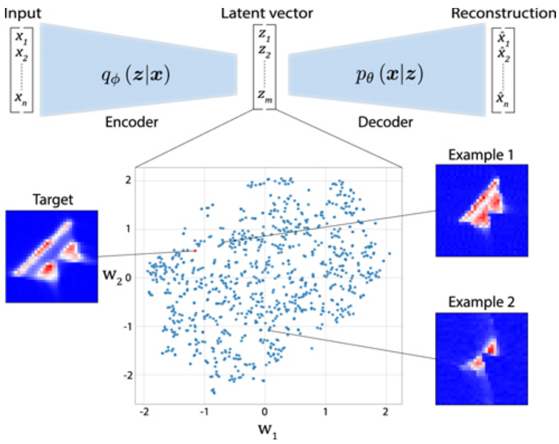
Master's Project

Machine Learning based Charge Stability Diagram Model and Feature Extractor



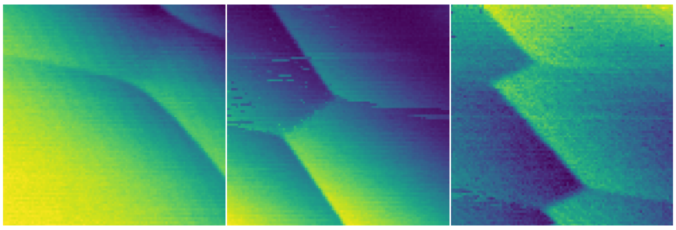


Figure 1 (left): A VAE[1] trained on Pauli spin blockade measurements (source: [2])
Figure 2 (top): A series of charge stability diagrams (CSD) recorded around an interdot transition. They have been measured in our lab.

Scientific Background

Quantum computation with electron spins in semiconductor heterostructures requires parameter tuning of individual quantum dots to calibrate out defects from fabrication and thus will need a lot of parameter optimizations to control the qubits with high fidelity. To form qubits, we confine electrons locally into dots by shaping the electrostatic potentials inside the heterostructure using voltages applied to metal structures on top the heterostructure. But with variations in the potential, confining the electrons solely by guessing the voltage configuration from simulations not feasible. That's why these confinements are tuned by hand. Which does not scale well to the Millions of qubits required for meaningful quantum computing.

Your Task

Create a simulation of quantum dot devices we have already gathered large amounts of data from, by means of generative models[2, 3]. Then quantify how well the region around the inter dot transition are recreated, how well the model generalizes to unseen regions of the parameter space, if the learned latent space can be dismantled into its principal components to manually change the features properties (e.g. to have a parametrized simulation) (see Fig. 4.b in [1]). You will also perform quantitative comparisons to classical approaches. (Project details can be adapted.)

Thus, obtain an algorithm to: • Train a model (ideally unsupervised) to extract the lever arm and tunnel couplings from 2D CSD measurements. • Simulate interdot transitions, including tunnel couplings and delayed electron transitions. • Detect if a given measurement fits to the already seen data and thus a tool to reject unknown defects.

This project will allow you to extend your knowledge in these topics, among other things:
Theory of electron spin qubits; Simulation of quantum effects; Generative neural networks

Contact

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[1] Auto-Encoding Variational Bayes https://arxiv.org/abs/1312.6114
[2] Quantum device fine-tuning using unsupervised embedding learning https://iopscience.iop.org/article/10.1088/1367-2630/abb64c
[3] Efficiently measuring a quantum device using machine learning https://www.nature.com/articles/s41534-019-0193-4