Finite-length information theory for quantum systems

Academic Year: (2023 / 2024) **Review date: 26/04/2023 12:57:57**

Department assigned to the subject: Signal and Communications Theory Department

Coordinating teacher: KOCH , TOBIAS MIRCO

Type: Electives ECTS Credits : 3.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

'Pre-quantum information and communication' and 'Quantum information and communication'

OBJECTIVES

Information Theory, established in Claude Shannon's 1948 landmark paper, provides a theoretical view on classical and quantum communication systems. While Shannon's original work considered an asymptotic setting where unbounded transmission delays are acceptable, Finite-Length Information Theory offers a more refined view that takes transmission delays into account. This is specially relevant in quantum systems, where existing technology does not allow to perform optimal measurements over a large set of quantum states.

This course introduces students to Finite-Length Information Theory and equips them with the main mathematical tools required to analyze performance bounds both in classical and quantum systems.

In particular, students will learn about:
- Peformance bounds for classical and quantum communication systems based on random coding and/or optimal decision theory.
- Asymptotic and numerical methods to analyze these bounds.
- Their applications in practical communication systems.

DESCRIPTION OF CONTENTS: PROGRAMME

1. Performance bounds in Finite-Length Information Theory
1.1 Random coding bounds
1.2 Quantum hypothesis testing and optimal decision theory

2. Asymptotic analysis
2.1 The channel coding problem: Capacity and strong converses
2.2 Large deviations and error exponents
2.3 The central limit theory and second-order coding rates

3. Evaluation of performance bounds
3.1 Semidefinite and linear programming
3.2 Saddlepoint approximations

4. Applications to practical communication systems
4.1 Additive Gaussian noise channels
4.2 Bosonic channels

LEARNING ACTIVITIES AND METHODOLOGY

LECTURES
Lectures provide an overview of the main concepts and analytical tools in Finite-Length Information Theory. The classes are mainly taught at the board, aided by slides or and audiovisual media for the illustration of certain topics.

EXERCISES
To deepen the understanding of the taught material, students are provided with problem sets which need to be solved at home and handed in once a month. These solutions will be graded from 1 to 10, and the average grade over the whole semester will constitute part the grade of the continuous assessment.

ASSESSMENT SYSTEM

% end-of-term-examination/test:	0
% of continuous assessment (assigments, laboratory, practicals…):	100

CONTINUOUS ASSESSMENT
Every month, students have to hand in the solutions to a set of problems. These solutions will be graded from 1 to 10, the average grade over the whole semester will constitute 40% the grade. Furthermore, at the end of the semester, there will be an exam, where each student is tested on the material taught in this course. The exam will constitute 60% of the grade.

CONVOCATORIA EXTRAORDINARIA
There will be an exam, where each student is tested on the material taught in this course.

ADDITIONAL BIBLIOGRAPHY

- Vincent Y. F. Tan Asymptotic Estimates in Information Theory with Non-Vanishing Error Probabilities, Foundations and Trends® in Communications and Information Theory, 2014

- Yury Polyanskiy, H. Vincent Poor, and Sergio Verdu Channel Coding Rate in the Finite Blocklength Regime, IEEE Transactions on Information Theory, 2010