Quantum machine learning with cold atoms

Supervision team: Silvia Bergamini, Calum MacCormick

Lead contact: Silvia Bergamini silvia.bergamini@open.ac.uk

Description:

Artificial intelligence and machine learning address the question of how to build computers that, through experience and access to data, automatically improve their predictions and decisions. They are among today's most rapidly growing technical fields and the limit is currently the computational power available. *Quantum machine learning* applies the power of quantum computing to machine learning algorithms, thus enabling to reach way beyond what can currently be done with classical computers.

Whilst a universal quantum computer is hard to build, a lot can be achieved with small-scale noisy systems (such as cold atoms in a dipole trap), which can outperform classical algorithms for specific tasks simply by virtue of modest quantum correlations. This massively reduces the complexity of the implementation of quantum tasks and the timeline for realization. The challenge is now to find meaningful algorithms that can fully exploit the potential of these systems to outperform classical machine in important mathematical tasks.

Deterministic quantum computation with one quantum bit (DQC1) is model of quantum computation that can be implemented in a cold atom set-up [1,2,3,4,5] and has been highlighted in literature for its power to outperform classical processors in specific tasks, such as finding the trace of a large matrix. Recent investigations carried out by this group, showed that it is possible to design a DQC1-style algorithm to implement a quantum circuit for specific kernels for Quantum Machine Learning, using a cold atoms system.

The purpose of this project is a feasibility study of the implementation of Quantum Machine Learning using Cold Atoms in laser tweezers [1,3]. We will explore different schemes and design the optimal implementation for this QML algorithm using qiskits and the IBM Quantum Computing [6]. We will also consider the effects of decoherence on the building blocks of the QML algorithm, in view of optimising the algorithm for our specific laboratory system [3], initially via numerical simulations.

Finally, the experimental investigation of the performance of the main operational blocks of the algorithm will demonstrate positive feasibility outcome. This work will be carried out in *the Cold Atoms Lab at the Open University* [7], a fully equipped facility aimed at quantum computing with laser-manipulated atoms.

This is an exciting, cutting-edge project that requires solid background knowledge of atomic Physics and quantum mechanics, and some previous laboratory experience. An interest in quantum computing and machine learning is desirable.

References:

1. Mansell and Bergamini New Journal of Physics, 16, Article 53045
2. Beterov, (Bergamini) Journal of Physics B: Atomic, Molecular and Optical Physics, Volume 53, Issue 18, id.182001
3. Krzyzanowska, K, (Bergamini S); et al Journal of Physics: Conference Series, Volume 793, Issue 1, article id. 012015
4. Auger, Bergamini et al Physical Review A, 96, Article 52320(5)
5. MacCormick , (Bergamini) Physical Review A, 93, Article 23805(9)
6. https://quantum-computing.ibm.com/
7. http://www.open.ac.uk/science/physical-science/research/physics/cold-atoms-quantum-technology

Qualifications required:

1st class or Upper 2nd degree in Physics.

Previous laboratory experience.