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Physics 495 Senior Project Description

In quantum computing, in order to measure the state of a transmon (a type of qubit), the transmon is first coupled to a resonator (such as a resonant cavity). While interacting with each other (dispersive interaction), the state of the qubit changes the frequency of the cavity and vice versa. We can then measure the state of the qubit by sending light near the cavity resonant frequency and analyzing the change in amplitude/phase of its reflection, since the complex and reflection coefficient of the cavity depends on its resonant frequency, which depends on the Qubit state. A digitizer (ADC) will take a measurement of the voltage signal, which sends a measurement signal composed of both real and imaginary parts ($Isin(wt) + Qsin(wt)$) to a computer. Ideally, the measurement signal will give a different set of I and Q values for the |0> state than for the |1> state of the qubit. However, due to noise from the measurement electronics and from quantum fluctuations, there will in fact be a distribution of I and Q values for each state, with some of these measurement signals potentially overlapping. The first feature of my project will therefore be an algorithm that, given a data set with two distributions of measurements (each assigned a qubit state), will optimize a threshold separating the measurement values corresponding to a |0> state to those pertaining to a |1> state.

To reduce the noise of the measurements, we can then send a stronger measurement tone and/or integrate our measurement for a longer time, but this can lead to a range of additional issues, such as the qubit changing state if the measurement tone is too strong, or jumping to another state if it takes too long. An additional feature of my project will then be another algorithm that, given a data set of many measurement distributions with varying strength and time, can find the ideal measurement strength and time so that the measurement error is minimized.

The algorithms I will code for my project are all intended to improve the accuracy, speed, and automation of Professor Levenson-Falk's lab measurements, which would help accelerate USC's Quantum Information Science research. They will take the form of a software library written in Python, and will make use of my algorithms, data science, and quantum physics knowledge learned throughout my four years at USC.

The rough milestones for the project are as follows:

Weeks 1-2 (January 18-31)

- Collect and visualize the data using python code and libraries.
- Research and brainstorm possible ways to implement the first algorithm (the state threshold algorithm), and decide on the best option(s).

Weeks 3-6 (February)

- Build the first prototype of the state threshold algorithm, assess the fidelity of the measurement results. (first two weeks)
- Improve on the prototype by collecting more data and tweaking the algorithm or trying out other methods until the algorithm is fully complete and deliverable. (By the end of the month)

Weeks 7-8 (March 1-14)

- Collect and visualize the data using python code and libraries.
- Research and brainstorm possible ways to implement the second algorithm (the ideal measurement strength/time algorithm), and decide on the best option(s).

Weeks 9-12 (March 15 - April 11)

- Build the first prototype of the second algorithm, assess the fidelity of the measurement results (first two weeks)
- Improve on the prototype by collecting more data and tweaking the algorithm or trying out other methods until the algorithm is fully complete and deliverable (by April 11)

Weeks 13+ - Project should be complete, so ideally some additional work could be done