Quantum Information Theory (L24)

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Quantum Information Theory (QIT) 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.

QIT is the study of 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, not only to improve the performance of certain information-processing tasks but also to accomplish tasks which are impossible or intractable in the classical realm.

The course will start with a short introduction to some of the basic concepts and tools of Classical Information Theory, which will prove useful in the study of QIT. Topics in this part of the course will include a brief discussion of data compression, transmission of data through noisy channels, Shannon's theorems, entropy and channel capacity. The quantum part of the course will commence with a study of open systems and a discussion of how they necessitate a generalization of the basic postulates of quantum mechanics. Topics will include quantum states, quantum operations, generalized measurements, POVMs, the Kraus Representation Theorem, the Choi-Jamilkowski isomorphism, quantum data compression limit, and random coding arguments.

We will further focus on data compression, reliable transmission of information over noisy communication channels, and introduce accessible information and coherent information. In particular, we will discuss the Holevo bound on the accessible information, the Holevo-Schumacher-Westmoreland (HSW) Theorem, and key properties of coherent information leading to surprising superadditivity effects for quantum channel capacities.

Pre-requisites

Familiarity with the Part II course *Quantum Information and Computation* or equivalent is essential.

Knowledge of basic quantum mechanics will be assumed.

Elementary knowledge of Probability Theory, Vector Spaces and Linear Algebra will be useful.

Literature

1. M. A. Nielsen and I. L. Chuang *Quantum Computation and Quantum Information.* Cambridge University Press, 2002.
2. M. M. Wilde *From Classical to Quantum Shannon Theory* Cambridge University Press, 2013.
3. J. Preskill, *Lecture notes on Quantum Information Theory*, Acta Applicandae, **56**, 1-98 (1999). Also available at http://www.theory.caltech.edu/~preskill/ph229/#lecture

Additional support

Four examples sheets will be provided and four associated examples classes will be given. There will be a revision class in the Easter Term.