1. **Course Description**

Information theory applied to communication systems. It covers digital signals and streams, codes, compression, error-correcting codes, block codes, convolutional codes, Viterbi algorithm, noise, maximum-entropy, Markov chains and channel capacity formalism.

Prerequisite: 4th year standard

2. **Course Objectives**

The objective of the course is to introduce students to the basics of information theory, error-correcting codes and digital compression.

A student who has successfully completed this course should be able to:

1. mathematically model common information sources.
2. mathematically model common noisy channels and classify them based on their probability distributions.
3. characterize a communication system based on Shannon’s basic information measures.
4. apply the basic relations between the information measures.
5. understand Markov chains and the data processing theorem.
6. apply the basic inequalities in information theory.
7. understand the zero-error data compression.
8. understand the channel coding theorem.
9. understand limit on the capacity of a channel.
10. understand and apply the error-correcting linear block codes.
11. understand and apply the error-correcting convolutional codes.

3. **Contribution of course to meeting the professional component**

<table>
<thead>
<tr>
<th>Professional Component</th>
<th>Credits</th>
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<tbody>
<tr>
<td>Mathematics and Basic Sciences</td>
<td>0</td>
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<tr>
<td>Engineering Topic</td>
<td>3</td>
</tr>
<tr>
<td>General Education</td>
<td>0</td>
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</tbody>
</table>

4. **Relationship of course to program outcomes**

PO (a): an ability to apply knowledge of mathematics, science, and engineering
- Applies knowledge of mathematics
- Applies knowledge of signal processing

PO (e): an ability to define, formulate, and solve engineering problems
- Demonstrates an ability to formulate engineering problems, to recognize and identify the basic governing theories and principles in the area of signal processing

5. **Course Outline**

**Source and Channel Models**
- Discrete and continuous sources
- Discrete and continuous channels
- Probabilistic characterization of stationary, time-invariant and memory-less sources
- Probabilistic properties of Markov sources
- Probabilistic characterization of stationary, time-invariant and memory-less channels
- Binary symmetric channels, M-ary symmetric channels, erasure channels, Gaussian channels
Shannon Information Measures
Entropy as a measure of the amount of uncertainty of a discrete source
Differential entropy of continuous sources
Informational divergence between two probability distributions
“Knowledge reduces uncertainty”: the conditional entropy
Mutual information
Venn’s diagram: relationship between entropy, conditional entropy and mutual information
Chain rules for entropy and mutual information

Chain Processing and Information Losses
Chain processing
Markov chains
“Knowledge does not always reduce the information”: the conditional mutual information
The data processing theorem

Basic Inequalities in Information Theory
Jensen’s inequality and its consequences
Fano’s inequality
Gibbs’ inequality and its application
Applying the basic inequalities to calculate the maximum entropy

Zero-error data compression
The rate of a code
Distortions introduced by a code
Zero-error compression and the entropy of a source
The Kraft-McMillan inequality
Huffman code
Optimality of the Huffman code

The Capacity-Cost function
Shannon’s channel coding theorem
General behavior of the capacity-cost function
Channel capacity for some common channels
Channel capacity of discrete and continuous adder channels

Error-Correcting Linear Block Codes
Rate of a code
Encoding and the generator matrix
Parity-check matrix and syndrome decoding
Error detecting capabilities of a linear code
Error correcting capabilities of a linear code
Coding gains under hard-decision detection and soft-decision detection

Error-Correcting Convolutional Codes
Linear sequential circuits
Encoder structure
Description in the D-transform domain
State diagram representation
Extended state diagram representation
Trellis representation
Convolution codes in systematic form
Distance properties of convolutional codes
Minimum free distance of convolutional codes
The Viterbi algorithm
Error probability analysis for convolutional codes
Hard-decision and soft-decision decoding

Introduction to cyclic codes
Introduction to more complex models and some open problems

6. Required tools / software / skills
Software: Matlab.

7. Textbook[s]
8. Additional References


9. Schedule of Exams & Grading Percentage

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Quizzes</td>
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<tr>
<td>Mid term 1</td>
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<tr>
<td>Mid term 2</td>
<td>25%</td>
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<tr>
<td>Final Exam</td>
<td>40%</td>
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10. Course Policies

- Failure to take a test or the final exam during the assigned class period will result in a grade of zero being recorded for that test unless the student has personally contacted me and received permission to be absent from the test.
- No makeup exams will be given for the two midterms. In case a student fails to take an exam, the 25% of the final grade assigned for this midterm will be redistributed in the following manner: 10% for the other midterm (that will now count for 35% of the final grade) and 15% for the final exam (that will now count for 55% of the final grade).
- Makeup exams will be given for students who fail to attend the final exam.
- The student is responsible for all business conducted and announcements made during any scheduled class period. LAU attendance policies are enforced.

11. General Comments

Homework sets will be given on a regular basis and their solutions will be posted on the course website. Most of the homeworks will be solved in class. Even though homeworks will not be graded, they are critical to learning the material and to doing well on the mid terms and final exam. Homework questions will appear regularly in quizzes and they may also appear in the tests. You are encouraged to discuss the homework with your colleagues.

In order to get the most out of the course, try to stay ahead. Before attending a lecture, make sure you have reviewed the material covered in the previous lectures. Read the assigned material, but at a minimum, make sure to review the slides posted on the course website. This way, lectures will be much more informative and meaningful. Studying on a daily basis will be very fruitful since quizzes count for 10% of the final grade.

It is intended that the overall work required be approximately six hours per week, including three hours of lecture. Students who find themselves spending substantially more than six hours any week should question whether they are stuck and might make more rapid progress if they asked the instructing staff for some hints or advice. I am available at these office hours:

Office Hours: TTH 11:00 - 01:00, W 12:00 – 02:00 or by appointment.
Office: Bassil 102.
Email: chadi.abourjeily@lau.edu.lb
Course Website: http://services.sea.lau.edu.lb/academia/courses/ele599/

12. General Rules & Regulations

- A student can miss no more than 4 sessions of instruction. By the 5th session, the instructor may ask the student to drop the course.
- Plagiarism: students caught cheating on an exam receive a grade of zero on the exam in the first cheating attempt and a warning. Students caught cheating for the second time in the same course receive an F grade in the course and a second warning. A grade of zero on an exam resulting from cheating must be counted in the student’s course grade. The zero cannot be dropped in computing the final grade in case the instructor has a policy of allowing students to drop their worst exam grade.
- Any student who receives 3 warnings will be suspended.

13. Person(s) who prepared this description and date of preparation

Chadi Abou-Rjeily, February 15, 2010