Master in Photonics – "PHOTONICS BCN"
ERASMUS+ "EUROPHOTONICS"

MASTER THESIS PROPOSAL

Dates: April - September 2020

Laboratory :Grup d'Informació Quàntica
Institution: Universitat Autònoma Barcelona
City, Country : Bellaterra (Barcelona) Spain

Title of the master thesis: Machine Learning for Quantum Error Correction Codes

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Keywords : Quantum error correction, toric codes, machine learning

Summary of the subject (maximum 1 page) :

Quantum systems are vulnerable to decoherence so if they are to be used for reliably processing or transmitting information they need to be guarded against noise. Quantum error correcting codes (QECC) [1] accomplish this task by spreading—so to speak—this information across multiple physical systems. Strictly speaking a QECC is a subspace —the *code space*—of the total state space of *N*, *d*-dimensional quantum systems on which quantum information can be *encoded*, and *decoded*. We would like to design QECC with large error tolerance, high storage capacity, and efficient encoding and decoding procedures. In this thesis you will apply powerful machine learning techniques [2] in order to design efficient encoding and decoding procedures for two highly promising class of QECC; topological codes [3] and low density parity check codes [4].

You will be working closely with Drs Ramon Muñoz-Tapia, Michalis Skotiniotis (UAB) and Dr. Felix Huber (ICFO). The UAB team has recently developed RL techniques to design near-optimal decoders for the toric code [5], and has experience with QECC both for communication and computation as well as in metrology. Dr. Felix Huber is an expert in the construction of QECC and their interplay with multi-partite entanglement [6]. The team is interested in exploring further the use of RL for the design of optimal decoders for various different tasks, such as computation, communication and metrology, as well as for fundamental questions in entanglement theory.

What you will learn:

1. The stabilizer formalism for QECC
2. Topological codes: Surface codes, Kagome lattice, toric codes
3. Low density parity check codes
4. Reinforcement Learning: state (action)-value functions, Bellman equations, optimal policies.
5. Implementation of RL using deep artificial neural networks

[1] Gottesman D. Stabilizer codes and quantum error correction. arXiv preprint quant-ph/9705052.
[2] Sutton RS, Barto AG. Introduction to reinforcement learning. Cambridge: MIT press.
[3] Bombín H. An introduction to topological quantum codes. arXiv preprint arXiv:1311.0277.
[4] Kovalev AA, Pryadko LP. Fault tolerance of quantum low-density parity check codes with sublinear distance scaling. Physical Review A.28;020304.
[5] Laia Domingo Colome, Michalis Skotiniotis, and Ramon Muñoz-Tapia. "Reinforcement learning for optimal error correction of toric codes." *arXiv preprint arXiv:1911.02308*(2019).
[6] Huber, Felix, and Markus Grassl. "Quantum Codes of Maximal Distance and Highly Entangled Subspaces." *arXiv preprint arXiv:1907.07733* (2019).

Additional information :

* Required skills : Basic knowledge of quantum information.
* Miscellaneous : Computing skills will be very helpful.