RET Project: "Quantum Computing Profiling"

Research Experience for Teachers (RET) Summer 2021

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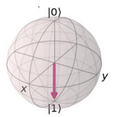
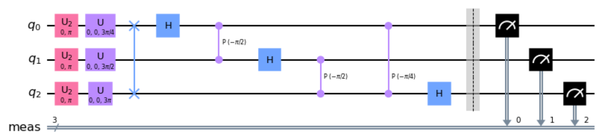
QUANTUM COMPUTER PROGRAMMING

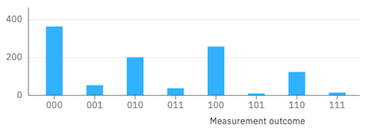
Prepare the Data: data in Quantum computers are stored in Qubits which can be in State 0 or 1 or in their superposition.



Create a Circuit: currently, to run a quantum algorithm we need to create a circuit that implements the steps in the algorithm as gates.

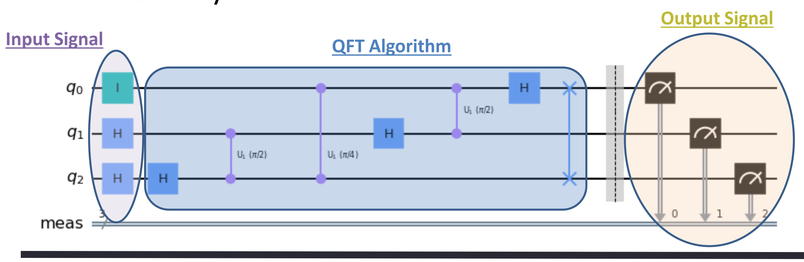


Analyze and Interpret the results: since they are provided as final 0/1 qubits states and are susceptible to random errors due to decoherence.



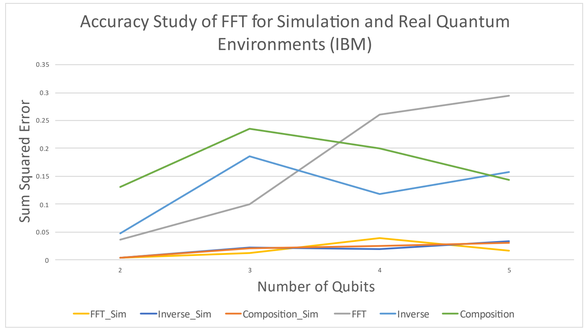
RESEARCH OBJECTIVES/PLAN

- Create a "Sample Code" that is relevant to the field of Quantum Computing to be used to profile current Quantum Computers and their Simulators.
- Run the sample code for IBM and Amazon environments.
- Profile each system.

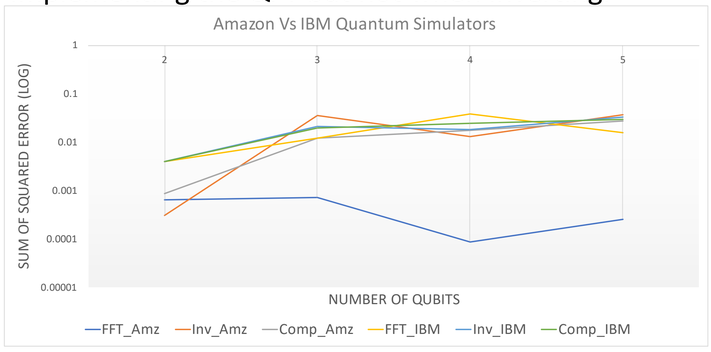


RESEARCH RESULTS/REMARKS

- The graph below shows QFT simulations on IBM Simulator and Real Quantum Machine (*ibmq_quito*).
- The error grows as the number if Qubits is added.
- Real QCs are not as reliable as the simulators predict.

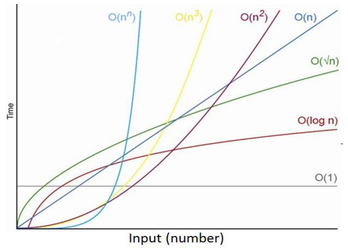


- The graph below compares QFT simulators for IBM and Amazon. There seem to be an Amazon advantage when implementing the QFT but not when inverting.



LESSON PLAN OBJECTIVES FOR MAT-227

- Use Big-O notation to study the growth of a given function. (MAT-227 MCCD Official Course Competencies).
- Introduce the idea of time/space complexity for algorithms and how it is computed.
- Explain the computation by using Big-O notation as well as counting principles that have been used since the beginning of the course.



LESSON IMPLEMENTATION/OUTCOMES

- The learners work in groups to find the complexity of two algorithms a min/max algorithm and a mean finding algorithm. We discuss the findings.
- Introduce Machine Learning ideas and present the difficulty to establish the complexity of algorithms that do not have a set number of steps due to their nondeterministic nature.
- Student work in groups to study a non-linear regression algorithm that will be the foundation for an individual take-home assessment.

RESEARCH REFERENCES

[1] J. Hidary, Quantum Computing: An Applied Approach. Champ: Springer, 2019.
[2] Weinstein, Yaakov S., et al. "Implementation of the quantum Fourier transform." Physical review letters 86.9 (2001): 1889.
[3] Terhal, Barbara M. "Quantum supremacy, here we come." Nature Physics 14.6 (2018):530.
[4] Qiskit Development Team "Learn quantum Computing Using Qiskit". URL: https://qiskit.org/textbook/preface.html (last accessed June, 2021).

TEACHING REFERENCES

[1] Levin, Oscar. "Discrete mathematics: An open introduction." 3rd Edition (2019). .
[2] R. Anderson "Algorithm Analysis & Time Simplified" July 19th, 2017. Medium.
[3] L. Li "Introduction to Linear Regression with Python" October 24th,2018. Toward Data Science.

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