QI 26: Quantum Control (joint session QI/Q)

Time: Thursday 11:00–13:00 Location: B305

Invited Talk QI 26.1 Thu 11:00 B305

Quantum firmware: optimal control for quantum simulators — •Tommaso Calarco — Forschungszentrum Jülich, 52428 Jülich, Deutschland — Universität zu Köln, 50937 Köln, Deutschland

Quantum optimal control has been shown to improve the performance of quantum technology devices up to their limits in terms e.g. of system size and speed of operation. This talk will review our recent results with a variety of quantum technology platforms, focusing in particular on ultracold atoms, and introduce our newly developed software for automatic calibration of quantum operations - the fundamental building block of next-generation quantum firmware.

QI 26.2 Thu 11:30 B305

Optimal Control in the Chopped Random Basis — •Matthias Müller — Forschungszentrum Jülich GmbH

We are at the verge of the second quantum revolution where quantum technology leaves the lab and enters industrial products. Fragile quantum systems with their unique features like superposition and entanglement can offer new perspectives in computation, communication and sensing/metrology. However, they need sophisticated mechanisms of control to perform the desired tasks. Quantum Optimal Control has proven to be a powerful tool to accomplish this task. I will report on the optimization in the dressed chopped random basis (dCRAB) [1], a versatile and robust approach to Quantum Optimal Control, that allows both closed-loop and open-loop optimization with limited pulse bandwidth and guaranteed convergence in a broad range of typical applications. The interplay of constraints, control resources and noise [2,3] is crucial for the overall performance of the controlled operation which obeys fundamental bounds that can be found also in full quantum control [4].

[1] M.M. Müller et al., Rep. Prog. Phys. 85 076001 (2022) [2] S. Lloyd et al., PRL 113, 010502 (2014) [3] M.M. Müller et al., arxiv:2006.16113 (2020) [4] S. Gherardini et al., Phys. Rev. Research 4 (2), 023027 (2022)

QI 26.3 Thu 11:45 B305

Graph test for controllability of qubit arrays — •Fernando Gago-Encinas, Monika Leibscher, and Christiane P. Koch — Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Universal quantum computing requires evolution-operator controllability of the system used as quantum processing unit. Given a specific architecture characterized by the two-qubit couplings and local controls it uses, we seek to determine whether it is controllable or not. The standard test constructing the dynamical Lie algebra becomes demanding and even unfeasible already for a relatively small number of qubits. We present a controllability test for arrays of coupled qubits based on graph theory that significantly broadens the number of cases that can be analyzed. We showcase the algorithm for different examples, including some systems based on IBM's devices.

QI 26.4 Thu 12:00 B305

Optimal Control of Bipartite Entanglement with Local Unitary Control — •Emanuel Malvetti — Department of Chemistry, Technische Universität München, Lichtenbergstr. 4, 85737 Garching, Germany — Munich Centre for Quantum Science and Technology & Munich Quantum Valley, Schellingstr. 4, 80799 München, Germany

A pure quantum state on a bipartite system can always be transformed into a diagonal form using local unitary transformations. This is the well-known Schmidt decomposition. Here we consider a closed bipartite system with local unitary control. The Schmidt decomposition allows us to define a reduced control system on the Schmidt values, which is equivalent to the original control system. We will explicitly describe this reduced control system and study its properties. In particular, we will treat the case of rank one drift Hamiltonians and some low dimensional cases in detail.

QI 26.5 Thu 12:15 B305

Taking Markovian Quantum Dynamics to Thermal Limits: Principles, Practice, and Perspectives — •Thomas Schulte-Herbrüggen[1,2], Frederik vom Ende[1,2], Emanuel Malvetti[1,2], and Gunther Dirr[3] — [1]Technical University of Munich (TUM) — [2]Munich Centre for Quantum Science and Technology (MCQST) and Munich Quantum Valley (MQV) — [3]Institute of Mathematics, Universität Würzburg

To begin with, consider the following engineering problem: Which quantum states can be reached by coherently controlling n-level quantum systems coupled to a thermal bath in a switchable Markovian way? We address this question by giving (inclusions for) reachable sets of coherently controllable open quantum systems with switchable coupling to a thermal bath of temperature T as an additional resource.

A core problem reduces to the dynamics of the eigenvalues of the density operator. It translates into a toy model of studying points in the standard simplex allowing for two types of controls: (i) permutations within the simplex, (ii) contractions by a dissipative semigroup. We show how toy-model solutions pertain to the reachable set of the original controlled Markovian quantum system. Beyond the case $T = 0$ (amplitude damping) we present results for $0 < T < \infty$ by using recent methods of extreme points of the d-majorisation polytope.

We give illustrating examples, experimental applications, and perspectives at the intersection of control theory with resource theory.

Refs.: Proc. MTNS (2022), 1069 and 1073

QI 26.6 Thu 12:30 B305

Tailoring feedback control loops to work best where it matters the most — •Robin Oswald — ETH Zürich

Experiments in AMO physics rely on many feedback control loops stabilizing quantities such as temperatures, magnetic fields and laser phase, frequency and intensity. In most cases, PID controllers are used for these tasks, but they only allow for coarse adjustment of the relevant trade-offs. Here, I will present methods to augment and tailor control loops to be particularly effective in one or several narrow frequency bands, i.e. where there are particularly strong disturbances or where the apparatus is especially vulnerable to them, or both. Using examples from our trapped-ion laboratory I will illustrate how we can leverage these techniques to improve the performance of the feedback loops, and ultimately our experiments.

QI 26.7 Thu 12:45 B305

Unitary Interpolation — •Michael Schilling, Matthias Müller, and Felix Motzoi — Forschungszentrum Jülich, Jülich, Deutschland

The generation of matrix exponentials and associated differentials, required to determine the time evolution of quantum systems, is frequently the primary source of running time in quantum control problems. We introduce two ideas for the time efficient approximation of matrix exponentials of linear parametric Hamiltonians. We modify the Trotter and Suzuki-Trotter product formulas from approximation to interpolation schemes to improve their accuracy. To achieve our target fidelities within a single interpolation step and avoid the need of exponentiation, we furthermore define the interpolation on a grid of interpolation intervals. We demonstrate a speed up of at least an order of magnitude when compared with eigenvalue decomposition, Runge-Kutta and Suzuki-Trotter based approaches. This holds true independent of system dimension, for problems with few time dependent controls.