Michigan State University
Department of Electrical and Computer Engineering

ECE 446: BIOMEDICAL SIGNAL PROCESSING (Fall 2019)

Course Overview

Staff

Instructor

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Helper

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Office hours: T, 4:30pm-6:00pm, 1522 EB (starting the week of 09/09)

Lectures

MW, 12:40pm-2:00pm, 2320 EB

Course Website

https://d2l.msu.edu

Click on FS19-ECE-446-001 - Biomedical Signal Processing

This website will serve as the mechanism for information exchange in this course. That is, all course notes, lecture notes, problem sets, projects, solutions, and any other handouts will be made available through this website. Class announcements will also be made by email sent via the website. Thus, **the course website should be visited frequently** throughout the semester.

Textbook

No textbook will be required, as formal course notes are provided. However, students may find the following textbooks (on reserve at the Main Library) to serve as helpful reference material:

- Oppenheim and Schafer (2010). *Discrete-time Signal Processing*, Prentice-Hall.
- Oppenheim and Wilsky with Nawab (1997). *Signals and Systems*. Prentice Hall.
- Papoulis and Pillai (2002). *Probability, Random Variables, and Stochastic Processes,* McGraw Hill.
- Quatieri (2001). *Discrete-Time Speech Signal Processing: Principles and Practice*, Prentice Hall.
- Rabiner and Schafer (1978). *Digital Processing of Speech Signals*, Prentice-Hall.

Prerequisites

ECE 280 (Electrical Engineering Analysis) and ECE 366 (Introduction to Signal Processing)

Course Synopsis

This course introduces basic digital signal processing theory in the context of biomedical applications. Major signal processing topics covered include data acquisition, frequency domain analysis, filtering, time-dependent processing, linear prediction, random signal properties, and interaction of random signals with linear systems. Practical experience is provided in applying these signal processing techniques to real physiologic signals through three MATLAB projects. These projects specifically focus on classical analysis of cardiac, speech, and neural signals and cover the physiologic origins of each of these signals. The course notes and projects are obtained from the well-developed HST 582 course offered at MIT by Dr. Julie Greenberg.

Course Schedule

Prior to the start of each week of the semester, the lecture materials for the week will be posted on the course website. That is, the lecture topics (see Detailed Course Outline below) and reading assignment (from the Course Notes) will be added to the Course Schedule on the course website, and the lecture notes will be posted. The student may therefore skim the material to be covered prior to the lectures and bring the lecture notes to class in order to facilitate understanding. In addition, problem set and project assignments (with due dates) for the week will be added to the Course Schedule.

Problem Sets

Problem sets will be posted on Wednesdays to re-enforce the concepts presented in the previous one to four lectures. **Each problem set will be due the next Wednesday in class.** A total of **9 problem sets will be assigned**. However, only **7 will be collected** (*i.e.*, the problem sets will not be collected during each exam week). Only a randomly selected subset of the problems assigned will actually be graded. These problems will specifically be evaluated according to a tertiary grading system (zero credit for no work with or without correct answer | half credit for wrong idea but demonstration of effort | full credit for right idea with or without correct answer). While students are encouraged to work together on the problem sets, the submissions must be original (no Xerox) and in the student's own handwriting. The solutions for each problem set will be made available after the problem set is due. Thus, **no late problem sets will be accepted**. For the problem sets that are not collected, the solutions will be posted with those problem sets.

Projects

Three MATLAB projects will be assigned. Each project report will be **due in class two to four weeks after it is assigned**. Late project reports must be turned in at 2216 EB or as otherwise arranged. Note that a **20% penalty will be imposed each day the report is late**. Thus, a report that is five or more business days late will receive a grade of zero. **The projects MUST be conducted in groups of two or three.** The projects are summarized below:

1. **ECG: Filtering and Frequency Analysis of the Electrocardiogram -** Design filters to remove noise from electrocardiogram (ECG) signals and then design a system to detect life-threatening ventricular arrhythmias. The detector is tested on normal and abnormal ECG signals.

2. **Speech Coding -** Implement, test, and compare two speech analysis-synthesis systems (vocoders). These systems utilize a pitch detector and a speech synthesizer based on the source-filter model of speech production.
3. **System Identification: Modeling Auditory Nerve Fibers -** Develop a functional model of an auditory-nerve fiber based on system identification techniques, using single-unit analysis techniques such as post-stimulus-time histograms and cross-correlation. Compare predictions from the identified model with measured auditory-nerve fiber responses to speech utterances.

Note that MATLAB tutorials may be found at the following website:

http://www.mathworks.com/academia/student_center/tutorials/launchpad.html

Exams

Two midterm exams will be distributed in class (October 14 and December 4). **The second midterm exam will not be cumulative, and there will be no final exam.**

Each exam will include true/false questions in which no partial credit will be given and problems in which partial credit will be given if valid work is shown. These questions and problems will arise from the lectures and problem sets. In fact, **a subset of the problems for each midterm exam will come from the problem sets**. Thus, the problem sets may be viewed as practice problems for the exams.

Make-up exams will only be given, if there is a legitimate reason such as illness or personal emergency that is documented by a physician or other appropriate official. A student who finds it necessary to miss a midterm exam should contact the lecturer before the exam to explain the circumstances.

Additionally, Michigan State University is committed to providing equal opportunity for participation in all programs, services and activities. Accommodations for persons with disabilities, with valid (*i.e.*, not expired) documentation from RCPD, may be requested by contacting the lecturer at the start of the term and/or two weeks prior to the accommodation date (*i.e.*, exam). Requests received after this date will be honored whenever possible.

Grading

Each of the above assignments carries the following weight towards the student's final grade:

7 problem sets	10% (equally weighted)
3 projects	30% (10% each)
2 midterm exams	60% (30% each)

The final quality point score (*e.g.*, 3.5, 4.0) for each student **will be assigned according to a curve**. Note that borderline grades can be "pushed up" by demonstration of effort (*e.g.*, significant class participation).

Incomplete grades will be given only in unusual cases of illness or other personal emergency, which causes the student to miss a significant amount of the course. This grade cannot be given for any other reason.

Article 2.3.3 of the Academic Freedom Report states: "The student shares with the faculty the responsibility for maintaining the integrity of scholarship, grades, and professional standards." In addition, this professor adheres to the University regulations, policies, and ordinances on academic honesty and integrity, as specified in General Student Regulation 1.0, Protection of Scholarship and Grades; the all-University Policy on Integrity of Scholarship and Grades; and Ordinance 17.00, Examinations, all of which are available on the MSU website (www.msu.edu). Students who violate these rules may receive a penalty grade, including, but not limited to, a failing grade on the assignment or in the course. The following conduct is specifically cited: (1) Supplying or using work or answers that are not one's own; (2) Providing or accepting assistance with completing examinations; (3) Interfering through any means with another's academic work; and (4) Faking data or results.

Detailed Course Outline:

1. Introduction (Introduction of course notes)
    a. Course information
    b. Background and motivation
2. Data acquisition (Chapter 1 of course notes)
    a. Continuous-time (CT) and discrete-time (DT) signals
    b. Sampling theorem
    c. Quantization
3. Digital filters (Chapter 2 of course notes)
    a. Linear and time-invariant (LTI) systems
    b. Causality and stability
    c. Filters defined by linear constant coefficient difference equations
4. The electrocardiogram (Project 1)
5. Fourier representation of signals and systems (Chapter 3 of course notes)
    a. Frequency response of LTI systems
    b. The DT Fourier Transform (DTFT)
    c. DTFT pairs and properties
    d. Filter design
    e. Time and frequency resolution – the uncertainty principle
6. The Discrete FT (DFT) (Chapters 4 and 5.3.2 of course notes)
    a. Definition
    b. Properties
    c. Block filtering
    d. Fast FT (FFT)
    e. Spectral analysis
7. The Z-transform (Chapter 6 of course notes)
    a. Definition and region of convergence
    b. Properties
    c. The system function
    d. Inverse Z-transform
8. Speech coding (Project 2)
9. Time-dependent processing of signals and the short-time FT (STFT) (Chapter 7 of course notes)
    a. General motivation
    b. Time-dependent processing
    c. STFT
    d. Applications of the STFT

10. Linear prediction (Chapter 8 of course notes)
    a. All-pole model of speech
    b. Autocorrelation method of linear prediction
    c. Applications
11. Engineering model of an auditory nerve fiber (Project 3)
12. Random signals: basic properties (Chapter 11 of course notes)
    a. Time averages
    b. Autocorrelation functions
    c. Crosscorrelation functions
13. Random signals and linear systems (Chapter 12 of course notes)
    a. Response of LTI systems to random signals
    b. Power spectra
    c. Cross spectra
    d. Wiener filters

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Week	Lecture Topics & Reading Assignment	Problem Set/Project Assignment	Notes
Week of 08/26	Topics: 1.a thru 1.b Reading: Introduction		**Class Starts (08/28)**
Week of 09/02	Topics: Reading:		**Labor Day (09/02)**
Week of 09/09	Topics: Reading:		
Week of 09/16	Topics: Reading:		
Week of 09/23	Topics: Reading:		
Week of 09/30	Topics: Reading:		
Week of 10/07	Topics: Reading:		
Week of 10/14	Topics: Reading:		**Midterm Exam 1 (10/14)**
Week of 10/21	Topics: Reading:		
Week of 10/28	Topics: Reading:		
Week of 11/04	Topics: Reading:		
Week of 11/11	Topics: Reading:		
Week of 11/18	Topics: Reading:		
Week of 11/25	Topics: Reading:		**Class Canceled (11/27)**
Week of 12/02	Topics: Reading:		**Midterm Exam 2 (12/04)**