Q 7: Quantum Information (Quantum Computing)

Time: Monday 10:30–12:30 Location: K 1.020

Group Report Q 7.1 Mon 10:30 K 1.020

Speeding-up the decision making of a learning agent using an ion trap quantum processor — •Theeraphot Sriarunothai[1], Sabine Wölk[2,1], Gouri Shankar Giri[1], Nicolai Friis[3,2], Vedran Dunjko[2,4], Hans Briegel[2,5], and Christof Wunderlich[1] — [1]Department Physik, Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany — [2]Institute for Theoretical Physics, University of Innsbruck, Technikerstraße 21a, 6020 Innsbruck, Austria — [3]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria — [4]Max Planck Institute of Quantum Optics Garching 85748, Germany — [5]Department of Philosophy, University of Konstanz, 78457 Konstanz, Germany

We report a proof-of-principle experimental demonstration of the quantum speed-up for learning agents utilizing a small-scale quantum information processor based on radiofrequency-driven trapped ions [1]. The decision-making process of a quantum learning agent within the projective simulation paradigm for machine learning is implemented in a system of two qubits. The latter are realized using hyperfine states of two frequency-addressed atomic ions exposed to a static magnetic field gradient. We show that the deliberation time of this quantum learning agent is quadratically improved with respect to comparable classical learning agents. The performance of this quantum-enhanced learning agent highlights the potential of scalable quantum processors taking advantage of machine learning.

[1] Th. Sriarunothai et al., arXiv: 1709.01366 (2017)

Q 7.2 Mon 11:00 K 1.020

Automatisierte Positionskontrolle von Ionen in einer segmentierten Paulfalle — •Janine Nicodemus, Thomas Ruster, Vidyut Kaushal, Daniël Pijn, Björn Lekitsch, Ulrich Poschinger und Ferdinand Schmidt-Kaler — Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Eine Möglichkeit zur Realisierung eines skalierbaren Quantenprozessors beruht auf Positionierung von Ionen in segmentierten Paulfallen [1]. Um einzelne Ionen anzusprechen und Zwei-Qubit-Verschränkungsoperationen zwischen spezifischen Ionen durchzuführen, werden verschiedene Bewegungsoperationen benötigt, wie z.B. der Transport von Ionen zwischen Speicher- und Laserinteraktionszonen [2] und die Ionenkristalltrennung [3]. Die zunehmende Komplexität der Sequenzen, beispielsweise bei der Verschränkung von vier Qubits [4], und der langreichweitige Einfluss der Fallenelektroden auf das Potential an entfernten Fallensegmenten fordern eine Optimierung der Bewegungsoperationen unter Einbeziehung aller gespeicherten Ionen und Fallensegmente. Wir stellen ein Software Framework zur automatisierten Erzeugung von optimierten Spannungskonfigurationen für Multi-Qubit-Register Bewegungsoperationen in einer segmentierten Paulfalle vor und zeigen die Verbesserungen anhand experimenteller Resultate.

[1] D. Kielpinski et al., Nature 417, 709-711 (2002)
[2] A. Walther et al., Phys. Rev. Lett. 109, 080501 (2012)
[3] T. Ruster et al., Phys. Rev. A 90, 033410, 033410 (2014)
[4] H. Kaufmann et al., Phys. Rev. Lett. 119, 150503 (2017)

Q 7.3 Mon 11:15 K 1.020

Investigation of surface noise in high-temperature superconducting surface ion traps — •Philip Holz[1], Kirill Lakhmanskiy[1], Dominic Schärtl[1], Muir Kumph[2], Ben Ames[1], Reouven Assouly[1], Yves Colombe[1], and Rainer Blatt[1,3] — [1]Institut für Experimentalphysik, Uni Innsbruck, Österreich — [2]IBM, Thomas J. Watson Research Center, USA — [3]Institut für Quantenoptik und Quanteninformation, Innsbruck, Österreich

Ion traps are a promising platform for quantum computation. One approach to scale up to larger numbers of qubits is to utilize microfaricated ion traps [1]. The close proximity of the ions to the trap surface leads, however, to an increase of the motional heating rate, which degrades the fidelity of quantum operations. The origin of this heating is not well understood [2]. Here we report on heating rate measurements performed in surface ion traps made of YBCO, a high-temperature superconductor. One trap is designed in such a way that Johnson noise is the dominant source of motional heating above the critical temperature T_c. By lowering the trap temperature below T_c we can directly compare Johnson noise with surface noise. Interestingly, for $T < T_c$ the frequency scaling of the heating rate shows deviations from a simple power law behavior as predicted by so called two-level fluctuator models. In a second trap we observe a clear plateau in the temperature dependence of the heating rate for temperatures $T > T_c$, which has not been observed so far. [1] R. Blatt and D. Wineland, Nature 453, 1008 (2008) [2] M. Brownnutt et al., Rev. Mod. Phys. 87, 1419 (2015)

Q 7.4 Mon 11:30 K 1.020

A Statistical Analysis of Tunable Quantum Annealing Devices — •Jonathan Brugger — Albert-Ludwigs-Universität Freiburg

Tunable quantum annealing devices (such as the D-Wave 2000Q) have recently gained growing attention and popularity since they have demonstrated to allow a quantum speedup for some complex computational problems and are believed to be valuable for many applications in machine learning and optimization problems in the near future. We present a statistical analysis to estimate the fidelity of such computations, and quantify the scaling behaviour of our results with the size of the machine's quantum register.

Q 7.5 Mon 11:45 K 1.020

Anti-concentration theorems for schemes showing a quantum speedup — •Dominik Hangleiter, Juan Bermejo-Vega, Martin Schwarz, and Jens Eisert — FU Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin

Demonstrating a quantum speedup in as simple a setting as possible is a key milestone in the development of quantum technologies. Within the last year, achieving this milestone has come into close reach, in part but not only due to the quantum computing programmes of IBM and Google. At the heart of any task suitable for demonstrating a quantum speedup lies a complexity-theoretic proof that a quantum device computationally outperforms any classical device. Most proposals for near-term devices are based on sampling from some probability distribution. The technique most often used to prove a speedup for such tasks in that require certain complexity-theoretic conjectures about the sampled distribution to be assumed, one of them being that the distribution 'anti-concentrates'. In this talk we will prove this conjecture for unitary two-designs which covers many interesting settings that are based on random quantum circuits including, most prominently, random universal circuits.

Q 7.6 Mon 12:00 K 1.020

Correlated Noise in Quantum Circuits — •Markus Heinrich and David Gross — Institut für theoretische Physik, Universität zu Köln

The celebrated quantum threshold theorem guarantees the existence of a, however unknown, noise threshold for arbitrary-precision quantum computing and, as such, is the foundation of fault-tolerant quantum computation. Here, we follow a path laid out by Buhrman et al. and Virmani to derive upper bounds on this threshold by computing the amount of noise needed to efficiently simulate any quantum circuit on a classical computer. In contrast to former work, we derive a general theoretical framework which captures most of the known noise models, including correlated noise. This allows us to study the effects of noise in more detail and to give tighter upper bounds on the error correction threshold.

Q 7.7 Mon 12:15 K 1.020

Fault-tolerant interface between quantum memories and quantum processors — •Hendrik Poulsen Nautrup[1], Nicolai Friis[1,2], and Hans J. Briegel[1] — [1]Institute for Theoretical Physics, University of Innsbruck, Technikerstr. 21a, 6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria

Quantum computation holds the promise to solve computational problems believed to be unsolvable on classical computers. Yet, before we can discuss solving problems on a quantum computer, we have to be able to build one. The major obstacles for any near-term implementation are noise and decoherence. Thus, in order to protect quantum computations from the deteriorating effects of noise, we need to encode qubits into error correction codes. And different codes can serve different purposes: Some codes will be the basis for a quantum memory, others that of a processor. To exploit the particular advantages of different codes for fault-tolerant quantum computation, it is necessary to be able to switch between them. We propose a practical solution, subsystem lattice surgery, which requires only two-body nearest neighbor interactions in a fixed layout in addition to the indispensable error correction. This method can be employed to create a simple interface, a quantum bus, between noise resilient surface code memories and flexible color code processors in a near-term implementation.