the silicon computer in terms of processing performance. There were three types of experimental performance analysis scenarios conducted under the context of basic programming statements which are the '*for loop*', '*while*', and, '*if else*' control statements. To obtain the average of the completion times, the experiments were repeated five times. The obtained results suggest that the silicon computers outperformed the quantum processing capabilities.

1. Introduction

Computers have progressed at an increasingly fast rate over the recent years. To think that back in the early 90s, the ENIAC machine, developed by John W. Mauchly and J. Presper Eckert at the University of Pennsylvania was the first major computer that operated on vacuum tubes. These days however, human-kind is employing silicon computers with transistors for a multitude of tasks. Furthermore, in certain things, an even more state-of-the-art computer which is known as the quantum computer is beginning to be utilized.

Silicon computers have and still is a part of our lives from the late 90s. We use them to simplify so many things such as calculations, scheduling, and planning. There are several classes such as personal computers, workstations, minicomputers, mainframes, and supercomputers [1]. Their processing capabilities differ based on their classes and that brings about a point of concern. Moore's Law states that the processing power of computers will double every two years and carry on indefinitely [2]. There will be a breaking point for this and that is why we need preparations to move on to better and improved technology that can compensate for this growth which is the '*Quantum Computer*'.

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Quantum computers are the next step in computer evolution [3]. The technology that will one day step-up to replace our silicon computers in terms of performance. Unfortunately, they are still in development. However, D-Wave Systems has released a flagship model known as D-Wave Two or Vesuvius [4]. Regrettably, the price tag is far beyond the capabilities of most people and even if they are purchased, there is no definitive use for them albeit from solving relatively complex algorithms.
This study aimed to do a performance analysis on how a quantum computer and silicon computer initiate simple algorithms involving control statements. There were several tests conducted with the various control statements of programming to differentiate the completion times between the computer generations.

This paper is organized to several sections. Our introductory sections discussed in brief about silicon and quantum computing. It then follows by motivation of the study. Next, method used in this study is discussed. It then follows by the results and discussion. Finally, we conclude our paper.

2. Motivation

Quantum computers are such powerhouses of the computer world [3]. However, they are not getting the attention they deserve. What this means is that development on quantum computers are not a priority compared to the furthering of the current technology of the silicon computer.

While it is relatively true that if it is not broke, do not fix it. There comes a time when change is necessary. Just as we have stepped away from vacuum tube computers. Now comes the time where we as humans must begin the journey away from silicon computers. This however is not a journey to be undertaken lightly as quantum computers are not to be associated with how we understand computers today in their structural entirety.

At the present moment, quantum computers have a major downside which is mainly focused around instability because even minor interference can interfere with its processes as calculations are taking place at the quantum level. To counter this, most experimental system have to rely on absolute zero cooling as well as heavy shielding. This is both monumentally expensive and inconvenient to work with.

The study conducted was for the purpose of exposing the processing capabilities of quantum computers within the context of control statements algorithm when compared to a silicon computer.
Thus, the main objective of this study was to analyze the effects of executing various control statement algorithms experiments between a quantum computer and silicon computer.

3. Method

Two phases involved in this study includes experimental design and, testing and evaluation.

3.1. Experimental Design Phase

Experimental design was the first phase in this study. Within this phase, the programming algorithm guidelines for the experiment were made by standardizing the algorithms which were executed on both the quantum and silicon computers. In addition, the experiment environment was then prepared by utilizing similarly stable control statement (*for, while and if-else*) algorithm which would then be executed through QScript and C.

3.2. Testing and Evaluation Phase

Testing and evaluation was the second phase of this study. During this phase, the prepared algorithms from the experimental design phase were executed on both the quantum and silicon computer programming environments. For the quantum computer, the program algorithms were executed online via *Qscript* on the "*Google Quantum Playground*", while on the silicon computer, it was executed via *C-Free 5.0* including an optional online *C* compiler. The experiments were repeated several times for all three experiments on both machines. During the execution of the experiments, the results, which were the completion times were recorded. Every algorithm was executed a minimum of five to any amount of times as deemed necessary to account for random inconsistencies which may occur.

4. Results

This section details the results throughout the experimentation phase of the study. Data from all three experiment mediums which include the physical silicon computer and the quantum computer were illustrated.

4.1. For loop experiment

Figure 1 and Figure 2 are both results from the '*for loop*' experiments conducted.
Results from Figure 1 suggest the silicon computer complete each cycle with a difference of about three seconds due to internet latency. The quantum computer on the other hand provided erratic results from the experiment which ranged from the fastest completion of 14.83 minutes, to the slowest time of 21.25 minutes. The quantum machine completed the experiment in terms of minutes.

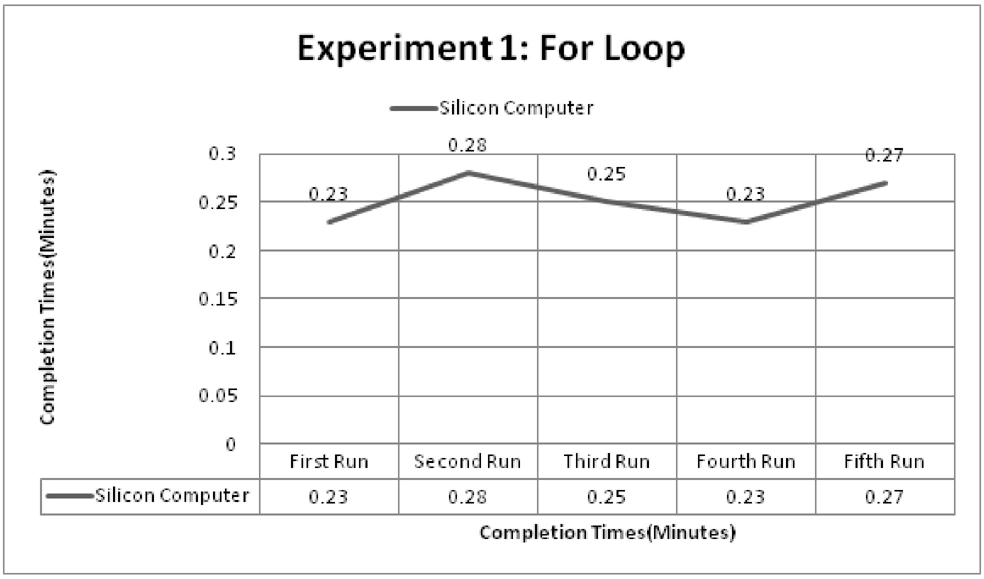

Figure 1: Physical Computer '*For Loop*' Experiment

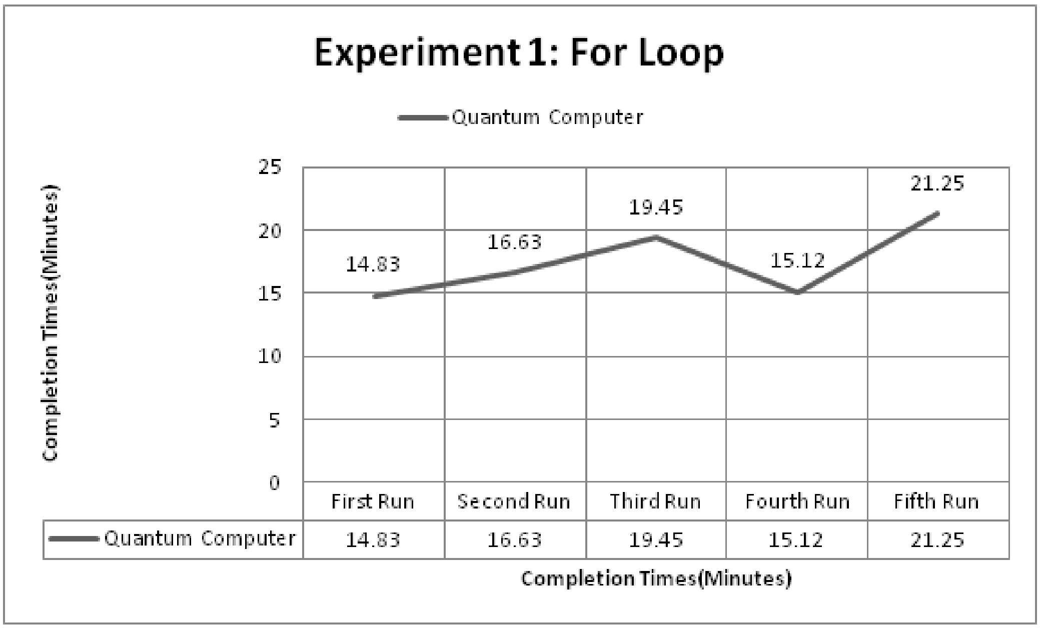

Figure 2: Quantum Computer 'For Loop' Experiment

4.2. While Experiment

Figure 3 and Figure 4 are results from the '*while*' experiment, the second that was conducted. The results from the silicon computers were relatively similar to the first '*for loop*' experiment in completion times with a difference of about three seconds as well between them most likely due to internet latency. Unlike the first experiment, there are no anomalies present in the completion times of the silicon machines. The silicon machines completed the experiment in terms of seconds.

The quantum computer on the second experiment also produced sluggish completions times of 14.1 minutes, to the slowest time of 17.85 minutes. The completion times are faster on average when comparing to the quantum computer results of the first experiment. This is most likely due to the '*while*' experiment not executing the extra processing requirements of the layered approach of the '*for loop*' whereby there are loops within loops. The quantum machine completed the experiment in terms of minutes.

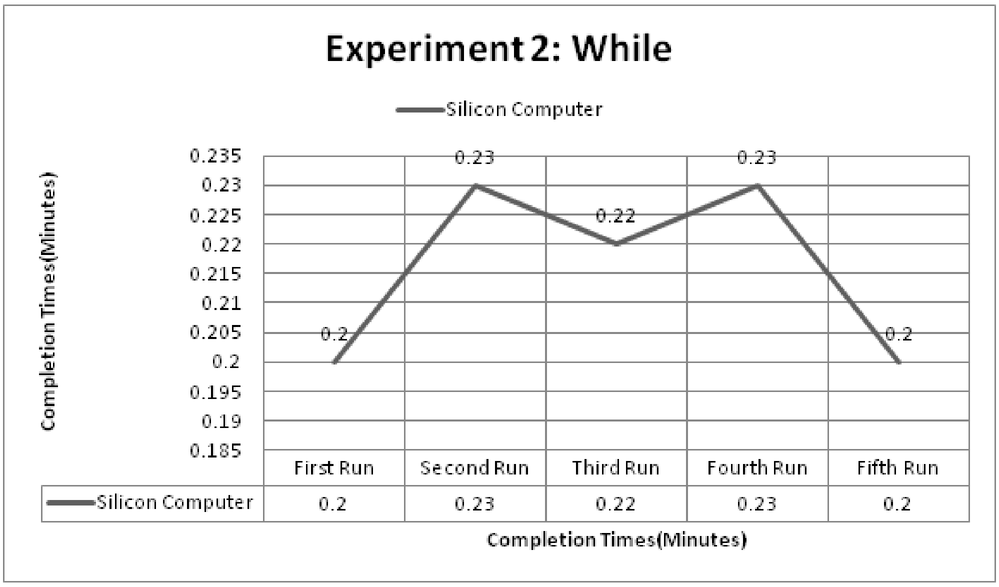

Figure 3: Physical Computer '*While*' Experiment

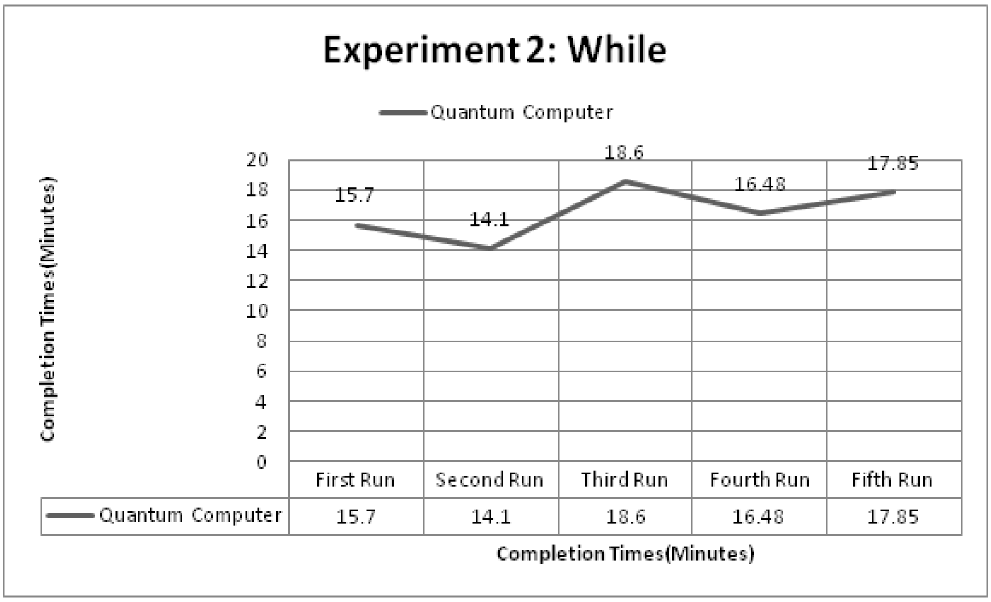

Figure 4: Quantum Computer 'While' Experiment

4.3. If-else Experiment

Figure 5 and Figure 6 are results from the '*if else*' experiment. The completion times of the physical silicon computer is relatively similar to the second experiment in average.

The quantum computer had the slowest average completion time out of all three experiments with the fastest completion time of this experiment being 16.35 minutes and the slowest being 20.45 minutes. The results are unexpected partly due to the physical silicon machine displaying an average completion time similar to the second experiment albeit having the slowest silicon machine completion times. These could be due to unexpected interference with the Internet connection during the course of this experiment. The quantum machine completed the experiment in terms of minutes.

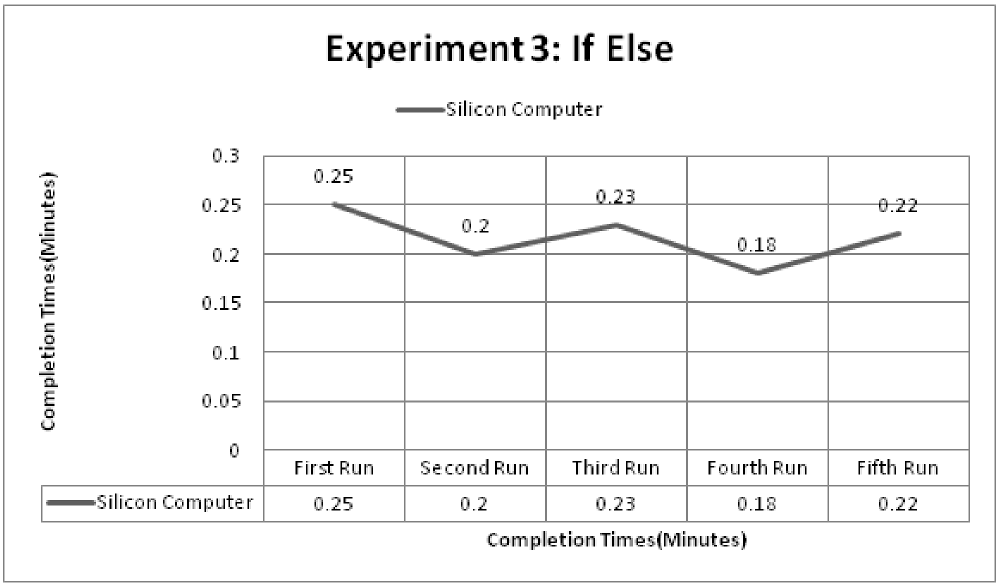

Figure 5: Physical Computer 'If Else' Experiment

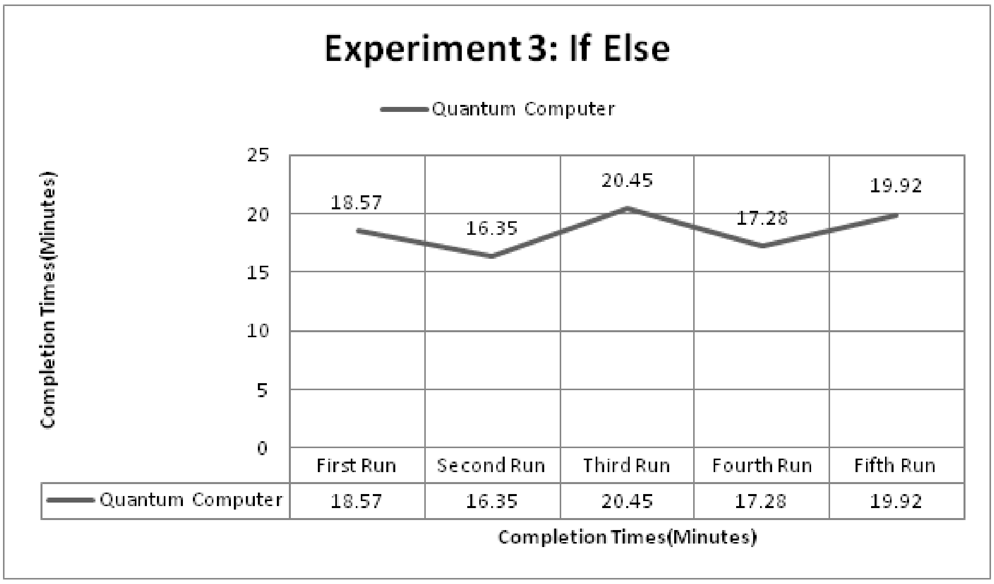

Figure 6: Quantum Computer 'If Else' Experiment

5. Discussion

All three of these experiments were conducted with both a physical silicon computer environment as well as a virtual quantum computer environment. The virtual capability of the quantum machine is stated at 22 *qubits* of processing power with about 2.2 *qubits* best effort basis per user while under heavy usage. The physical capability of the silicon machine on the other hand, is running at a processor with the following statistic: *Intel® Core™ i7-4720HQ CPU @ 2.60GHz*. Based on the bare minimum processing capability afforded by the quantum machine when compared to physical silicon machine, it was assumed during the course of the study that the quantum machine would outperform the silicon machines in completion times for the experiments but the results of this study proved otherwise.

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Physical silicon machines were able to compile, execute, and complete the simple control statement algorithms within terms of seconds with a minor difference in completion times between three to four seconds between the two machines most likely due to latency between executing the program algorithms and displaying the results. The results from the silicon machines were in terms of seconds. The average completion times between the three experiments were between 11 seconds to 20 seconds from physical environments of the silicon machines.

The quantum machine on the other hand was only available in a virtual-state and was also able to compile, execute and complete the simple control statement algorithms. The results from the quantum machine were in terms of minutes. The average completion times between the three experiments ranged between 14 minutes to 21 minutes overall.

Quantum computing itself is a relatively new technology which has recently picked up the pace within the recent years. On paper, the hardware specifications claim to outperform silicon computing significantly. Research previously conducted on quantum computing such as those discussed in chapter two of this study clearly portray the paper specifications are not merely just for show. However, this study has not been able to remotely achieve any significant evidence of quantum computing superiority in terms of executing simple control statement algorithms.

There may be a plethora of variables which had influenced the end-results of the study but it comes down to the availability of the quantum computer itself. This study was conducted without a physical quantum computer and substituting the variable with a virtual quantum computer hosted publically by Google which is known as, *Google's Quantum Playground*. The latency of the Internet most definitely affected the results and the availability of only a single compiler executing *QScript* was also likely to influence the experiments. Experiments previously conducted to analyse the performance of quantum computers may have utilized entirely difference compilers built to specifically execute and complete algorithms of specific natures. *QScript* on the other hand was just a general compiler offered to the public to experiment with the limitations of *Google's Quantum Playground*.

The additional inclusion of a stop watch was also needed as to properly record the results of executing the *QScript* algorithms since there was no time comparison functions during the course of this study. Nevertheless, *Google's Quantum Playground* improves as days goes by and it may most likely portray significantly better results in the near future as it receives updates to both the architecture of *QScript* and the minimum *qubit* limitations per user on best effort basis. However, as of now, it may be better to utilize a physical quantum machine but the steep pricing on physical units may be deterrence to most people.

6. Limitation of the Study

Throughout the entirety of the study, there were several limitations imposed.

The main limitations were the lack of a physical quantum computer, the reliance on a publically shared virtual quantum computer hosted by Google with functioned under best-effort-basis, and the utilization of only a single experimental compiler known as *QScript*.

The next limitation is the utilization of *Google's Quantum Playground* as an alternative quantum computer for use in the study. It was fortunate there even was a publically available quantum computer for public use globally. However, this was the issue as the quantum computer only offered a maximum performance capability of 22 qubits.

The final limitation was the quantum computer's compiler offered by *Google's Quantum Playground*, the *QScript* compiler. It is estimated that no matter how powerful a computer hardware may be, it is always limited by its software utilization of said hardware.

7. Conclusion

The study was undertaken to explore the performance capabilities of the new quantum computers when compared to our currently utilized silicon computers. Initially, the study predicted that the quantum computers would surpass the silicon computers without much effort.

Remarkably, that was entirely the opposite of the findings this study. After completion of all experiments, the results were used to determine which computer is more capable performance-wise in executing control statements when comparing the completion times between a quantum computer and silicon computer. The quantum computer had sluggish results with a massive gap in completion times when compared to the silicon computer.

Acknowledgment

This research work was supported by Ministry of Education (MOE), Malaysia and Universiti Teknologi MARA, Malaysia under Research Acculturation Grant Scheme (RAGS), Project code: "600-RMI/RAGS 5/3 (8/2014)".

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