Universität Tübingen
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Information for the Seminar — October 2022 - February 2023

List of Topics

Below I present a list of the different topics that will be addressed in this seminar, as well as a brief overview on each of them and the order in which they will take place. Some of these topics are still subject to change depending on the specific interest and/or background of the attendees.

Note that the speaker written for each of the topics is preliminary and it could be changed until the beginning of the semester.

Session 1: Introduction to quantum information theory

We will provide a short introduction to quantum mechanics, as well as review some topics such as qubits, elementary gates, classical and quantum circuits, etc.

The main bibliography for this part will be Sections 1.4.1-1.4.3 of these notes.

Speaker: Angela Capel

Session 2: First protocols in quantum computing

In this session, we will discuss some of the first protocols that appeared in Quantum Information Theory. In particular, we will review the no-cloning theorem, quantum teleportation and superdense coding.

The main bibliography for this part will be Sections 1.4.4-1.4.6 of these notes.

Speaker: Katharina Leibfarth

Session 3: Shor's factoring algorithm

Here, the famous Shor's factoring algorithm will be presented, describing the algorithm itself as well as some of the techniques required to understand its proof (including Fourier transform and phase estimation).

The main bibliography for this part will be Chapters 3 and 4 of these notes.

Speaker: Tobias Schnieders

Session 4: Hamiltonian simulation and the HHL algorithm

We will present a first introduction to Hamiltonian Simulation and discuss some of the methods used more frequently: Lie-Suzuki-Trotter, Linear Combination of Unitaries and Transforming Block-Encoding Matrices. Next, we will briefly review the HHL algorithm.

The main bibliography for this part will be Chapters 9 and 10 of these notes.

Speaker:

Session 5: Models for computation and quantum complexity theory

In this session, we will present an overview on some basic notions concerning quantum computing and quantum complexity theory. These notions include Turing machines, quantum circuits and some complexity classes.

The main bibliography for this part will be Chapter 3 of this book.

Speaker: Shrish Roy

Session 6: Entanglement and non-locality

Here, we will discuss the notion of non-locality in quantum theory, as well as its applications in communication and information theory, as well as cryptography.

The main bibliography for this part will be this review (until Section V).

It is also possible that we choose a different paper to discuss, also in the line of non-locality.

Speaker: Can Atacan

Session 7: MIP$*$ =RE

This is one of the most important breakthroughs in the development of Quantum Information Theory. In this paper, it was proven that the two complexity classes mentioned in the name are equal. This has important implications in other fields of Mathematics, as it is equivalent to proving in the negative both the Connes' Embedding Problem as well as the Tsirelson's Problem.

The main bibliography for this part will be this paper, but I expect the speaker of this session to give just a rough overview of the result and to base their talk in some previous talks on the paper and some material oriented to a non-specialized audience. The corresponding speaker will be informed about the specific material.

Speaker:

Session 8: Undecidability of the spectral gap

In this session, we discuss the following result: Given the Hamiltonian of a quantum many-body system, the question whether it is gapped or gapless, is an undecidable problem. Specifically, we will show some families of quantum spin systems on a two-dimensional lattice with certain conditions for which the spectral gap problem is undecidable.

The main bibliography for this part will be this paper, but I expect the speaker to prepare their talk either with this shorter version or with some previous talks on the paper and some material oriented to a non-specialized audience.

Speaker: Carla Rubiliani

Session 9: Theory of quantum error-correction. Stabilizer codes

Here, we will show a brief overview on the theory of quantum error-correction. We will see how to construct some basic codes, as well as discuss the stabilizer codes.

The main bibliography for this part will be the first part of Chapter 7 of these notes or Chapter 10 of this book (until 10.5, included).

Speaker:

Session 10: Fault tolerance. State of the art

Building up on the previous session, we will discuss how encoded quantum information can be processed without serious propagation of errors, and how it may be possible to incorporate intrinsic fault tolerance into the design of quantum computing hardware.

The main bibliography for this part will be this paper or Section 10.6 of this book. For the state of the art, an updated reference will be provided to the speaker in due time.

Speaker:

Session 11: Quantum advantage. State of the art

Quantum advantage is the goal of demonstrating that a programmable quantum device can solve a problem that no classical computer can solve in any feasible amount of time (irrespective of the usefulness of the problem). We will discuss some of the most important achievements in this direction, as well as the current state of the art of the problem.

Ths specific bibliography will be provided to the corresponding speaker in due time.

Speaker:

Session 12: Topological quantum computation

Here, we will briefly review the basics of topological quantum computation, i.e. quantum computing with anyons. For that, we will introduce anyons at the system-independent level of anyon models and discuss the key concepts of protected fusion spaces and statistical quantum evolutions for encoding and processing quantum information.

The main bibliography for this part will be Chapter 9 of these notes.

Speaker: Marius Wesle

Session 13: Quantum cryptography

In this session, we will provide an introduction to Quantum Cryptography, i.e. the design cryptographic systems that explicitly rely on quantum effects.

The main bibliography for this part will be Chapter 17 of these notes.

Speaker: Sebastian Krüger

Session 14: Quantum machine learning

Here, we will discuss how quantum computing changes and helps machine learning. In this setting, the learner will be a quantum computer, and the data may be classical or quantum.

The main bibliography for this part will be Chapter 18 of these notes.

Speaker: Jasper Toussaint