ELE 486 – Transmission and Compression of Information

Spring Semester, 2019

Instructor

Dr. Christopher G. Brinton, PhD
Lecturer of Electrical Engineering
Associate Director of the EDGE Lab
Princeton University
www.cbrinton.net

E-mail: cbrinton@princeton.edu
Phone: (609) 258-8351
Office: EQUAD C330
Office Hours: Mon and Wed, 4:30pm-6:00pm, or by appointment.

Course Information

Meeting times: Monday and Wednesday, 11:00am-12:20pm
Room: Friend Center 112

Description: Our digital world relies heavily on the ability to extract, store, and transfer information. Over the years much effort has been devoted to the development of methodologies that perform these tasks efficiently. This course covers the fundamental algorithms and limits of data compression and transmission, detailing key components of information theory and coding theory such as entropy, source/channel codes, and information measures. We also draw connections between these theories and several techniques in supervised and unsupervised machine learning, including data clustering, principal component analysis and graphical models.

Prerequisites: Linear algebra and basic probability theory

Textbook

We will follow *Elements of Information Theory* (EIT), Second Edition by Cover and Thomas for a good portion of this course. Buying a copy is not required, as lecture notes will be provided, but having access to a copy might be useful. We may also draw from *Principles of Digital Communication* by Gallager and *Pattern Recognition and Machine Learning* by Bishop at points.

Evaluation

This class will have three groups of assessments:

1. *Homeworks (35%)*

There will be 6 problem sets, due roughly every third lecture. Each homework will be released and its due date announced at least a week in advance.

The problems in the homeworks will be a blend of mathematical proofs and numerical computations. In each case, all work must be shown to receive credit. Some problems may be taken from textbooks, and you are thus not permitted to consult solution manuals while doing homeworks. You may collaborate with one person on each problem set if you choose, but even so you each must turn in your own individual submission and include the name of the person you worked with.

Problem sets must be turned in to the instructor as a hardcopy by the beginning of lecture on the due date. Late submissions will be accepted for up to three (business) days, losing one full letter grade for each day late. No submissions will be accepted after the third day.

2. *Midterm Exam (30%)*

The midterm will be administered in class the second lecture after Spring break, covering the first four units of the course. The problems can generally be expected to be more difficult than examples covered in class but less time consuming than the homeworks.

3. *Final Exam (35%)*

The final exam will be administered in class during the final exam period. The problems will be of a similar nature to the midterm questions, but the exam will be cumulative.

Course Topics and Tentative Schedule

The course will be divided into eight units, each with 2-4 lectures. The following is a tentative schedule of topics and due dates, which will be updated and filled out during the semester.

<table>
<tr><th>Lecture</th><th>Date</th><th>Unit</th><th>Topics Covered</th><th>Due</th><th>Reading</th></tr>
<tr><td>1</td><td>2/04</td><td rowspan="5">Entropy and Mutual Information</td><td>Introduction
Defining Entropy
Joint Entropy, Conditional Entropy</td><td></td><td>EIT 1, 2.0-2.2</td></tr>
<tr><td>2</td><td>2/06</td><td>Relative Entropy, Mutual Information
Chain Rules</td><td></td><td>EIT 2.3-2.5</td></tr>
<tr><td>3</td><td>2/11</td><td>Jensen’s Inequality and Consequences
Log Sum Inequality</td><td></td><td>EIT 2.5-2.7</td></tr>
<tr><td>4</td><td>2/13</td><td colspan="3">No Class</td></tr>
<tr><td>5</td><td>2/18</td><td>Data-Processing Inequality
Fano’s Inequality</td><td></td><td>EIT 2.8, 2.10</td></tr>
</table>

6	2/20	Asymptotic Equipartition Property	AEP Theorem Typical and Nontypical Sets	HW #1	EIT 3.1, 3.2
7	2/25		AEP Data Compression High-Probability Sets		EIT 3.2, 3.3
8	2/27	Entropy Rates of a Stochastic Process	No Class		
9	3/04		Stochastic Processes Entropy Rate		EIT 4.1, 4.2
10	3/06		Random Walks on Graphs Functions of Markov Chains	HW #2	EIT 4.3, 4.5
11	3/11	Data Compression	Classes of Codes Kraft Inequality Optimal Codes		EIT 5.1-5.3
12	3/13		Bounds on Optimal Codes Kraft Inequality for		EIT 5.4, 5.5
-	3/18 3/20		Spring Break		
13	3/25		Huffman Codes Optimality of Huffman Codes		EIT 5.6-5.8
14	3/27		Midterm Exam		
15	4/01		Shannon-Fano-Elias Coding Competitive Optimality		EIT 5.9, 5.10
16	4/03	Channel Capacity	Channel Capacity and Examples Preview of Channel Coding Theorem	HW #3	EIT 7.0-7.4
17	4/08		Channel Definitions and Terminology Joint Typicality		EIT 7.5-7.6
18	4/10		Channel Coding Theorem Zero-Error Codes		EIT 7.7-7.8
19	4/15		Coding Theorem Converse Source-Channel Separation		EIT 7.9-7.10, 7.13
20	4/17	Differential Entropy	Definitions and Examples AEP for Continuous RVs	HW #4	EIT 8.0-8.2
21	4/22		Quantization Entropy Joint, Conditional, Relative Entropy More Properties		EIT 8.3-8.6
22	4/24	Gaussian Channel			
23	4/29				
24	5/01			HW #5	
TBD		Final Exam			

Grading Policy and Procedures

Grading in this class will be performed in accordance with the policies set forth here by the Office of the Dean of the College (ODOC). The teaching staff will take responsibility for ensuring that each assessment – problem sets, labs, and exams – is marked in a manner that constitutes "substantive feedback to give students clear information about the quality of their work."

Note also that there are no exact numerical ranges associated with how letter grades will be allocated. For this reason, the instructors reserve the right to institute curves, both on individual assessments and on the final grades, as they see fit. Both upward and downward curves as possible, though the former is more likely if at all. That being said, students can also expect that their final letter grades will not deviate too substantially far from what would be expected on a traditional scale.