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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAADA-2024-49**
(à rappeler dans toute correspondance)

Lieu : Châtillon

Département/Dir./Serv. : DAAA

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DESCRIPTION DU STAGE

Thématique(s) : Quantum computing, partial differential equations, linear algebra, neural networks

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Quantum computing for solving scalar partial differential equations

Sujet : Quantum computers offer the possibility of technology exponentially more powerful than current classical computers, but the current state of the art is largely experimental with several obstacles to useful applications [1]. We are here interested in evaluating quantum computing and associated algorithms for physical simulations based on the resolution of partial differential equations (PDEs).

We will focus on variational quantum computing (VQC) which is a quantum-classical hybrid approach for solving optimization problems where the evaluation of the cost function is delegated to a quantum computer, while the optimization of variational parameters is performed on a classical computer. This approach has been used to solve nonlinear PDEs [2] whose solution is defined as the solution of a minimization problem. Quantum algorithms based on quantum nonlinear processing unit (QNPU) are introduced to efficiently calculate the cost function. Another approach in [3] consists in using quantum neural networks to encode the solution in a high-dimensional function space of a qubit register. Using differentiable quantum circuits allows accurate evaluation of the gradients required in the learning process coupled with an accurate spectral approximation of the solution in the function space.

However, most of the time is spent in the classical algorithm which mitigates the expected speedup of these hybrid approaches. We are therefore interested in another algorithms that would delegate more instructions to the quantum computer.

The candidate will evaluate quantum algorithms based on VQC based on the existing literature [2,3] for the approximation of solutions to problems involving scalar linear and nonlinear PDEs. We will consider the linear transport equation and the nonlinear Burgers' equation. We will focus on resolution methods using expansive linear algebra operations to enhance the relative part of the quantum computing.

To this end, the candidate will implement and run experiments by using a quantum simulator's programming framework (e.g., myQLM from Atos). The results will be analyzed in terms of accuracy, impact of noise, theoretical performance, etc.

[1] https://en.wikipedia.org/wiki/Quantum_computing

[2] M. Lubasch et al., Variational quantum algorithms for nonlinear problems, Phys. Rev. A, 101 (2020), 010301, https://doi.org/10.1103/PhysRevA.101.010301.

[3] O. Kyriienko et al. Solving nonlinear differential equations with differentiable quantum circuits, Phys. Rev. A, 103 (2021), 052416, https://doi.org/10.1103/PhysRevA.103.052416.

Est-il possible d'envisager un travail en binôme ? **Non**

Méthodes à mettre en oeuvre :

☒ Recherche théorique ☐ Travail de synthèse

☒ Recherche appliquée ☐ Travail de documentation

☐ Recherche expérimentale	☐ Participation à une réalisation
Possibilité de prolongation en thèse :	**A renseigner**

Durée du stage : Minimum : 5 months Maximum : 6 months

Période souhaitée : February to September 2024

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Background in quantum mechanics, applied mathematics and scientific computing; programming skills in python; motivation to learn	M.Sc. in applied mathematics, mechanics or a related discipline, with excellent academic records