Master thesis Project

Quantum inspired algorithms meet artificial intelligence

Quantum computers are expected to change computations as we know it. How are they supposed to do that? Essentially they allow us to perform a subpart of linear algebra (certain matrix-vector multiplications) on exponentially large vectors. A natural mathematical famework to understand what they do is the tensor network formalism. Conversally, tensor networks are becoming popular as tools that can take the place of quantum computers, yet run on perfectly classical hardware. To do so, they rely on a hidden underlying structure of some mathematical problems (a form of intrication) that can be harvested to compress exponentially large vectors into small tensor networks. An increasing number of, apparently exponentially difficult, problems are getting solved this way. Tensor networks are also intimately linked to artificial intelligence. For instance, automatic differentiation – the core algorithm at the center of all neural network optimizations – amounts to the contraction of a tensor network.

This internship lies at the intersection between theoretical quantum physics and applied mathematics. The goal will be to develop and apply new algorithms to "beat the curse of dimensionality", i.e. to push the frontier of problems that we are able to access computationally. More specifically, we will explore a new approach to address a class of high dimensional integrals that arise in the context of Feynman diagram calculations [1]. The envisionned algorithms combine the normalization flow approach (from neural networks) with the tensor cross interpolation (from tensor networks).

Good mathematical skills as well as scientific programming are necessary for the success of the project. The work will involve theoretical / formalism aspects as well as numerics. The Internship/PhD will take place within the theory group of CEA Grenoble, IRIG, PHELIQS (Photonics NanoElectronics and Quantum engineering). Our group contains 15-20 researchers working on nanoelectronics, superconductivity, magnetism and electronic correlations in close collaboration with experimental groups. The group has a long standing commitment in the development of open source softwares such as the Kwant project (http://kwant-proejct.org), the Tkwant project (http://tkwant.kwant-project.org) and more recently tensor networks (https://tensor4all.org). The project itself will be done under the direction of Xavier Waintal. We seek highly motivated students with a strong background in theoretical physics, quantum nanoelectronics and/or numerical simulations. The master project could naturally be extended into a PhD thesis upon mutual agreement.

[1] https://journals.aps.org/prx/abstract/10.1103/PhysRevX.10.041038

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