Q 16: Quantum Information and Simulation

Time: Monday 14:00–15:45 Location: K 1.020

Q 16.1 Mon 14:00 K 1.020

Improving the consistency of a quantum experiment with reinforcement learning — •Sabine Wölk and Hans Jürgen Briegel — Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria

In quantum experiments, expectation values of observables are determined by repeating their measurement many times. Meaningful results can only be obtained if the conditions under which the experiment is performed can be kept constant for all the measurements. For setups with unstable conditions, e.g. frequency drift, this may require calibration measurements during data acquisition, which however increases the amount of resources, e.g., time, number of qubits, or general equipment. The problem of finding an optimal calibration strategy is in general highly non-trivial since the only available information is probabilistic.

We show that a learning agent using projective simulation [1] is able to find good solutions based solely on the experimental data. In this way, we also demonstrate that projective simulation is not limited to deterministic rewards but can also learn from probabilistic ones.

[1] H. J. Briegel and G. De las Cuevas, Sci. Rep. **2**, 400 (2012)

Q 16.2 Mon 14:15 K 1.020

Open quantum generalisation of classical Hopfield neural networks — •Eliana Fiorelli[1,2], Pietro Rotondo[1,2], Matteo Marcuzzi[1,2], Juan P Garrahan[1,2], Markus Muller[3], and Igor Lesanovsky[1,2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, UK — [2]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham — [3]Department of Physics, Swansea University, Singleton Park, Swansea SA2 8PP, UK

Neural networks (NNs) are artificial networks inspired by the interconnected structure of neurons in animal brains. They are now capable of computational tasks where most ordinary algorithms would fail, such as speech and pattern recognition, with a wide range of applicability both within and outside research. Hopfield NNs [1] constitute a simple, but rich example of how an associative memory can work; they have the ability to retrieve, from a set of stored network states, the one which is closest to the input pattern. In the last decades, many models have been proposed in order to combine the properties of NNs with quantum mechanics, aiming at understanding if NNs computing can take advantage from quantum effects. Here we discuss a quantum generalisation of a classical Hopfield model [2] whose dynamics is governed by purely dissipative, yet quantum, processes. We show that this dynamics may indeed yield an advantage over a purely classical one, leading to a shorter retrieval time. [1] J.J. Hopfield, Proceedings of the National Academy of Sciences, 79, 2554, (1982) [2] P. Rotondo et al., arXiv:1701.01727 (2017).

Q 16.3 Mon 14:30 K 1.020

Projective simulation memory network for solving toy and complex problems — •Alexey Melnikov[1], Vedran Dunjko[2], Hendrik Poulsen Nautrup[1], and Hans Briegel[1,3] — [1]Institute for Theoretical Physics, University of Innsbruck — [2]Max-Planck-Institute for Quantum Optics — [3]Department of Philosophy, University of Konstanz

The projective simulation (PS) model is a physical approach to artificial intelligence. In the PS model, learning is realized by internal modification of the episodic memory network, both in terms of its structure and the weights of its edges. Through interactions with a task environment, the PS memory network adjusts itself dynamically, so as to increase the probability of performing better in subsequent time steps. Here we consider several examples of environments, in which the PS agent does self-adjustments due to the glow, the generalization and the meta-learning mechanisms. The emphasis is made on examples of the PS agent applied to quantum optics experiments in which the agent autonomously learns to reach various entanglement classes.

Q 16.4 Mon 14:45 K 1.020

Projective simulation applied to non-Markovian problems — •Lea M. Trenkwalder[1], Vedran Dunjko[2], and Hans J. Briegel[1] — [1]University of Innsbruck — [2]MPI for Quantum Optics

The idea of machines acquiring complex behaviour can be studied in terms of learning agents. In reinforcement learning models, an agent learns through interaction with an environment, as it receives rewards and information about the environment in terms of percepts. An agent is confronted with a Markovian task environment if a given percept contains all the information needed to determine the probability distribution over the subsequent environmental states. Projective simulation (PS) is a novel learning model, which has been used to solve a variety of Markovian reinforcement learning tasks. The projective simulation model is a physics-inspired approach where the internal deliberation process of the agent can be described by a random walk through its episodic memory. Moreover, this random walk possesses a quantum analogue, providing the PS framework with a natural route to quantisation. For a variant of PS called rPS, it was proven that quantum effects can be exploited to achieve a quadratic speed-up in its active learning time. Recently, it was shown that complex Markovian task environments such as the design of certain quantum experiments, can be tackled using PS. In the present work, we generalise projective simulation to solve a set of non-Markovian problems, in which the perceptual input does not enclose all the information needed to determine the development of the environment. The approach allows the projective simulation model to be applied to a wider range of task environments.

Q 16.5 Mon 15:00 K 1.020

Using quantum physics to simulate discrete-time, highly non-Markovian complex processes — •Felix Binder[1], Jayne Thompson[2], Chengran Yang[1], Varun Narasimhachar[1], and Mile Gu[1,2,3] — [1]School of Physical and Mathematical Sciences, Nanyang Technological University, 637371 Singapore, Singapore — [2]Centre for Quantum Technologies, National University of Singapore, 3 Science Drive 2, 117543 Singapore, Singapore — [3]Complexity Institute, Nanyang Technological University, 639673, Singapore

Stochastic processes are as ubiquitous throughout the quantitative sciences as they are notorious for being difficult to simulate and predict. In this talk I present a unitary quantum simulator for discrete-time stochastic processes which requires less internal memory than any classical analogue throughout the simulation. The simulator's internal memory requirements equal those of the best previous quantum models. However, in contrast to previous models it only requires a (small) finite-dimensional Hilbert space. Moreover, since the simulator operates unitarily throughout, it avoids any unnecessary information loss. Interestingly, the formalism of matrix product states may be used to systematically derive the memory states and the unitary operator which define the simulator. This renders the results useful for direct experimental implementation with current platforms for quantum computation and I will present results obtained from simulation on IBM's Quantum Experience for a representative example process.

Q 16.6 Mon 15:15 K 1.020

Modeling the atomtronic analog of an optical polarizing beam splitter, a half-wave plate, and a quarter-wave plate for phonons of the motional state of two trapped atoms — •Naeimeh Mohseni[1,2], Marjan Fani[3], Jonathan Dowling[4], and Shahpoor Saeidian[1] — [1]Department of Physics, Institute for Advanced Studies in Basic Sciences, Zanjan, Iran. — [2]Max Planck institute for the science of the light — [3]Department of Physics, University of Isfahan, Isfahan, Iran — [4]Hearne Institute for Theoretical Physics and Department of Physics and Astronomy, Louisiana State University, Baton Rouge, Louisiana 70803, USA

We propose a scheme to model the phonon analog of optical elements, including a polarizing beam splitter, a half-wave plate, and a quarter-wave plate, as well as an implementation of CNOT and Pauli gates, by using two atoms confined in a two-dimensional plane. The internal states of the atoms are taken to be Rydberg circular states. Using this model we can manipulate the motional state of the atom, with possible applications in optomechanical integrated circuits for quantum information processing and quantum simulation. Towards this aim, we consider two trapped atoms and let only one of them interact simultaneously with two circularly polarized Laguerre-Gaussian beams.

Q 16.7 Mon 15:30 K 1.020

Holography and criticality in matchgate tensor networks — Alexander Jahn, •Marek Gluza, Fernando Pastawski, and Jens

Eisert — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

The AdS/CFT correspondence conjectures a holographic duality between gravity in a bulk space and a critical quantum field theory on its boundary. Tensor networks have come to provide toy models to understand such bulk-boundary correspondences, shedding light on connections between geometry and entanglement. We introduce a versatile and efficient framework for studying tensor networks, extending previous tools for Gaussian matchgate tensors in $1 + 1$ dimensions. Using regular bulk tilings, we show that the critical Ising theory can be realized on the boundary of both flat and hyperbolic bulk lattices. Within our framework, we also produce translation-invariant critical states by an efficiently contractible network dual to the multi-scale entanglement renormalization ansatz. Furthermore, we explore the correlation structure of states emerging in holographic quantum error correction. We hope that our work will stimulate a comprehensive study of tensor-network models capturing bulk-boundary correspondences.