BIRZEIT UNIVERSITY

Faculty of Engineering and Technology
Department of Electrical and Computer Engineering
First Semester 2021/2022

Information and Coding Theory ENEE 5304
Course Outline

Instructor: Dr. Wa'el Hashlamoun First Semester 2021-2022

General Information

Instructor
Dr. Wael Hashlamoun
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Office hours: To be announced; in class, on ritaj, and on the door of my office (during the pandemic and online teaching, office hours will be given online, usually, one or two days before the exams)

Textbook: There is no required textbook for this course. However, there are many available references. In addition, class slides will be distributed.

References:

1. W. A. Hashlamoun, ENEE 5304 Lecture Slides, to be made available to students on ritaj.
2. S. Haykin, Communication Systems, 4th Edition, John Wiley & Sons, 2001 (Chapters 9 and 10)
3. T. Cover and J. Thomas, Elements of Information Theory, John Wiley & Sons, 2006.
4. G. A. Jones and J. M. Jones, "Information and Coding Theory," Springer ISBN 1-85233-622-6, 3rd Edition.
5. R. W. Hamming, Coding and Information Theory, 2nd Ed., Prentice-Hall Inc.,1986

6. R. B. Wells, Applied Coding & Information Theory for Engineers, Prentice Hall, NJ 1999.
7. R. E. Ziemer and W. H. Tranter, Principles of Communications: Systems, Modulation, and Noise, 6th Edition, Hoboken, NJ : Wiley, 2009.
8. S. M. Moser and P.-N. Chen, A Student's Guide to Coding and Information Theory, Cambridge, 2012.

Prerequisites:

- ENEE 3306 (Modern Communication Systems), for Electrical Engineering Students
- ENEE 339 (Communication Systems), for Computer Engineering Students
- Knowledge of basic probability theory (ENEE 2307 Probability and Engineering Statistics).

Course Description

The aim of this course is to introduce the undergraduate students to the fundamental concepts in information theory and coding.

Information theory is the mathematical theory that deals with the fundamental aspects of communication systems. Its objective is to answer two fundamental questions.

The first question, which is concerned with the source, is: ***Given an information source, how much can we faithfully compress the data? Is there any limit?***

The answer comes through the *Source Coding Theorem*.

The second question, which is concerned with the channel, is: ***Given a noisy channel, what is the maximum rate of reliable communication over the channel, i.e., the rate below which the probability of error can be made arbitrarily small?***

The answer comes through the Channel Coding Theorem.

Researchers have proposed source coding techniques and channel coding techniques in an attempt to reach the fundamental limits derived by Shannon. The objective of this course is to develop the fundamental ideas of information theory and to indicate where and how the theory can be applied. In particular, we introduce to the students the concept of amount of information, entropy, channel capacity, error-detection and error-correction codes, block coding, convolutional coding, and Viterbi decoding algorithm.

Intended Learning Objectives

- Understand the difference between “data” and “information in a message”.
- Learn how to analyze and find the information per symbol emitted by a source.
- Be introduced to the concept of entropy H of a discrete memory-less source and a Markhoff source.

- Learn how to analyze the information-carrying capacity of the communication channel.
- Learn how to design lossless source compression codes to improve the efficiency of information transmission.
- Learn how to design error control codes to improve the reliability of information transmission over a noisy channel.

Course Outcomes

At the end of this course, this is what students should have acquired

- Should be able to model a discrete time source and find its entropy.
- Be able to encode a discrete time source so that the Shannon theoretical limit can be achieved, asymptotically.
- Be able to encode a source in a lossless manner by using some algorithms like the Huffman and Limpel-Ziv encoders.
- Be able to find the capacity of a discrete memoryless channel.
- Be able to find the capacity of the Gaussian channel.
- Have developed an understanding of linear block codes and their ability to correct errors over a noisy channel.
- Have developed an understanding of a convolutional encoder and its representation as a tree, a finite state machine, and as a trellis.
- Be able to use the maximum likelihood method and the Viterbi algorithm to decode messages encoded using a convolutional encoder.

(ABET) Relationship of course to Electrical Engineering Program Student Outcomes:

- (a) Ability to apply mathematics, science and engineering principles.
- (e) Ability to identify, formulate and solve engineering problems.

- (k) Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Subject to be covered

- **Information Theory**: Uncertainty, Information, Entropy, Discrete Memory-less Sources, Extension of DMS, Markov Sources, Source-Coding Theorem, Data Compression, Prefix-Free Codes, Kraft Inequality, Huffman Coding, Lempel-Ziv Coding, Discrete Memoryless Channels (DMC), The Binary Symmetric Channel, Mutual Information, Capacity for a Discrete Memory-less Channel, Capacity of the Gaussian Channel, Channel Coding Theorem, Information Capacity Theorem.
- **Error-Control Coding**: Block Codes, Linear Codes, Hamming Codes, Generator Matrix, Parity-Check Matrix, Syndrome, Cyclic Redundancy Check.
- **Convolutional Codes**: Convolutional Encoder, General Rate 1/n Constraint Length K Code, Tree Representation of Convolutional Codes, Finite-State Machine Code Representation, Trellis Representation of Convolutional Codes, Maximum Likelihood Decoding of a Convolutional Code, Viterbi Decoding Algorithm, Free Distance of a Convolutional Code.

Course Assessment (assuming regular teaching model)

Quizzes:	18%
Course Project:	14%
Midterm Exam:	30%
Final Exam:	38%

Remark: The above distribution may change in case we are compelled to move to online teaching due to the spread of the pandemic.

Missed Quizzes: Three in-class quizzes will be given during the course. **Makeup of missed quizzes will NOT be possible**. Exact time of each Quiz will be announced at least one week in advance.

Missed Midterm: Makeup of missed midterm exams is only possible in extremely exceptional situations, provided there is an extremely compelling reason (such as verifiable medical emergencies).

Course Policy: It is the responsibility of each student to adhere to the principles of academic integrity. (You can find all about academic integrity on Ritaj). Academic Integrity means that the student should be honest with him/herself, fellow students, instructors, and the University in matters concerning his or her educational endeavors. **Cheating will not be tolerated in this course.** University regulations will be pursued and enforced on any cheating student.