Assignment 05: Observer effect, Measurements and Error Mitigation

Objectives

- You will understand why qubits cannot be measured
- You will measure the results of quantum experiments
- You will compare the results of a real Quantum Computer with a simulator
- You will get to know some limitations of Quantum Computers
- You will learn how errors can be mitigated

Requirements

- Notebook or Desktop Computer with access to the internet
- Access to IBM Quantum Lab (https://lab.quantum-computing.ibm.com/)

Solution Steps

As you already know from the previous assignments, we always added classical bits to our circuits to be able to measure the states of the qubits as it is not possible to measure qubits by themselves. Why is this the case?
In physics there is a phenomenon called the “observer effect” which states that the act of observation might disturb the observed system. In the real world, for example when we are measuring the pressure of tires, in most cases some air is going out of the tire and hence the pressure is changed. Nevertheless, in the real world the effects of observation on the observed objects are mostly negligible. In quantum mechanics however, it was found that the act of observation/measurement affects the experimental outcome. To avoid that the measurement influences the state of a qubit we indirectly measure qubits by using classical bits [1].

However, even if we do not directly measure qubits by themselves, errors can occur when we use a real Quantum Computer.

Why are Quantum Computers so prone to errors?
Both, internal as well as external factors can cause noise in quantum computations.
External factors can reach from magnetic fields, to variation in temperature, vibrations and impurities in the material of qubits, to name only some of them. On the other side also the interactions between qubits themselves can lead to errors [2].

IBM enables us to use real quantum devices. However, as there is only a limited number of Quantum Computers available there are often long queues and hence it takes sometime several minutes until the job is executed. Due to the fact that the realization of this learning lab is bound to time constraints and the use of real quantum computers does not allow for planning security, you are provided with a video that implements the experiment with the following link: https://youtu.be/KCRztPenN48

In case you want to execute this experiment by yourself please feel free to use the github link to access the code:
https://github.com/alexanderfechtel/Quantum-Computing/blob/db7e5b63a3a24446067c8d17eca855503cf4a0c3/Assignment%205_Error%20Mitigation.ipynb

Useful Resources for Own Research

The Problem with Quantum Computers:
https://blogs.scientificamerican.com/observations/the-problem-with-quantum-computers/

How IBM Quantum is advancing quantum error correction with hardware experiments:
https://research.ibm.com/blog/advancing-quantum-error-correction

How Quantum Computers will correct their errors:
https://www.quantamagazine.org/how-quantum-computers-will-correct-their-errors-20211116/

Thought experiment Schrödinger's Cat: https://youtu.be/UjaAxUO6-Uw

New approach for dealing with noise in Quantum Computing:
https://scitechdaily.com/scientists-work-to-turn-noise-on-quantum-computers-to-their-advantage/#:~:text=Scientists%20simulate%20'fingerprint'%20of%20noise,a%20death%20knell%20for%20computations.

Retrospective

Please answer the following questions:

1. What is the observer effect about?
2. What are different internal and external factors that can create noise for Quantum Computers?
3. What can be applied to reduce the error rate of a Quantum Computer?

Sources

[1] https://singularimages.net/2020/11/25/quantum-elements-abstractions-observer-effect/
[2] https://www.supertrends.com/the-biggest-obstacle-to-quantum-computing-is-noise/
[3] https://www.youtube.com/watch?v=yuDxHJOKsVA