Boston University
Department of Electrical and Computer Engineering
ENG EC 517 Introduction to Information Theory
Spring 2020

Course Information

Motivation and overview: The field of information theory was pioneered by Claude Shannon, beginning with his landmark paper "A Mathematical Theory of Communication" in 1948. This theory delineates the fundamental limits of efficient data compression and reliable transmission over noisy channels. Subsequent efforts have revealed that information theory plays a fundamental role in many other disciplines, including networks, statistics, machine learning, and theoretical computer science. This course is an introduction to information theory with a focus on core concepts, theorems and their proofs, and simple examples. Bits are now well-known as the "currency" of information and this course will put this notion on sound mathematical footing.

Prerequisites: This course assumes knowledge of probability at the undergraduate level (e.g., ENG EK 381) as well as the basics of undergraduate linear algebra and signals and systems. In particular, students should be familiar with the notions of joint and conditional probability distributions, conditional expectation, independence, and Gaussian random vectors. During the first week, we will review some of these topics, but at a quick pace meant to establish notation and serve as a reminder for those already familiar with the topics covered.

If you have not already taken these classes (or their equivalent) or have any doubts about your understanding of these concepts, please discuss them with the instructor. In addition to the formal prerequisites, it is assumed that you have the interest, commitment, and maturity for understanding concepts in depth. Your responsibilities may involve seeking out information outside the regular course materials for additional reference.

Logistics:

Instructor:	Prof. Bobak Nazer Office: PHO439 Email: `bobak@bu.edu` Web: `http://iss.bu.edu/bobak` Phone: (617)-358-5858
Office hours:	TBD in PHO439
Lectures:	Monday and Wednesday 12:20–2:05 pm in PHO201
Web site:	`http://learn.bu.edu/`
Textbook:	[C&T] T. M. Cover and J. A. Thomas *Elements of Information Theory*, Wiley-Interscience, 2nd ed. 2006. **Free PDF download with BU login:** `http://onlinelibrary.wiley.com.ezproxy.bu.edu/book/10.1002/047174882X`
Pre-Pandemic Grading:	Homework: 25%, First Midterm 25%, Second Midterm: 25%, Final: 25%
Post-Pandemic Grading:	Homework: 20%, First Midterm 40%, Course Project: 40%

Piazza: This semester we will be using Piazza as a discussion board. The system is highly catered to getting you help quickly and efficiently from myself and your fellow classmates. You have the option of asking (and answering) questions anonymously, meaning that your name will only be displayed as ”Anonymous” to everyone else. Rather than emailing questions, I encourage you to post your questions on Piazza. If you have any technical issues or feedback for the developers, email team@piazza.com.

References: In addition to the main textbook, the BU Science and Engineering Library has been requested to place the the following reference books on reserve for this course:

- C. E. Shannon and W. Weaver, *The Mathematical Theory of Communication*, University of Illinois Press, Urbana, 1962. (Also available online, see blackboard.)
- R. G. Gallager, *Information Theory and Reliable Communication*, Wiley, New York, 1968.
- D. J. C. MacKay, *Information Theory, Inference, and Learning Algorithms*, Cambridge University Press, Cambridge, UK, 2003. (Also available online, see blackboard.)
- R. W. Yeung, *A First Course in Information Theory*, Kluwer Academic/Plenum Publishers, New York, 2002. (Also available online, see blackboard.)
- I. Csiszar and J. Körner, *Information Theory: Coding Theorems for Discrete Memoryless Systems*, Academic Press, New York, 1981.
- T. Berger, *Rate Distortion Theory; a Mathematical Basis for Data Compression*, Prentice-Hall, Englewood Cliffs, 1971.

Course Topics: This semester, we will be trying to include material connected to high-dimensional statistics and machine learning, in addition to the traditional applications to data compression and reliable communication. This will be an evolving experiment, and as such no detailed lecture schedule is available. When we start a new topic, I will provide pointers to relevant sections of the textbook as well as other online resources. Time permitting, I plan to cover the following topics:

- Basic Information Measures: Entropy, Divergence, and Mutual Information
- Typicality and Concentration
- Fano's Inequality and Converse Arguments
- Source Coding and Data Compression
- Entropy Rate and Information Sources with Memory
- Binary Hypothesis Testing
- M-ary Hypothesis Testing
- Channel Coding and Reliable Communication
- Differential Entropy and Gaussian Channels
- Rate Distortion and Quantization
- High-Dimensional Estimation
- f-Divergences

Course Project: Due to the pandemic, I have decided to substitute the second midterm and the final exam with a course project. You will be given a list of potential topics and readings. The objective of the project is to summarize the reading with a writeup, and then explain the key ideas during a 30-minute one-on-one Zoom call. For a theory-based topic, a successful project should include a discussion of the motivating applications, a formal problem statement, a statement of one or more theorems from the paper along with a sketch of the key proof arguments, and an easy-to-understand example. For a simulation-based topic, a successful project should include a discussion of the motivating applications, a formal problem statement, a statement of one or more algorithms from the paper along with a discussion of why the algorithm is expected to succeed, and at least one plot along with an interpretation.

Homework: Each student must submit an original set of solutions to the instructor at the beginning of class on the due date. Requests for late submissions and/or extensions will not be entertained (except under exceptional circumstances which must be discussed with the instructor).

Collaboration policy: You are required to *independently solve* and write your own solutions. You should approach the instructor for clearing your doubts. While you may discuss homework problems with other students for clarifying your understanding, you are required to solve homework problems on your own. Contact the instructor if you are not sure whether the extent of your collaboration with other students is acceptable. You will be cheating yourself if you simply copy your friend's solution without understanding it. When detected, the penalties can be severe.

General policies

Academic misconduct

The student handbook defines academic misconduct as follows.

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Academic misconduct is conduct by which a student misrepresents his or her
academic accomplishments, or impedes other students' opportunities of being
judged fairly for their academic work. Knowingly allowing others to represent
your work as their own is as serious an offense as submitting another['s work
as your own.
```

This basic definition applies to ENG EC 517 A1. If you are ever in doubt as to the legitimacy of an action, please talk to me immediately. The penalty for academic misconduct at BU is severe. For further information on the BU College of Engineering Academic Code of Conduct, visit the following website:
`https://www.bu.edu/academics/policies/academic-conduct-code/`

Make-up exams

As such, there will be no make-up exams. If there is a legitimate reason for missing an exam, such as illness as supported by a doctor's note, then the scores of other exams will be used appropriately to compensate for the missed exam. If there is no legitimate reason provided for missing an exam, a grade of *zero* will be assigned for the missed exam.

Incomplete grades

Incomplete grades will not be given to students who wish to improve their grade by taking the course in a subsequent semester. An incomplete grade may be given for medical reasons if a doctor's note is provided. The purpose of an incomplete grade is to allow a student *who has essentially completed the course* and who has a legitimate interruption in the course, to complete the remaining material in another semester. Students will not be given an opportunity to improve their grade by doing "extra work".

Drop dates

Students are responsible for being aware of the drop dates for the current semester. Drop forms will not be back-dated.