Q 67: Machine Learning

Time: Friday 14:30–16:30 Location: Aula

Invited Talk Q 67.1 Fri 14:30 Aula

Towards an Artificial Muse for new Ideas in Quantum Physics — •Mario Krenn — Max Planck Institute for the Science of Light, Erlangen, Germany

Artificial intelligence (AI) is a potentially disruptive tool for physics and science in general. One crucial question is how this technology can contribute at a conceptual level to help acquire new scientific understanding or inspire new surprising ideas. I will talk about how AI can be used as an artificial muse in quantum physics, which suggests surprising and unconventional ideas and techniques that the human scientist can interpret, understand and generalize to its fullest potential.

[1] Krenn, Kottmann, Tischler, Aspuru-Guzik, Conceptual understanding through efficient automated design of quantum optical experiments. Physical Review X 11(3), 031044 (2021).

[2] Krenn, Pollice, Guo, Aldeghi, Cervera-Lierta, Friederich, Gomes, Häse, Jinich, Nigam, Yao, Aspuru-Guzik, On scientific understanding with artificial intelligence. Nature Reviews Physics 4, 761 (2022).

[3] Krenn, et al., Forecasting the future of artificial intelligence with machine learning-based link prediction in an exponentially growing knowledge network. Nature Machine Intelligence 5, 1326 (2023).

Q 67.2 Fri 15:00 Aula

Artificial Intelligence for Quantum Sensing — •Victor Jose Martinez Lahuerta, Jan-Niclas Kirsten-Siemss, and Naceur Gaaloul — Leibniz University Hannover, Institut of Quantum Optics, Welfengarten 1, 30167 Hannover, Germany

Algorithms from the field of artificial intelligence (AI) and machine learning have been employed in recent years for a variety of applications to efficiently solve multidimensional problems. In physics, these algorithms are applied with increasing success, for example, to solve the Schrödinger equation for many-body problems, or used experimentally to generate ultracold atoms and control lasers. In this project we aim to work on three fundamental pillars of AI in atom interferometry: theory modeling, measurement data extraction, and operation of experiments. Within this context, I will talk about our results modeling a diffraction phase-free Bragg atom interferometry.

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Q 67.3 Fri 15:15 Aula

Optimizing the active isolation of an optical table with machine learning — •Jan-Niklas Feldhusen, Artem Basalaev, and Oliver Gerberding — Institut für Experimentalphysik, Universität Hamburg, 22761 Hamburg, Germany

Environmental seismic disturbances, also called seismic noise, limit the sensitivity of ground based gravitational wave detectors.

These disturbances couple via the optical components into the signal. To mitigate this noise, the optical components are passively isolated with suspensions. Parts of the suspension system include an active isolation, which suppresses the inflicted movement by knowing the transfer function of the suspension system and the motion on the ground.

We study if it is possible to improve the active isolation with an artificial neural network. In our laboratory at Universität Hamburg we have a large vacuum chamber with a seismically isolated optical table inside, intended for in-vacuum testing of interferometric inertial sensors - a task that has qualitatively similar requirements for seismic isolation as the first isolation stages of gravitational wave detectors. In this study we show that it is possible to infer averaged spectral density of motion of the table from measurements with seismometers on the floor, by utilizing artificial neural networks. We can get a better estimate of the seismic noise spectral amplitudes on the optical table than a Wiener Filter. We also investigate the ability of the neural network to predict future motion to get a real-time active isolation by feedforward of the inverted anticipated motion.

Q 67.4 Fri 15:30 Aula

Evalutation of machine learning algorithms for applications in quantum gas experiments — •Oliver Anton[1], Victoria Henderson[1], Elisa Da Ros[1], Philipp-Immanuel Schneider[3,4], Ivan Sekulic[3,4], Sven Burger[3,4], and Markus Krutzik[1,2] — [1]Institut für Physik and IRIS, Humboldt-Universität zu Berlin — [2]Ferdinand-Braun-Institut, Berlin — [3]JCMwave GmbH, Berlin — [4]Zuse Institute Berlin (ZIB), Berlin

The generation of clouds containing cold and ultra-cold atoms is a complex process that requires the optimization of noisy data in multi dimensional parameter spaces. Optimization of this problem can present challenges both in and outside of the lab due to constrains in time, expertise, or access for lengthy manual optimization.

Machine learning offers a solution thanks to its ability to efficiently optimize high dimensional problems without the need for knowledge of the experiment itself. In this presentation, we show the results of benchmarking various optimization algorithms and implementations, testing their performance in real-world experiment, subjected to inherent noise. This work is partially supported by the German Space Agency (DLR) with funds provided by the Federal Ministry of Economic Affairs and Climate Action (BMWK) under grant numbers No. 50WM2067, 50WM2175 and 50WM2247.

Q 67.5 Fri 15:45 Aula

Machine learning optimal control pulses in an optical quantum memory — •Elizabeth Robertson[1], Luisa Esguerra[1,2], Leon Messner[1], Guillermo Gallego[3], and Janik Wolters[1,2] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Rutherfordstr. 2, 12489 Berlin, Germany — [2]Technische Universiät Berlin, Institute for Optics and Atomic Physics, Hardenbergstr. 36, 10623 Berlin, Germany — [3]Einstein Center Digital Future and Science of Intelligence Excellence Cluster 10117 Berlin, Germany

Efficient optical quantum memories are a milestone required for several quantum technologies including repeater-based quantum key distribution and on-demand multi-photon generation [1,2]. We present an optimization of the storage efficiency of an optical electromagnetically induced transparency (EIT) memory experiment in a warm cesium vapor using a genetic algorithm to update the control laser waveform. The write pulse is represented either as a Gaussian or free-form pulse, and the results from the optimization are analyzed and compared. We find that the free-form pulses offer a 3%(7) improvement in efficiency, over the learned Gaussian. By limiting the allowed pulse power in a solution, we show a power-based optimization giving a 30% reduction in power, with minimal efficiency loss.

[1] M. Gündoğan et al., Topical white paper: A case for quantum memories in space (2021), arXiv:2111.09595 [2] J. Nunn et al., Multimode memories in atomic ensembles, Physical Review Letters 101, 260502 (2008).

Q 67.6 Fri 16:00 Aula

Bayesian Optimization for Robust State Preparation in Quantum Many-Body Systems — •Tizian Blatz[1,2] and Annabelle Bohrdt[2,3] — [1]Ludwig-Maximilians-Universität München, München, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), München, Germany — [3]University of Regensburg, Regensburg, Germany

New generations of ultracold atom experiments are continually raising the demand for efficient solutions to optimal control problems. We present a Bayesian-optimization approach to improve a state- preparation protocol recently implemented in an ultracold-atom experiment to realize a two-particle fractional quantum Hall state. Compared to manual ramp design, we demonstrate the superior performance of our optimization approach in a numerical simulation, resulting in a protocol that is faster by an order of magnitude at the same fidelity, even when taking into account experimentally realistic levels of disorder in the system. We extensively analyze and discuss questions of robustness and the relationship between numerical simulation and experimental realization, and how to make the best use of the surrogate model trained during optimization. We find that numerical simulation can be expected to substantially reduce the number of experiments that need to be performed with even the most basic transfer learning techniques. The proposed protocol and workflow will pave the way toward the realization of more complex many-body quantum states in experiments.

Q 67.7 Fri 16:15 Aula

Entanglement certification for mixed quantum states prepared on noisy quantum hardware — •Andreas J. C. Woitzik[1], Eric Brunner[1,2], Jiheon Seong[3], Hyeokjae Kwon[3], Seungchan Seo[3], Joonwoo Bae[3], Andreas Buchleitner[1,4], and Edoardo Carnio[1,4] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Freiburg im Breisgau, Federal Republic of Germany — [2]Quantinuum, London, United Kingdom — [3]School of Electrical Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Republic of (South) Korea — [4]EUCOR Centre for Quantum Science and Quantum Computing, Freiburg im Breisgau, Federal Republic of Germany

Entanglement is a fundamental aspect of quantum physics, conceptually, as well as for its many applications. Classifying a given mixed state as entangled or separable – a task referred to as the separability problem – poses a significant challenge, since a N-qubit state can be entangled with respect to many different partitions of the N qubits.

We have developed a classification method that feeds the statistics of random local measurements into a non-linear dimensionality reduction algorithm, to determine with respect to which partitions a given quantum state is entangled. After training a model on randomly generated quantum states with different entanglement structures, and of varying purity, we verify the accuracy of its predictions on synthetic test data, and finally apply it to states prepared on IBM quantum computing hardware.