Education and Culture DG

ERASMUS MUNDUS

EUROPHOTONICS-POESII MASTER COURSE

PROPOSAL FOR A MASTER THESIS

Dates: April 1st, 2016 – September 30th, 2016

Laboratory: Quantum Information Theory, ICFO-The Institute of Photonic Sciences
City, Country: Castelldefels (Barcelona), Spain

Title of the master thesis: Towards Establishing the Limits of Computational Learning Theory with Quantum Resources

Name of the tutor of the master thesis: Peter Wittek and Antonio Acín
Email address: peter.wittek@icfo.es
Phone number: 935542237
Mail address:

Summary of the subject (maximum 1 page) :

With the growing size of available data in various fields such as finance, medical science, and social network, the current machine learning technique must be improved to enable the processing of big data. Recent theoretical developments hint at the benefits of applying quantum methods to learning algorithms. To begin with, computational complexity can be reduced exponentially in some cases, whereas we see quadratic reduction in others. Examples include quantum support vector machines, quantum nearest neighbour clustering, quantum associative memories, and quantum neural networks. As an umbrella term, we label these approaches as quantum machine learning. Quantum annealing (adiabatic quantum computing) is beginning to see scalable implementations, and this hardware appears to be extremely efficient in certain global optimization and learning problems. Apart from the pure academic interest, private companies also started to pay attention to this field.

Improved computational complexity and reduced training time are just one part of the equation. Through non-convex objective functions, quantum machine learning algorithms are more robust to noise and outliers, which might make their generalization performance – a key indicator of the quality of learning algorithms – better than that of many known classical algorithms. A plethora of open questions await further work. For instance, generalization performance is seldom studied in quantum algorithms. It is also unclear how the various forms of learning – inductive, transductive, active, supervised, unsupervised, or semi-supervised – map to quantum processes in general. One particular feature of quantum theory is that the data encoded on a quantum state might be difficult to access by the party performing computation on them. This allows for building blind quantum classifiers, relevant

in distributed yet secure learning settings. Addressing these issues will help us generalize known important classical results to the quantum case: sample and model complexity, the trade-off between complexity measures, “no free lunch” theorems, and the limits attainable by using quantum resources.

Practical questions also remain to be answered: for instance, it is possible to violate the time limits imposed by the gap in the adiabatic evolution and perform the process at a temperature higher than necessary, but the result is likely to be a low-level excited state of the target model rather than the ground state. This local optimum is still extremely useful for machine learning, but we need to understand the limits imposed by this methodology.

Keywords : machine learning, reinforcement learning, nonconvex optimization, model complexity, sample complexity, Grover search, adiabatic quantum computing

Additional information :

* Required skills : foundations in statistics and quantum information processing
* Miscellaneous :