Quantum Computing PHYS-541g, Project 5

Teacher : vincenzo.savona@epfl.ch
Assistant : sara.alvesdossantos@epfl.ch, david.linteau@epfl.ch, shao.chiew@epfl.ch

Classical simulation of quantum circuits

How far can we go with the classical simulation of a quantum circuit?

In this project, we will study one of the most advanced techniques for simulating the output probability amplitudes of a quantum circuit on a classical computer. We will refer to the following article by the Google collaboration. The article is long but we will focus only on Sections 1 to 4.

The simulation method is based on a Schrödinger-Feynman approach, consisting of "cutting" the quantum circuit into several smaller parts "connected" by several two-qubit operations. Each part can be simulated separately, by applying in a smart way the unitary evolution. "Cutting" a two-qubit gate will result in a Feynman path-integral summation, which can be done sequentially, thus trading off memory requirements for time or parallel resources. This method leads to quite surprising results in terms of the maximal size of a quantum circuit that can be simulated at a reasonable cost. It highlights how difficult it is to reach quantum supremacy.

The goal of the project is:

1. Read and understand the article, in particular, Sections 1 to 4, and present its results.
2. Implement on your own PC (desktop or laptop), a "smart" Schrödinger simulation (one that does not store full unitary operators on the whole Hilbert space of n qubits) and see how large (in terms of the number n of qubits) and deep (in terms of the number d of layers) you can reasonably simulate. Present some results of this simulation.
3. Now implement a Schrödinger-Feynman approach using the Schrödinger algorithm that you have just developed. How far you can go now on your laptop? Present some results of this simulation.
4. Finally, present the role of noise in the quantum circuit, as discussed in Section 3 of the article. How can you take advantage of noise to speed up the classical simulation of a given quantum circuit?