Q 74: Quantum Information – Concepts and Methods

Time: Friday 11:00–13:00 Location: P 10

Q 74.1 Fri 11:00 P 10

Computational Capabilities and Compilation Strategies for Trapped-Ion Quantum Computers — •Jurek Eisinger[1], Ludwig Schmid[2], Daniel Schönberger[2], Janine Hilder[1,3], Christian Marciniak[3], Ulrich Poschinger[1], Ferdinand Schmidt-Kaler[1], and Robert Wille[2] — [1]QUANTUM, University of Mainz, Department of Physics, Staudingerweg 7, Germany — [2]Chair for Design Automation, Technical University of Munich, Germany — [3]neQxt, 63906 Erlenbach am Main, Germany

Trapped-ion quantum computers mature to larger qubit numbers, but their computational capability is limited by architectural and control constraints. We present a framework for quantifying and optimizing the computational capabilities of trapped-ion processors. Using compiler techniques from classical computer science, we show how arbitrary quantum circuits can be mapped to hardware-efficient sequences of operations, optimized for metrics such as shuttling distance and gate overhead. The approach is demonstrated for both 1D and 2D [Schoenberger et al., Proc. IEEE QSW (2025), DOI: 10.1109/QSW67625.2025.00023] shuttling architectures, and extended toward logical qubit encodings to support fault-tolerant operations in future large-scale systems. In this context, we introduce a universal routing and scheduling algorithm for a shuttling-based trapped-ion quantum computer that efficiently orchestrates qubit register reconfiguration, and gate execution, tailored to varying levels of ion-qubit connectivity.

Q 74.2 Fri 11:15 P 10

Studying the feasibility of distributed quantum computing enabled via satellite communication — •Lukas Pausch[1], Davide Orsucci[2], Philipp Kleinpass[2], Alexander Sauer[1], Florian Moll[2], and Matthias Zimmermann[1] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Quantum Technologies, Ulm, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Communications and Navigation, Oberpfaffenhofen, Germany

In future quantum networks, satellite-mediated quantum communication could be used to enable distributed quantum computing (DQC). In this talk, we present the current state of our ongoing analysis on potential use cases for satellite-enabled distributed quantum computing and on their feasibility based on hardware restrictions and algorithm requirements: On the one hand, we investigate entanglement distribution via satellites, considering different orbits and entanglement distribution schemes, and we evaluate restrictions regarding, e.g., entanglement distribution rates or connection times. On the other hand, we analyse and assess possible DQC applications that might require long-range communication. Furthermore, we investigate the current state of the art of quantum-computing hardware and interconnects between matter qubits and flying qubits (photons), with a particular focus on DQC. These considerations will enable us to evaluate the gap to be bridged by future developments and to identify the necessary steps to be taken for a future implementation of satellite-enabled DQC.

Q 74.3 Fri 11:30 P 10

QuKAN: A Quantum Circuit Born Machine Approach to Quantum Kolmogorov Arnold Networks — •Yannick Werner[1,2], Akash Malemath[2], Mengxi Liu[1], Vitor Fortes Rey[1,2], Nikolaos Palaiodimopoulos[1,2], Paul Lukowicz[1,2], and Maximilian Kiefer-Emmanouilidis[1,2] — [1]DFKI Kaiserslautern — [2]RPTU Kaiserslautern-Landau

Kolmogorov Arnold networks, based on the Kolmogorov Arnold representation theorem, provide a compact alternative to conventional neural networks by placing learnable functions on edges rather than nodes. While highly expressive in classical settings, their potential in quantum machine learning remains largely unexplored. In this work, we present an implementation of these KAN architectures in both hybrid and fully quantum forms using a Quantum Circuit Born Machine. We adapt the KAN transfer using pre-trained residual functions, thereby exploiting the representational power of parametrized quantum circuits. In the hybrid model we combine classical KAN components with quantum subroutines, while the fully quantum version the entire architecture of the residual function is translated to a quantum model. We demonstrate the feasibility, interpretability and performance of the proposed Quantum KAN (QuKAN) architecture.

Q 74.4 Fri 11:45 P 10

Exploring Disorder Effects in Quantum Generative Models — •Nikolaos Palaiodimopoulos[1,2], Yannick Werner[1,2], Jasmin Frkatovic[1], Vitor Fortes Rey[1], Matthias Tchöpe[2], Sungho Suh[2], Paul Lukowicz[1,2], and Maximilian Kiefer-Emmanouilidis[1,2] — [1]RPTU Kaiserslautern-Landau — [2]DFKI Kaiserslautern

Disordered quantum many-body systems (DQS) and quantum neural networks (QNNs) exhibit strong structural parallels, with a DQS effectively functioning as a QNN with randomly initialized parameters. We show that random processes can act as a deceptive quantum generative mechanism in QNNs, where unitarity preserves memory effects absent in classical networks. These effects impact both the learnability and trainability of QNNs and can lead to an overestimation of their generative capabilities. While DQS can be useful for tasks such as image augmentation, we caution that evaluations on overly simple datasets may misrepresent the true power of current quantum generative models.

Q 74.5 Fri 12:00 P 10

On the Generalization Limits of Quantum Generative Adversarial Networks with Pure State Generators — Jasmin Frkatovic[1], •Akash Malemath[1], Ivan Kankeu[1], Yannick Werner[1,2], Matthias Tschöpe[1], Vitor Fortes Rey[1,2], Sungho Suh[3], Paul Lukowicz[1,2], Nikolaos Palaiodimopoulos[1,2], and Maximilian Kiefer Emmanouilidis[1,2] — [1]RPTU Kaiserslautern-Landau — [2]DFKI, Kaiserslautern — [3]Korea University, Seoul

Quantum Generative Adversarial Networks (QGANs) have emerged as promising candidates for quantum-enhanced generative modelling, yet their practical capabilities remain insufficiently understood. In this work, we investigate the generalization performance of two state-of-the-art fully quantum GAN architectures, QuGAN and IQGAN, in image generation tasks. Using extensive numerical experiments on MNIST and CIFAR-10, we systematically show that both models fail to learn the underlying data distribution and instead converge to reproducing only the dominant average features of each class, even under multi-class training and increased circuit expressivity. To explain these empirical failures, we derive an analytic lower bound on the achievable fidelity of pure-state quantum generators. Using the Helstrom bound, we prove that any QGAN whose generator outputs a single pure quantum state cannot approximate high-rank data distributions beyond the fidelity associated with the dataset's leading eigenvector. Our results highlight intrinsic expressivity bottlenecks in current QGAN designs and motivate the development of quantum generators capable of producing mixed-state outputs or incorporating non-linear mechanisms.

Q 74.6 Fri 12:15 P 10

Applications of blind quantum computation - hiding a Grover search algorithm — •Alexander Sauer, Alexander von Consbruch, and Matthias Zimmermann — German Aerospace Center (DLR), Institute of Quantum Techologies, Wilhelm-Runge-Straße 10, Ulm, 89081, Germany

With quantum-capable devices becoming readily available and the ongoing development of quantum computers, quantum networks are within grasp. Apart from the enhanced computational power of quantum computers, these networks also provide new opportunities in security and secrecy. One new method that becomes available is blind quantum computing, in which a powerful quantum computer acts as a server and performs computations for a distant client without getting knowledge about details of the computation [1]. We investigate applications of blind quantum computing and the introduced overhead on communication between the involved parties and complexity on the quantum server. In particular, we present a protocol for a hidden Grover search algorithm utilizing additional qubits on a quantum server which are securely initialized by the client.

[1] Fitzsimons, J.F. (2017), npj Quantum Information 3(1), 23.

Q 74.7 Fri 12:30 P 10

Two-qubit encoding strategy for a continuous quantum system — •Sebastian Luhn and Matthias Zimmermann — DLR e.V., Institut für Quantentechnologien, Ulm

Bosonic codes employ particular states of an infinite-dimensional Hilbert space to encode a qubit within a continuous quantum system. Despite the enormous resources available in a continuous quantum system [1], typical encodings only exist for single qubits [2]. Here we go one step further and present an encoding scheme for two qubits (four states), which protects against errors in small shifts of the canonical variables position q and momentum p. Furthermore, we present a universal set of single and two-qubit operations, based on particular symmetry operations for continuous quantum states represented by a square lattice in phase space.

[1] Lloyd, S. and Braunstein, S., Quantum Computation over Continuous Variables, Phys. Rev. Lett. **82**, 1784-1787 (1999).

[2] Gottesman, D., Kitaev, A., and Preskill, J., Encoding a qubit in an oscillator, Phys. Rev. A **64**:012310 (2001).

Q 74.8 Fri 12:45 P 10

Exploring Multi-class Image Segmentation Through Localization Phenomena — •Akshaya Srinivasan[1,2], Yannick Werner[2,3], Alexander Geng[1], Berta Garcia Heras[3], Ali Moghiseh[1], Alexey Bochkarev[2], and Maximilian Kiefer-Emmanouilidis[2,3] — [1]Fraunhofer ITWM, Kaiserslautern — [2]RPTU Kaiserslautern-Landau, Kaisersluatern — [3]DFKI, Kaiserslautern

We propose an unsupervised, quantum-inspired method for multi-class segmentation of abdominal CT scans based on Anderson localization in image-derived 2D lattice Hamiltonians. Each CT slice is mapped onto a lattice in which pixel intensities define a disordered on-site potential, while nearest-neighbor hopping terms are set by a Gaussian similarity kernel that encodes local image structure. This formulation induces Anderson-like localization of eigenstates driven by contrast variations across the image. Diagonalization of the resulting single-particle Hamiltonian enables segmentation by binning eigenmodes according to their localization lengths, which naturally correspond to anatomical scales. Distinct clusters of localized states align with major anatomical regions, including liver, pancreas, kidneys, and background, producing coherent multi-label segmentation masks without annotated data, pre-processing, or model training. Validation on clinical abdominal CT datasets demonstrates robust performance under varying contrast and noise conditions. The framework is purely linear-algebraic and highlights the potential of Hamiltonian-based models and localization physics for interpretable, physics-driven medical image analysis and quantum-inspired computer vision algorithms.