MON 18: Quantum Algorithms

Time: Monday 16:30–18:15 Location: ZHG007

MON 18.1 Mon 16:30 ZHG007

Simulation of IQP circuits with hypergraph states — •Matthias Heller[1], Paul Haubenwallner[1], and Mariami Gachechiladze[2] — [1]Fraunhofer Institut für Graphische Datenverarbeitung IGD, Darmstadt, Germany — [2]Techniche Universität Darmstadt, Darmstadt, Germany

Instantaneous quantum polynomial (IQP) circuits have recently gained a significant amount of attention due to their special structure, which allows for fault-tolerant implementation in the near future. It has been argued that classical sampling from these circuits is computationally hard, making this task a prime candidate for demonstrating quantum advantage. In this talk, we discuss the connection between IQP circuits and hypergraph states and show how graphical rules can be used to simulate these circuits. We test our approach for hypercube IQP circuits, a fault-tolerant instance of IQPs that has been introduced recently in the literature. Finally, we identify IQP structures which are easy to simulate.

MON 18.2 Mon 16:45 ZHG007

Variational quantum algorithms for continuum modelling of batteries — •Albert Pool[1,2], Michael Schelling[1,2], and Birger Horstmann[1,2,3] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Wilhelm-Runge-Str. 10, 89081 Ulm — [2]Helmholtz Institute Ulm, Helmholtzstr. 11, 89081 Ulm — [3]Department of Physics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm

We present variational quantum algorithms (VQAs) for continuum models in electro-chemical energy-storage-systems, focusing on transport equations in batteries. Our method uses a space-time encoding with time evolution based on the Feynman-Kitaev Hamiltonian, as introduced in [1]. We show how to implement the non-linear terms of the transport equations and discuss efficient quantum circuits to evaluate the terms of this Hamiltonian, and to realize suitable boundary conditions. Further, we present an adaptive optimisation strategy to find the ground state, which represents the solution to a differential-algebraic system of equations.

[1] Pool et al. Phys. Rev. Research 6, 033257 (2024).

MON 18.3 Mon 17:00 ZHG007

Influence of different feature maps on solving partial differential equations on quantum computers — •David Steffen[1,2], Michael Schelling[1,2], Felix Schwab[1,2], and Birger Horstmann[1,2,3] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Wilhelm-Runge-Str. 10, 89081 Ulm — [2]Helmholtz Institute Ulm, Helmholtzstr. 11, 89081 Ulm — [3]Department of Physics, Ulm University, Albert-Einstein-Allee 11, 89081 Ulm

Differentiable quantum circuits (DQCs) [1] are variational algorithms to solve partial differential equations on quantum computers. We investigate the potential of this method to solve systems of coupled partial differential equations as they occur in the simulation of electrochemical systems, e.g., fuel cells and batteries. A crucial part of DQCs is the feature space in which the input variables are encoded into quantum states. Possible choices are a Chebyshev feature map or a Fourier feature map, that generate a set of corresponding basis functions to fit the desired model. We show results on the influence of different feature maps on the expressibility and trainability for spatiotemporal models, on the use case of transport equations from battery simulation.

[1] Kyriienko, O. et al., Phys. Rev. A 2021, 103, 052416

MON 18.4 Mon 17:15 ZHG007

Bridging wire and gate cutting with ZX-calculus — •Marco Schumann[1,2], Tobias Stollenwerk[1], and Alessandro Ciani[1] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Computing Analytics (PGI-12), 52425 Jülich, Germany — [2]Theor. Physics, Saarland University, 66123 Saarbrücken, Germany

Wire cuts and gate cuts allow one to reduce the required number of qubits for evaluating expectation values of the output states of quantum circuits. This comes at the price of a sampling overhead. While throughout the literature, wire and gate cutting are mostly seen as two independent methods for circuit cutting, our contribution in this work [1] is to establish a connection between them. We find that, since in ZX-calculus only connectivity matters, many known gate cuts can be obtained by cutting wires in these gates. Furthermore, we obtain a decomposition of the multi-qubit controlled-Z gate with decreased sampling overhead. Our work gives new ways of thinking about circuit cutting that can be particularly valuable for finding decompositions of large unitary gates. Besides, it sheds light on the question of why exploiting classical communication decreases the sampling overhead of a wire cut but does not do so for certain gate decompositions. In particular, using wire cuts with classical communication, we obtain gate decompositions that do not require classical communication.

[1] M. Schumann, T. Stollenwerk, A. Ciani, Bridging wire and gate cutting with ZX-calculus (2025). arXiv: 2503.11494.

[2] C. Ufrecht et al., Cutting multi-control quantum gates with zx calculus, Quantum 7, 1147 (2023).

MON 18.5 Mon 17:30 ZHG007

Optimizing ZX-diagrams with deep reinforcement learning — •Maximilian Nägele[1,2] and Florian Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]Physics Department, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

ZX-diagrams are a powerful graphical language for the description of quantum processes with applications in fundamental quantum mechanics, quantum circuit optimization, tensor network simulation, and many more. The utility of ZX-diagrams relies on a set of local transformation rules that can be applied to them without changing the underlying quantum process they describe. These rules can be exploited to optimize the structure of ZX-diagrams for a range of applications. However, finding an optimal sequence of transformation rules is generally an open problem. In this work, we bring together ZX-diagrams with reinforcement learning, a machine learning technique designed to discover an optimal sequence of actions in a decision-making problem and show that a trained reinforcement learning agent can significantly outperform other optimization techniques like a greedy strategy, simulated annealing, and state-of-the-art hand-crafted algorithms. The use of graph neural networks to encode the policy of the agent enables generalization to diagrams much bigger than seen during the training phase.

MON 18.6 Mon 17:45 ZHG007

Quantum Text Generation with Quantum Context-Sensitive Word Embeddings: A Comparative Architecture and Experimental Analysis — •Charles Varmantchaonala M.[1], Niclas Götting[1], Nils-Erik Schütte[1], J. L. E Fendji[2,3], and Christopher Gies[1] — [1]Institut für Physik, Fakultät V, Carl von Ossietzky Universität Oldenburg, 26129 Oldenburg — [2]Department of Computer Engineering University Institute of Technology University of Ngaoundéré, Ngaoundere, Cameroon — [3]Stellenbosch Institute for Advanced Study (STIAS) Wallenberg Research Centre at Stellenbosch University Stellenbosch, South Africa

Quantum machine learning has recently gained attention for its potential to enhance natural language processing tasks[1,2]. In this talk, we present a quantum-based text generation architecture that incorporates a quantum-native word embedding method using parameterized quantum circuits. This approach encodes classical contextual information into quantum states by designing specific quantum circuits, resulting in word embeddings that leverage quantum properties. These embeddings are then used in a prototype text generation model. To assess its effectiveness, we perform a comparative analysis against a classical model using small-scale and controlled datasets. The talk highlights both the current limitations and the potential of quantum word embeddings in language modeling. We conclude with a discussion on outlooks toward near-term quantum language tasks.

1. C. Varmantchaonala M. et al., IEEE Access 12, 99578 (2024)
2. J. Shi et al., IEEE TNNLS, 1 (2024)

MON 18.7 Mon 18:00 ZHG007

yquant - Typesetting quantum circuits in a human-readable language — •Benjamin Desef — DLR e.V., Ulm, Germany

After many months of intense work, you want to write down your results in a presentable way. Working in quantum information, it may well be that your paper will contain one, two, or many quantum circuits—either to quickly visualize something that is said in the main text anyway or because it is an integral part of your work. Of course, the result should look nice and embed well with the rest of your document, so you would rather not use some external tools to generate a picture. But you also don't want to spend hours trying to bring it to the tabular form that is required by qcircuit and quantikz. In fact, it would be nice if by looking at the LaTeX source code, you could directly understand the circuit and make modifications without going back to whatever tool generated this fify-column table.

To answer these—my own—demands, I developed yquant, which allows to write quantum circuits in a human-readable language directly in LaTeX, with no external tools involved. In this talk, I will give a quick overview, demostrate you can even use the package for your quick-and-not-dirty-at-all sketches, answer questions, and collect ideas for future features.