SFB/TRR 21 - Seminar
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Jiri Vala
(Department of Mathematical Physics, National University of Ireland, Maynooth, Ireland, and School of Theoretical Physics, Dublin Institute for Advanced Studies, Dublin, Ireland)

Geometric theory of two qubit operations and its control applications

We present the geometric theory of nonlocal two-qubit operations. By applying a Cartan decomposition to su(4), we find that the geometric structure of nonlocal gates is a 3-torus. We derive the invariants for local transformations, and connect these local invariants to the coordinates of the 3-torus. Since different points on the 3-torus may correspond to the same local equivalence class, we use the Weyl group theory to reduce the symmetry of the 3-torus. We obtain a tetrahedron of the local equivalence classes of two-qubit gates.

We then present applications of the geometric theory to quantum control. The nonlocal operations generated by a given Hamiltonian are investigated to explicitly construct a universal quantum circuit that can simulate any arbitrary two-qubit gate exactly, providing an efficient implementation of universal quantum computation and simulation. An analytic approach to simulate any arbitrary operation in SU(4), given an entangling two-qubit gate together with local gates, is provided in a closed form solution. We also provide a uniform upper bound of the applications of the given entangling gates, and find that exactly half of all the controlled-unitary gates satisfy the same upper bound as the CNOT gate. The minimum number of applications needed for an arbitrary controlled-unitary gate to construct a universal quantum circuit is derived and an analytic circuit construction procedure is presented and shown to be either optimal or close to optimal. We then present a newly discovered quantum gate, B, that can implement any arbitrary two-qubit quantum operation with minimal number of both two-qubit and single-qubit gates. We conclude with brief discussion of the applications of geometric theory in the context of optimal control.

The presentation is based on a joint work with Jun Zhang, Shankar Sastry and Birgitta Whaley.

References:

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Universität Ulm, Raum N24 / 227
Albert-Einstein-Allee 11, 89081 Ulm

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