Quantum Computing PHYS-541, Project 12

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State tomography using classical shadows

As quantum devices evolves in size and complexity, there is an increasing need to characterize and validate the quantum states we can create with them. The procedure of reconstruction of the quantum state from measurements on the system is called quantum state tomography. As we have seen during the course, interaction with the environment is unavoidable and therefore our quantum device has to be described as an open quantum system in terms of a density matrix. In this project, we will study how to perform the tomography of the state of a quantum computer, to estimate its density matrix.

Exact quantum state tomography places a high demand on computational resources, making it unfeasible for anything except small systems. For this reason, we will study a handy approximation of it, called classical shadows tomography. The procedure was introduced in this work and extensively reviewed here.

The goal of the project is:

1. Read and understand the main article and present its results.
2. Using Qiskit, write down a code to implement quantum state tomography of an N-qubit circuit and use it to measure the density matrix of a GHZ state of increasing size.
3. Using the QASM simulator, add a noise model from a IBM-Q backend and study how hardware noise and number of shots impact the density matrix of the system and its tomography. Measure the *fidelity* between the state you obtain and the pure GHZ state.
4. Implement the shadow tomography procedure as described in "Algorithm 1" in the main paper, measure the fidelity with the pure GHZ state (again considering a noise model), and compare the results to the standard tomography ones.
5. Discuss the strengths and the weaknesses of the two methods. What's the computational cost of shadow tomography? When does it become useful?