Q 10: Quantum Information: Concepts and Methods II

Time: Monday 14:30–16:30 Location: K/HS1

Group Report Q 10.1 Mon 14:30 K/HS1

Good News for Controlling Closed and Open Quantum Systems — •Thomas Schulte-Herbrüggen[1], Ville Bergholm[2], Corey O'Meara[1], Luca Arceci[1,3], Gunther Dirr[4], Moritz August[5], and Thomas Huckle[5] — [1]Dept. Chem., TU-München — [2]ISI Foundation, Torino — [3]Dept. Mathematics, TU-München — [4]Math. Inst., University of Würzburg — [5]Dept. Computer Science, TU-München

Optimal control is proving more and more indispensable for steering quantum devices with high fidelity. Recent examples in NV centres include error correction [1], where single-shot readouts with up to 99.6% fidelity were obtained. Another experiment implemented entanglement of distant NV centres [2] with fidelities of over 82%.

Here we report on latest examples extending the optimal-control platform DYNAMO [3]. They include switchable noise [4] and recent results on fixed-point engineering as well their implications for reachability under open-loop *versus* closed-loop control designs.

References:
[1] G. Waldherr et al., *Nature* **504**, 204 (2014).
[2] F. Dolde et al., *Nature Commun.* **5**, 3371 (2014).
[3] S. Machnes et al., *Phys. Rev. A* **84**, 022305 (2011).
[4] V. Bergholm and T. Schulte-Herbrüggen, arXiv:1206.4945

Q 10.2 Mon 15:00 K/HS1

Landscape Engineering: Removing local traps for state to state transfer — •Niklas Rach, Matthias Müller, Tommaso Calarco, and Simone Montangero — Institut für komplexe Quantensysteme, Universität Ulm, D-89069 Ulm, Germany

In Quantum Optimal Control, the success of optimization algorithms are drastically determined by the landscape of the cost functional F. It is known, that the landscape of an unconstrained state to state transfer problem in a controllable system contains only global maxima, however, the landscape of constrained optimizations are characterized by the presence of traps [1,2]. Considering an Ising chain with broken symmetry we study the influence of these traps in the Chopped Random Bases algorithm (CRAB), as the expansion of the control into a truncated basis introduces a constraint on the control. We show that with increasing number of basis functions the success probability converges to one. In addition, we introduce an iterative version of CRAB which allows to engineer the landscape in a way that removes these false traps and converges always to a global maximum regardless of the number of basis functions involved.

[1] Herschel A. Rabitz et al. Science 303 , 1998 (2004).
[2] K.W. Moore, H. Rabitz, J. Chem. Phys. 137, 134113 (2012).

Q 10.3 Mon 15:15 K/HS1

Quantum Optimal Control and the rotating wave approximation — •Maximilian Keck, Tommaso Calarco, and Simone Montangero — Institut für komplexe Quantensysteme, Universität Ulm, D-89069 Ulm, Germany

The rotating wave approximation (RWA) is a well established method to simplify the description of laser-driven systems in the low intensity regime. We study the interplay between RWA and optimal control problems, in particular, we apply the RWA generalized version to N-dimensional systems with several laser-like driving fields which represent a great number of quantum optimal control (QOC) problems. With the help of graph theory concepts we identify an important subset of problems* where the corresponding graph is connected and acyclic * that can be recast in time-independent ones. As a starting point, we investigate the two-level system presenting the analytic solution to the (wave function) controllability, the state-to-state transfer, and time optimality problem. Furthermore we show how to solve the general connected and acyclic system numerically, showing that the approximate description given by the RWA solves QOC problems.

Q 10.4 Mon 15:30 K/HS1

Symmetries completely determine the computational power of controlled quantum systems — Zoltán Zimborás[1], •Robert Zeier[2], Thomas Schulte-Herbrüggen[2], and Daniel Burgarth[3] — [1]Department of Computer Science, University College London, Gower Street, London WC1E 6BT, UK — [2]Department Chemie, Technische Universität München, Lichtenbergstrasse 4, 85747 Garching, Germany — [3]Department of Mathematics and Physics, Aberystwyth University, Aberystwyth SY23 2BZ, UK

Given a quantum system, what can one do with it? We present a technique based on analyzing symmetries which decides if a controlled quantum system can simulate a given effective Hamiltonian. Moreover, our technique can compare the respective computational power of two controlled quantum systems. We emphasize that our approach improves on the conventional approach of computing Lie-closures of generators and harnesses the symmetries of the quantum system in order to reduce Lie-algebraic computations to effective linear-algebra ones.

Q 10.5 Mon 15:45 K/HS1

Quantum optimal control: Theoretical considerations and application — •Jonathan Zoller — Ulm university, Germany

We employ and compare different optimal control algorithms as the CRAB and Gradient methods. These algorithms require initial guess pulses which, in general, result in different final fidelities: we perform a statistical analysis of the final fidelity distribution and of the algorithm performances. We apply this analysis to two paradigmatic optimal control problems such as a state to state transfer of an atom in a double-well between states located in two different wells and the generation of optimal protocols for the manipulation of Nitrogen-vacancy center in diamond.

Q 10.6 Mon 16:00 K/HS1

Optimal control of long distance entanglement in disordered spins chains — •Jian Cui[1,2] and Florian Mintert[1,2] — [1]Imperial College London, the United Kingdom — [2]Freiburg Institute for Advanced Studies, Freiburg, Germany

Long spin chains can be described efficiently in terms of matrix product states (mps), even if analytic solutions are not available. We consider optimal control based on mps. For the sake of efficiency we pursue a time-local control strategy and use time-dependent target functionals to overcome resulting limitations. With analytically construct optimal control Hamiltonians for the creation of entanglement among distant spins, we show that entanglement of two or more spins can rapidly be generated despite substantial disorder in a linear chain.

Q 10.7 Mon 16:15 K/HS1

Dynamical decoupling by pulses with non-equal time delays — •József Zsolt Bernád, Johannes Viering, and Gernot Alber — Institut für Angewandte Physik, Technische Universität Darmstadt, D-64289 Germany

Quantum information processing is a promising research field with procedures that are not accessible to classical information approaches. Environmentally induced decoherence poses a serious hurdle in experimental implementations. Dynamical decoupling is a method which can decouple qubits from their environment and can thus increase coherence times of quantum states. One possibility to optimize the suppression of decoherence is to use non-equidistant pulse sequences, like Uhrig's dynamical decoupling scheme [1]. We investigate this problem from a general point of view and relate it to ergodic theorems and to weighted Cesàro means. We show that in the limit of continuous control the suppression mechanism becomes independent of the non-equidistant timing of the pulses. For the case of finite numbers of pulses an inequality is derived and within this approach non-equidistant applications of pulses are optimized.

[1] G. S. Uhrig, Phys. Rev. Lett. 98, 100504 (2007).