FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
FACULTY OF SCIENCES

Fraunhofer IIS

Master Thesis

Learning Shallow Quantum Algorithms

Motivation

Spurred by the recent experimental demonstration of so-called quantum advantage for a classically hard random-number generation problem with actual quantum hardware, the research community has increased its efforts to propose new types of quantum algorithms for the still imperfect, noisy intermediate scale quantum (NISQ) computing devices we have today.
One class of algorithms that have emerged as viable candidates for achieving quantum advantage with NISQ devices also in other application domains beyond random number generation are **variational quantum circuits** (VQCs). These quantum circuits lend themselves as a platform for **quantum machine learning**, here understood as the generation of quantum algorithms from data. While the requirements on the expressivity of these circuits to reach quantum advantage and related complexity-theoretic problems pose open research questions, experimentation with available architectures might uncover promising directions.

Project Idea

Within the framework of a joint master thesis project between the Chair for Quantum Theory at Friedrich-Alexander University Erlangen-Nürnberg and the Self-Learning Systems group at the Fraunhofer Institute for Integrated Circuits, the potential of VQCs for the task of learning efficient and NISQ-compatible quantum algorithms is to be explored.
While quantum algorithms coming with the guarantee of exponential speed-ups seem to require fault-tolerant quantum computation, it remains an open question, whether shallow and thereby NISQ-compatible quantum algorithms with (maybe non-exponential) speed-up are possible. One approach to shorten existing algorithms is by employing optimization strategies to minimize gate count when expanding and approximating a quantum circuit by a given universal gate set.
Another approach is to try and learn a quantum algorithm for a specific purpose with a given gate budget from appropriately generated data via the paradigm of variational quantum circuits. As many machine learning and optimization algorithms rely on matrix inversion, it would be very desirable to employ such a procedure to arrive at NISQ implementation of, e.g., the HHL quantum algorithm, or similar algorithms, for matrix inversion.
The goal of the master thesis project is the development of a structure- and parameter-learning method for VQCs, along with the required experimentation and benchmarking, for the purpose of learning efficient and NISQ implementable quantum circuits.

Required Skills

Basic knowledge of variational quantum circuits and machine learning, Python programming

Literature

[1] Mauro E.S. Morales, Timur Tlyachev, Jacob Biamonte, “Variationally Learning Grover's Quantum Search Algorithm”, Phys. Rev. A 98, 062333 (2018)
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[4] Mateusz Ostaszewski, Edward Grant, Marcello Benedetti, “Quantum circuit structure learning”, arXiv:1905.09692 [quant-ph]
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