UEE3504:

Information Theory

Fall Semester 2015
Prof. Dr. Stefano Rini

Brief

Instructor: Stefano Rini
Office: Engineering Building 4, Room 729
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Lecture: Tuesday 10:10-12:00,
Friday 13:20-15:10
in room B07, Engineering Building 4.

Office Hours: Tuesday and Thursday 15:20-16:20
in room ED716a, Engineering Building 4.

Pre-req. Probability (UEE2102) and Linear Algebra (UEE1061) or permission of the instructor

Grading: 40 % Final Exam
20 % Midterm Exam
20 % Homework
20 % Class participation

Syllabus

Course Objectives

The course covers the fundamentals of information theory, a mathematical theory developed to quantify the amount of information contained in a random source and study how such information can be manipulated. While studying these topics, we will also develop some basic data compression and data transmission algorithms.

The course will cover approximately the following topics:

- Introduction and Basic Definitions:
  - entropy
  - mutual information
  - relative entropy
- Review of Probability Theory:
  - discrete probability theory
  - discrete random variables
  - continuous random variables
- Data Compression for a Single Variable:
  - Kraft inequality
  - Shannon-type codes
  - Fano code
  - Huffman code
- Data Compression for an Information Source:
  - Tunstall code
  - Arithmetic coding
- Stochastic Processes and Entropy Rate:
  - Discrete stationary sources
  - Markov processes
  - Entropy rate
- Data Compression for an Sources with Memory:
  - Elias - Willems coding,
  - Lempel - Ziv coding
- Fundamentals of Optimization:
  - Convex functions and convex sets
  - Maximization of convex functions
  - KarushKuhnTucker (KKT) conditions
- Gambling and Horse Betting:
  - Problem setup
  - Optimal gambling strategies

- Gambling with side-information

- Data transmission over a noisy channel:
  - Asymptotic Equipartition Property (AEP)
  - Fano's inequality and data processing lemma
  - The Bhattacharyya Bound
- Computing Capacity:
  - Symmetric channels
  - Weakly symmetric channels
  - Mutual information and convexity
- Error Exponent and Channel Reliability Function:
  - Gallager bound
  - Gallager exponents
  - Channel reliability function
- Gaussian Channel:
  - channel coding theorem for the Gaussian channel
  - bandlimited AWGN channel
  - parallel Gaussian channels

The first half of the course will focus on source coding, in the second part, we will focus channel coding. We hope that a student who finishes the course will be able to better understand the principles underlying all state-of-the-art data compression and data communication systems and the difficulties encountered when designing and trying to improve upon them.

Textbook

- Stefan M. Moser, *Information Theory (Lecture Notes)*
  (version 4.2 from 1 February 2015), 4th edition,
  available online at http://moser-isi.ethz.ch/scripts.html

Other useful textbooks are

- *A First Course in Information Theory (Information Technology: Transmission, Processing, and Storage)*, Raymond W. Yueng, Plenum Pub Corp, 2002.
- *Elements of Information Theory*, Thomas M. Cover and Joy A. Thomas, John Wiley and Sons, 1991.
- *Principles and Practices of Information Theory*, Richard E. Blahut, Addison Wesley, 1988.

Exercises

Every week, a new homework assignment will be posted on the course website. This homework will consist of several problems that need to be solved at home and handed in during the class of the following week. Each homework will also contain a numerical simulation exercise which must be solved using MATLAB or a similar mathematical simulation software.

A model solution will be published online after the homework has been collected.

To pass the course you need to hand in at least 10 exercises.

Exams

There will be one mid-term and one final exam, each will be a take home exam and you will be given a week to solve it.

Special Remarks

The lecture will be held in English.