Spring 2014
ECE 542: INFORMATION THEORY AND CODING

Logistics:

Instructor:	Prof. Anand D. Sarwate Office: CoRE 517 Email: `asarwate@ece.rutgers.edu` Web: `http://www.ece.rutgers.edu/~asarwate/`
Office hours:	Mondays, 10-11 in CoRE 517
Lectures:	6:40 PM - 9:30 PM in SERC 217
Website:	`http://sakai.rutgers.edu/`
Textbook:	T. M. Cover and J. A. Thomas *Elements of Information Theory*, Wiley-Interscience, 2nd ed. 2006. R. E. Blahut, *Principles of Information Theory*, Cambridge University Press. (This is a book in progress – excerpts will be handed out in class)

Unofficial overview: The groundwork for the digital revolution was laid by Claude Shannon in 1948 when he created a mathematical framework that quantified information in terms of "bits." Information theory builds, from first principles, a model to understand both the fundamental limits of information representation (data compression) and transmission (digital communication). This class will introduce these fundamental tools as well as some of the applications that embody the core concepts. The central approach is to model data sources and communication channels using probabilistic models – this course will be be on the mathematical side, with theorems and proofs. This course is about how and why "bits" have become the way we measure information, how information-theoretic thinking informs our storage and transmission systems, and how these ideas and information measures connect to central questions in statistics. This course is ideally suited to graduate students in ECE, computer science, statistics, physics, and mathematics. A solid grounding in probability, linear algebra, and calculus will be extremely helpful.

Topics: This course is an introduction to the mathematical modeling of information transmission using tools from probability. Topics include:

- fundamental information measures on discrete and continuous alphabets such as entropy, mutual information, Kullback-Leibler divergence and fundamental inequalities (data processing, Fano)
- the method of types, the asymptotic equipartition theorem, and connections between information theory and statistical inference

- data compression, Shannon's source coding theorem, practical coding schemes approaching these limits, rate-distortion theory and lossy compression
- the noisy channel coding theorem and its converse, implications for communication systems, extensions to Gaussian sources and channels, rate-distortion theory and lossy compression, and the basics of multi-terminal systems.

More on prerequisites: Students should have completed at the minimum the undergraduate probability course, and preferably a graduate course in stochastic processes and systems (such as ECE 541 – Stochastic Signals and Systems). Concepts such as joint distributions, conditional expectations, independence, jointly Gaussian variables, and Gaussian processes are central to the modeling used in the course. There will be a brief overview of these concepts at the beginning of the course, but this is meant as a reminder. Students will be expected to have the mathematical maturity to read and understand the material in the textbook, including the proofs. If you have any concerns about whether you should take the course, please contact the instructor before classes begin.

Additional references: Students may find some the following as useful supplements to the material in the course.

- C. E. Shannon and W. Weaver, *The Mathematical Theory of Communication*, University of Illinois Press, Urbana, 1962.
- 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.
- R. W. Yeung, *A First Course in Information Theory*, Kluwer Academic/Plenum Publishers, New York, 2002.
- I. Csiszar and J. Körner, *Information Theory: Coding Theorems for Discrete Memoryless Systems*, 2nd edition, Cambridge University Press, Cambridge, UK, 2011.
- T. Berger, *Rate Distortion Theory; a Mathematical Basis for Data Compression*, Prentice-Hall, Englewood Cliffs, 1971.

Schedule: This is an approximate schedule of topics for the class, together with assigned reading and homework dates. The schedule is subject to change based on the progress of the course.

Date	**Topic**	**Reading**	**HW Assigned**	**HW Due**
Jan. 22	Introduction & Probability Review		HW 1	
Jan. 29	Typicality and Entropy	C&T: 2, 3		
	Divergence and Mutual Information	Blahut: 1, 2		
Feb. 5	Fano's Inequality, AEP	C&T: 2, 3	HW 2	HW 1
	Intro. to Source Coding	Blahut: 2		
Feb. 12	Lossless Source Coding	C&T: 5		
	Huffman and Other Codes	Blahut: 2		
Feb. 19	Prefix-free codes	Ch. 13		
	Huffman and Other Codes	Ch. 7		
Feb. 14	(no lecture)			HW 2
Feb. 26	**Midterm 1**			HW 2
Mar. 5	Universal Source Coding	Ch. 7	HW 3	
	Channel Coding	Ch. 8		
Mar. 12	Channel Coding	Ch. 8	HW 4+5	HW 3
	Continuous Sources			
Mar. 19	**No Class – Spring Break**			
Mar. 26	Differential Entropy	Ch. 8		HW 4
	Gaussian Channels	Ch. 9		
Mar. 31	(no lecture)			HW 5
Apr. 2	Parallel Gaussian Channels	Ch. 9		
	Practical Considerations		HW 6	
Apr. 9	**Midterm 2**			
	Rate Distortion	Ch. 10	HW 7	HW 6
Apr. 16	Rate Distortion for Gaussians	Ch. 10		
	Information Theory and Statistics	Ch. 11	HW 8	HW 7
Apr. 23	**Quizlet**			
	Introduction to multi-terminal IT	Ch. 15		
Apr. 30	Multiple-Access Channels	Ch. 15		HW 8
	Broadcast Channels	Ch. 15		
	Final thoughts			
	FINAL EXAM			

Grading and assessment:

Grading: Homework: 10% (8 assignments)
First midterm exam: 25%
Second midterm exam: 25%
Quizlet: 5%
Final exam: 35%

Homework: Homework is due at the beginning of class on the due date. There are no extensions or late submissions without the prior consent of the instructor. Such consent will only be given in exceptional circumstances. Each student must prepare their own original solutions to the homework.

- *Collaboration policy:* I expect students to independently solve the problems on the homework and write up the solutions individually. Discussing with other students is permissible, but these are not meant to be "group assignments." Treating the homework as such is cheating yourself and will only hurt you later on during the exam. Copying the solution from another student is a form of *academic misconduct* (see below) and there may be severe penalties. If you are concerned about whether your collaboration is appropriate, please contact the instructor. If you have difficulties with the homework, come to office hours.

- *Some tips:* Since this is a more mathematical course, doing the homework is very important! Developing proficiency in applying the concepts will give you a depth of understanding that will serve you well on the exams. Don't leave the homework to the night before. If you have problems, come to office hours, and if you miss a question, make sure you understand the solution when it is posted.

Exams: Exams are closed-book and closed-notes. No calculators, computers, or communication devices will be allowed. They will not be needed. You may bring one US Letter (8.5-inch × 11-inch) sheet of handwritten notes to the first exam, two such sheets to the second exam and quizlet, and three such sheets to the final exam.

General policies

Academic Integrity. Students should be familiar with the Academic Integrity policy at Rutgers University:

`http://academicintegrity.rutgers.edu`

If you have any questions about whether your actions may compromise academic integrity in some way, please contact the instructor as soon as possible.

Misrepresenting your work or contributions hurts not only yourself, but others. As the website states, "every member of the University community therefore bears a responsibility for ensuring that the highest standards of academic integrity are upheld." Among other things, this means *copying homework solutions* and *letting others copy your solutions* are both serious offenses. Violations of the academic integrity code may result in disciplinary proceedings.

Responsibilities. As a student, it is your responsibility to manage your schedule such that you can come to lectures prepared and on-time. Homework is due at the beginning of class on the due date indicated – late homework will not be accepted. Similarly, there will be no make-up exams. If there is a legitimate reason for missing an exam, such as illness supported by a doctor's note, then the score for that exam will be assigned based on scores from the other exams. Without such a legitimate reason, the score assigned will be *zero*.

Incomplete grades and dropping the course 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".

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