ECE 697PT - Physical Information Theory

Department of Electrical and Computer Engineering
University of Massachusetts Amherst

Fall 2014

Day • Time • Place	TuTh • 10:00–11:15 • ELAB 327
Instructor:	Professor Neal G. Anderson (210E Marcus, anderson@ecs.umass.edu)
Office Hours:	Monday and Wednesday, 1:30-3:00 or by appointment.
Prerequisite:	Graduate standing in ECE, Physics, or Computer Science. Background in basic probability theory, discrete random variables, and linear algebra. Prior acquaintance with information theory and/or quantum mechanics is helpful but is not assumed or required.
Credits:	3

Overview

Information processing requires that abstract "data" be represented in, manipulated by, and extracted from real physical systems. Fundamental physical law (read: quantum mechanics) thus determines the ultimate information processing capabilities of physical artifacts used to implement information processing operations. Fundamental implications of this fact for memory, communication, and computation are the primary concerns of this course.

The course begins with self-contained overviews of essential aspects of Shannon's ("classical") information theory and quantum mechanics. Concepts and results from physical information theory are then developed along two lines: First, the quantification, communication, and processing of "classical" information (i.e. bits), as limited by the quantum nature of information carriers, is discussed, and the physical cost of implementing logical operations is considered as well. Second, the quantification, communication, and processing of quantum information ("qubits") is considered. Fundamental aspects of these topics are emphasized, although technological implications for nanoelectronics, communications, and computing are discussed throughout.

Course Outline

1. Classical Information Theory

   The Communication Process, Information Sources and Shannon Entropy, Data Compression and Noiseless Coding, Noisy Channels and Mutual Information, Coding for Noisy Channels: The Channel Capacity, Computation Channels

2. Toward Physical Information Theory

   Elements of Physical Description, Communication and Computation as Physical Processes

3. Quantum Theory

   Quantum Mechanics I: Individual Systems and Composite Systems in Pure States, Quantum Mechanics II: Mixed States and Density Operators, von Neumann Entropy, Decoherence, Quantum Measurement Revisited

4. Physical Information Theory I - Classical Information in Quantum Systems

   Classical Information in Quantum Systems, Classical Noiseless Coding and Quantum Channels, Accessing Information in Quantum Systems: The Holevo Bound, Classical Capacities of Quantum Channels, Physical Cost of Information Processing: Landauer's Principle and related concepts.

5. Physical Information Theory II - Quantum Information

   Introduction to Quantum Information: Qubits, Quantum Compression and Coding, Communicating Quantum States, Quantum Information Processing

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Resources

The course will be based primarily on notes developed by the instructor, which will be distributed in class. A list of additional resources will be posted and regularly updated as the semester progresses.

Grading

Homework - 30%
Midterm Exam - 35% (tentatively October 29)
Final Exam - 35%
