Quantum Information Theory (M16)

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Quantum Information Theory lies at the intersection of Mathematics, Physics and Computer Science. It was born out of Classical Information Theory, which is the mathematical theory of acquisition, storage, transmission and processing of information.

This course will provide an introduction to how these tasks can be accomplished using quantum-mechanical systems. The underlying quantum mechanics leads to some distinctively new features which have no classical counterparts. These new features can be exploited both to improve the performance of certain information-processing tasks and to accomplish tasks which are impossible or intractable in the classical realm.

The course will cover a selection of topics including:

- Basic concepts in quantum theory and quantum information: pure and mixed states, density matrix, the Schmidt decomposition, quantum operations.
- Study of open systems: Generalization of the postulates of quantum mechanics, generalized measurements, POVMs, Kraus representation, the Choi-Jamilkowski isomorphism, etc.
- Quantum channels: Application to coherent communication and purification, quantum data compression limit, and random coding arguments. Quantum channel capacities and Holevo bound on the accessible information.
- Trace distance, fidelity and entropy measures. Quantum relative entropy and entropy inequalities. Applications to hypothesis testing, monotonicity and recoverability.

Prerequisites

For this course, familiarity with an undergraduate level quantum mechanics course, such as Part II Quantum Mechanics or Part II Quantum Information and Computation, is highly beneficial. In particular, knowledge of basic quantum mechanics will be assumed.

Elementary knowledge of probability theory, vector spaces and linear algebra will be very useful.

Literature

1. M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information*; Cambridge University Press, 2000.
2. M. M. Wilde, *From Classical to Quantum Shannon Theory*; Cambridge University Press, 2017, `http://arxiv.org/abs/1106.1445`.
3. J. Watrous, *The theory of quantum information*; Cambridge University Press, 2018, `https://cs.uwaterloo.ca/~watrous/TQI/`.
4. E. Carlen, *Trace inequalities and quantum entropy: An introductory course*; lecture notes, 2009, `http://www.ueltschi.org/AZschool/notes/EricCarlen.pdf`.
5. M. M. Wolf, *Quantum Channels and Operations. Guided Tour*; lecture notes, 2012, `https://mediatum.ub.tum.de/doc/1701036/1701036.pdf`.

Additional support

Three examples sheets will be provided and three associated examples classes will be given. There will be a one-hour revision class in the Easter Term.