CSCI 4140 Assignment Two

Due: November 20, 2020

Introduction

Our current quantum computers have physical qubits and not logical qubits. We've developed all of our algorithms using logical qubits, so they might not perform as well with noisy physical qubits. In this assignment you will explore the impact of noise on one of the classical quantum algorithms. The algorithm that I've selected is Grover's algorithm, since you have already implemented this algorithm in laboratory five. This assignment involves a little bit of programming, but mainly consists of running two experiments investigating different ways noise could impact this algorithm.

Noise Model

You will use the following noise model in this assignment:

```
def get_noise(p_meas,p_gate):

    error_meas = pauli_error([('X',p_meas), ('I', 1 - p_meas)])
    error_gate1 = depolarizing_error(p_gate, 1)
    error_gate2 = error_gate1.tensor(error_gate1)

    noise_model = NoiseModel()
    noise_model.add_all_qubit_quantum_error(error_meas, "measure") # measurement error is applied to measurements
    noise_model.add_all_qubit_quantum_error(error_gate1, ["x", "h", "mct"]) # single qubit gate error is applied to x gates
    noise_model.add_all_qubit_quantum_error(error_gate2, ["cx"]) # two qubit gate error is applied to cx gates

    return noise_model
```

This noise model is similar to ones that we have used before. The first parameter controls the measurement error and the second parameter controls the gate error.

Problem Oracles

We will use two problem oracles, both of which are produced by the grover_problem_oracle function that we used in laboratory five. The following table shows the parameters used to create the two problem oracles for this assignment.

Problem	Bits	Variant
Problem One	4	0
Problem Two	5	2

You have seen both of these oracles in laboratory five. You can also use the initialize_s and diffuser functions from that laboratory.

Experiment One

Start by implement both the Grover problems without a noise model. This will give you the base case for both experiments. You have already done this in laboratory five, so just copy your code from there. Note the probability of getting the correct result for both of these problems.

The first experiment involves investigating the impact of gate error rates on the two Grover problems. Start with a noise model with 0.01 as the values for both the measurement error and the gate error. What impact does this have on the result of Grover's algorithm? Try several different gate error rates to find the error level where the result is within 10% of the result obtained with no noise model.

Produce a table that has two rows, one for each of the Grover problems. The table has a column for each of the gate error rates that you tried (there should be at least 4 of them). The table entries contain the probability of the correct results, which you can read off of the histogram. This is the first part of your assignment report.

Experiment Two

Grover's algorithm is an iterative algorithm where the two basic steps are repeated until a solution is produced. Hypothesis: noise decreases the probability of obtaining the correct result, so performing more iterations of Grover's algorithm will produce a better result. In this part of the assignment you will run an experiment to determine if this hypothesis is true.

This can be done by adding iterations to your program code from the first experiment. Each iteration is two lines of code, so it is easy to cut and paste more iterations into the algorithm. Try this to see what happens to the probability of obtaining the correct result as the number of iterations increases. Is the hypothesis true? Why do you think this is the case? The second part of the assignment report is your answers to these two questions.

Assignment Report

The assignment report consists of two parts. The first part is the table you produced for the first experiment. The second part is the answers to the two question from the second experiment. Submit your report as a PDF file.