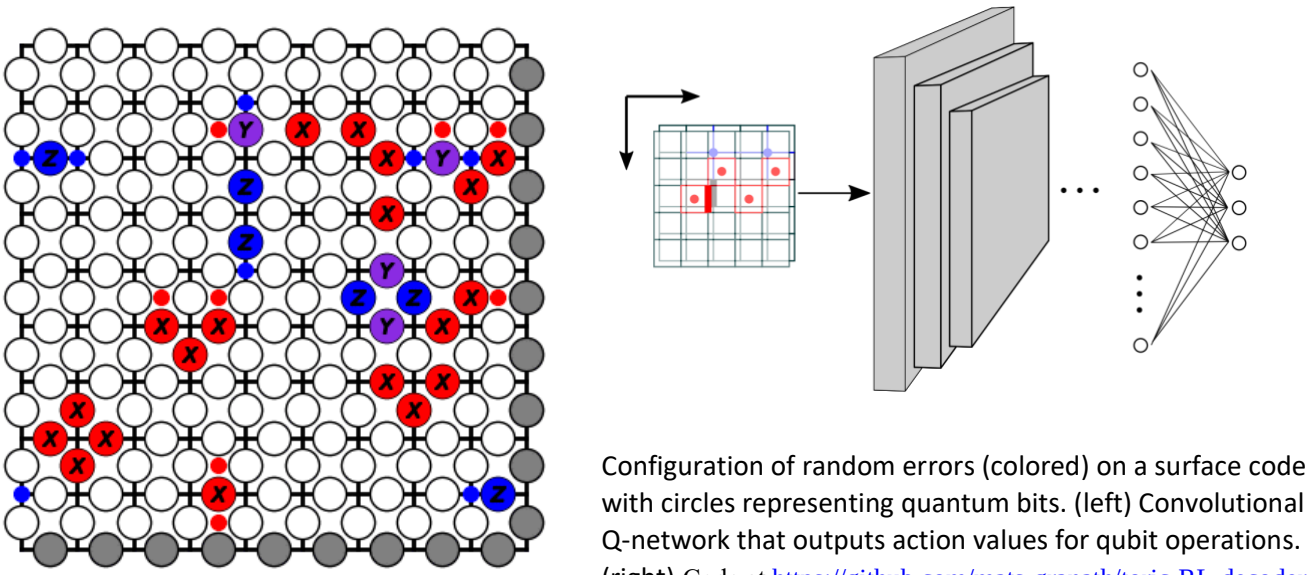
Master project: Machine learning for quantum error correction

Background

Due to the inherent fragility of quantum bits (qubits) a future universal quantum computer will require quantum error correction (QEC), the quantum version of the check bits of a classical computer. One of the most promising approaches is based on the surface code, where qubits are arranged on a lattice, interacting to build up a single more robust topological qubit. Even for this system, errors will be randomly introduced, and it is necessary to have a procedure for correcting errors without destroying the quantum state. In a recent project we have used deep reinforcement learning (deep Q-learning) to train an agent to do QEC Quantum 3, 183 (2019), Phys. Rev. Research 2, 023230 (2020).



Configuration of random errors (colored) on a surface code with circles representing quantum bits. (left) Convolutional Q-network that outputs action values for qubit operations. (right) Code at https://github.com/mats-granath/toric-RL-decoder

Project proposal

As part of our research in the area of QEC and quantum computing using machine learning (ML), several master thesis projects are available: 1) Expand existing framework using deep reinforcement learning to the more challenging (realistic) scenario that also includes random measurement error. This effectively introduces a non-Markovian time series aspect into the problem which may be addressed using recurrent neural networks. 2) A novel Monte Carlo based decoder has been developed in the group (Hammar et al, in preparation). This can be used to generate data for a large-scale supervised training effort on a network that contrary to existing approaches can do error correction in a partially error model independent fashion. 3) Development of QEC code tailored for the quantum hardware being built at Chalmers. (Non-ML project.) 4) ML assisted optimization using a quantum computer. This is a part of an effort to develop applications for a future quantum computer, using it to solve hard classical optimization problems.

Coding will be done in Python using PyTorch for ML applications. Compute resources at SNIC/C3SE will be used, including the new AI/ML cluster Alvis. Depending on interest the project can be geared more towards ML or more towards basics quantum computing and QEC.

The project is suitable for one or more students. Office space at Physics is expected to be available. The thesis is closely connected to research within The Wallenberg Centre for Quantum Technology WACQT.

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