BME 50500: Image and Signal Processing in Biomedicine

Academic Load: 3 credit; 2 weekly 75-minute session

Instructor(s): Lucas Parra, PhD

Textbook: Selected chapters from will be provided:

- Kayvan Najarian and Robert Splinter, Biomedical Signal and Image Processing, CRC Press, 2005.
- Eugene N. Bruce, 2001. *Biomedical Signal Processing and Signal Modeling*. Wiley.
- Semmlow, J.L., 2005. *Circuits, Signals, and Systems for Bioengineers: A MATLAB-based Introduction*. Elsevier Academic Press.
- Jerry L. Prince & Jonathan Links, 2006. *Medical Imaging Signals and Systems*. Pearson.

Catalog Description:

This course introduces biomedical signal processing methods and basic medical imaging. It will provide an overview of medical imaging modalities such as computed tomography (CT), magnetic resonance imaging (MRI), and Ultrasound. The main goal of the course is to develop an understanding for fundamental physical and engineering constraints associated with imaging and signal analysis. Basic signal analysis will be introduced in the context of linear systems, and some simple intensity manipulations will be presented for images. Students will gain hands-on experience in image and signal processing through Python or Matlab programming in class and in homework assignments. Students are expected to bring laptops to class to gain hands-on programming experience with an opportunity to ask detailed questions. Students will also learn to analyze a system by recording signals from an electronic circuit. This work will start as lab projects and will be completed as homework assignments. 3 hr./wk.; 3cr. Fall Only

Prerequisites: BME 40500 or BME 10500 (EE 25900 and EE 30600 and EE 33000)

Co-requisites:

Designation: Required course (ABET category: Engineering)

Course Objectives:

1. Understand the basic physics of various medical imaging modalities.
2. Understand the basic design criteria of an imaging system.
3. Learn basics concepts of signal processing and apply them to practical problems.
4. Experience in analyzing and interpreting physiological data.
5. Hands on programming experience.
6. Hands on experience collecting signals.
7. Self study from a variety of book chapters

Student outcomes of the BME program:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social,

environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Outcomes addressed by the course (Performance Indicators)

1. Knowledge of medical imaging modalities [1,2]
2. Knowledge of trade-offs between wavelength, spatial resolution, temporal and frequency resolution. [1,2]
3. Programming skills to implement basic filtering methods. [2,6]
4. Programming and experimental skills to record and model a linear system. [1,2,6]

7. Topics Covered:

- **Linear systems in discrete time/space:** Impulse response, shift invariance, Convolution, Discrete Fourier Transform, Power spectrum.
- **Introduction to medial imaging modalities:** MRI, Tomography, CT, PET, Ultrasound
- **Engineering tradeoffs:** Sampling, aliasing, Time and frequency resolution, Wavelength and spatial resolution, Aperture and resolution
- **Filtering:** Magnitude and phase response, Filtering, Correlation, Template Matching
- **Intensity manipulations:** A/D conversion, linearity, Thresholding, Gamma correction, Histogram equalization
- **Phython**
- **Recording signals**

Teaching Assistant: : bme505@gmail.com

Class hours: Tuesday, Thursday 11:00PM-12:15PM.

Office hours: Thursday 4PM-5PM

Homework: Most of the homework assignments will be Python/Matlab programming projects (we will select which language to use at the beginning of the semester). Detailed instructions are provided in the class slides or website. Typically you will have one week to complete these assignments. For some of the assignments you may submit your homework three days ahead to deadline and will receive the homework back graded with suggestions for improvements within a day or two. After correcting it you can submit again until the deadline. We expect that you will need to use this iterative process for many of your homework assignments to obtain full credit. Some of the assignments involve collecting data.

Exams: There will be a midterm and final exam. See class notes for more detail. The exams test for knowledge and understanding of the material presented in class. Homework assignments are not intended to prepare students for taking the exams. Slides are not sufficient to study for the exam. You will need to take your own notes during class. Book chapters offered for reading are not directly linked to exam questions and are supposed to supplement your understanding from what you learned during class. The most direct way to prepare for the exam is to review your own lecture notes and answer extensive practice questions that are distributed before the exam.

Course material: This class does not use Blackboard. Instead, all class material is provided at https://www.parralab.org/teaching/signal-and-image/ . This includes class slides, insturctions and data required for all homework assignments.

Grading: 60% assignments, 15% midterm exam, 25% final exam

COVID related adjustments:

This course will start online for the Spring 2022 and hopefully transition to in-person instruction during the semester. Classes will be on zoom https://us06web.zoom.us/j/9460803414 . Video connection is strongly recommended for every class, and strictly required in order to participate in the midterm and final exams, including appropriate bandwidth to support video. Lectures will be recorded and links provided after class. They will be available for a few weeks only. If you want to preserve them for longer, you must download. You may not post video lectures online!

The labs will be conducted at home with every student receiving in the mail a A/D converter as well as breadboard and electronic parts: Diligent Analog Discovery Studio, Case, Cables and breadboard. Most of you have already received these items in BME 405. All student are responsible for keeping these tools in good order and return them complete at the end of the course to receive a grade.

Last update: 01/25/2024