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Introduction to quantum communications and computing

Academic Year: (2020 / 2021) **Review date: 30-06-2020**

Department assigned to the subject: Signal and Communications Theory Department

Coordinating teacher: VAZQUEZ VILAR, GONZALO

Type: Electives ECTS Credits : 3.0

Year : Semester :

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Students are expected to have a basic background in probability theory and linear algebra. Therefore, having passed the 1st year courses 'Statistics' and 'Lineal Algebra' is highly recommended.

OBJECTIVES

- Understand the fundamental differences between classical and quantum probability theories.
- Describe mathematically a quantum state of a single qubit and that of several qubits.
- Know and use the axioms that govern the evolution of a quantum system.
- Know and use the axioms that govern the measurement of a quantum state.
- Model and analyze simple quantum communication channels and their cryptographic guarantees.
- Interpret and implement a quantum computing algorithm.

DESCRIPTION OF CONTENTS: PROGRAMME

This course introduces the fundamental concepts of quantum communication and computing. Starting from an experimental basis, we will motivate why the classical theory of probability is not able to model certain real physical systems. We will present a generalization of the concept of probability that allows us to model these experiments, as well as their (unexpected) consequences. The new quantum theory of probability will then be used to analyze several simple problems, including the transmission of information, the distribution of quantum entanglement and the teleportation protocol. Finally, the current state of the technology and its future perspectives will be discussed.

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Contents

Unit 1. Introduction: bits versus qubits

1.1. What is a qubit?
1.2. Probability theory
1.3. Bell's theorem

Unit 2. Axioms of quantum mechanics

2.1. Principles of quantum mechanics
2.2. Combined systems: quantum entanglement
2.3. Temporal evolution of a quantum system
2.4. Simulating quantum systems

Unit 3. Quantum communications

3.1. Classical versus quantum information
3.2. Transmission of information over quantum channels
3.3. Teleportation and other communication protocols
3.4. Secure links and quantum cryptography

Unit 4. Quantum computing

4.1. Quantum computers and quantum gates
4.2. Quantum circuits and algorithms
4.3. Programming a quantum computer
4.4. Present and future of quantum computing

LEARNING ACTIVITIES AND METHODOLOGY

- 9 theoretical sessions presenting the generalization of the classical probability theory, basic concepts of quantum mechanics and illustrative examples.
- 2 practical sessions to simulate simple quantum systems and quantum experiments.

- 2 practical sessions to develop algorithms in real quantum computers.
- 1 practical session to present and simulate a secure communications link.

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Teaching material

The material used in the course sessions will be uploaded to the platform 'Aula Global' in electronic format. Before each session, the students will have available all the information and recommended reading for the best understanding of the session. Exercises will also be given, some of which will be solved in practical sessions.

ASSESSMENT SYSTEM

- Homework and quizzes:	50%
- Practical assignments:	50%

The assessment in the ordinary call will be based on the student work during the course. To this end, homework exercises and quizzes will contribute to the 50% of the final grade and lab reports to the other 50%.

The assessment in the extra-ordinary period will be based on a single exam covering both theoretical questions and practical problems.

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

ADDITIONAL BIBLIOGRAPHY

- Eleanor Rieffel, Wolfgang Polak Quantum Computing: A Gentle Introduction, The MIT Press, 2011