Utilisation of Quantum Computers in Simulations of Heat Transfer in Flowing Fluids

Sicner, Matej (School: The St. Cyril and Methodius Comprehensive School and Pedagogical High School Brno)

Quantum computing promises significant advancements in computational speed and efficiency, presenting new opportunities for solving complex scientific problems. This project aims to fully demonstrate the practical application of quantum algorithms—specifically, the Harrow-Hassidim-Lloyd (HHL) and Variational Quantum Linear Solver (VQLS)—in the field of fluid dynamics by simulating heat conduction in flowing fluids. Traditional computational methods, such as Gaussian elimination, are limited by cubic scaling with system size, rendering them inefficient for large-scale problems. Our approach involves a comprehensive process that begins with the physical problem description, followed by the spatial discretization of fluid dynamics equations to formulate systems of linear equations. These systems are then solved using the HHL and VQLS algorithms, which are theoretically capable of logarithmic and poly-logarithmic complexity scaling, respectively. The simulations were executed using the qiskit library to approximate quantum computations on classical hardware. Results demonstrate that quantum algorithms can maintain a relative solution accuracy deviation as low as 1.8% compared to classical solutions. The HHL algorithm, in particular, shows promising quadratic scaling in relation to matrix size and near-linear scaling with the matrix condition number. These outcomes highlight the quantum algorithms' potential to effectively translate theoretical computational advantages into practical, real-world applications in engineering. Our study not only showcases the full process of applying quantum computing from conceptualization to solution but also underscores the need for further research to enhance algorithm performance.