M2 internship proposal

Quantum control and parameter estimation
for cat codes implemented on superconducting circuits

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Cat codes offer a very promising path towards the full quantum error correction of quantum processors based on superconducting circuits. As the system size grows larger, it becomes complex to optimize its control and measurement. Besides, parameter drifts (magnetic flux, drive amplitude and phase, …) require strategies to track them and adapt control pulses in real time. Recently, our group demonstrated the interest of using reinforcement learning to optimize the preparation of cat states in a microwave cavity [1]. Besides, in collaboration with Alice & Bob, we demonstrated autonomous correction protocols based on Josephson junctions [2]. We would now like to apply machine learning and feedback control to improve cat codes. However, until recently, it was not possible to train a large neural network (NN) with low latency between the NN and the quantum device.

Last June, we became one of the first labs in the world to get equipped with an Nvidia DGX Quantum instrument. This instrument couples an Nvidia Grace Hopper server to our devices with a few µs latency only! The intern will leverage this impressive computing power to realize quantum feedback on superconducting circuits with unprecedented computing power. The first task will consist in optimizing the drives that realize a CNOT gate between two cat qubits. We will use machine learning to learn what is the best driving sequence and identify possibly unknown parasitic terms in the Hamiltonian of the system. This task is part of the RobustSuperQ France 2030 project of PEPR Quantique.

After the internship, the PhD will focus on leveraging a new important result of quantum trajectories [3] by our collaborators at Mines ParisTech and Alice & Bob. When a quantum system is continuously monitored, it is possible to compute its current quantum state using the stochastic master equation. If one wants to use it on an actual quantum system, the time Δt between two measurement recording is nonzero, and the expressions from past theories were only accurate for infinitesimal Δt. The result of [3] provides a solution at any order in Δt! We will design an experiment on superconducting circuits to illustrate this result experimentally. In a later experiment, the DGX Quantum could be used to compute the quantum trajectory in real time and update the control of the system conditionally on the trajectory. This is a long-time dream in the field of quantum control. Finally, the student will perform real-time parameter estimation [4] of a cat qubit device and correct their drift by feedback.

The student will perform experiments in close collaboration with a postdoctoral fellow. The activities involve quantum-limited measurements in the microwave domain, temporal shaping and analysis of microwave pulses, numerical simulations, data post-processing, and manuscript writing. The position requires a sound knowledge of quantum information, a taste for both experiment and theory, interest in machine learning and a positive attitude to working in a team.

The internship will take place at ENS de Lyon, in the Quantum Circuit group (www.physinfo.fr) in collaboration with Alice & Bob (Thèse Cifre). If interested, please send your resume and reference contacts to Benjamin HUARD. Contact: benjamin.huard@ens-lyon.fr