Northeastern University

BIOE5810 Design of Biomedical Instrumentation

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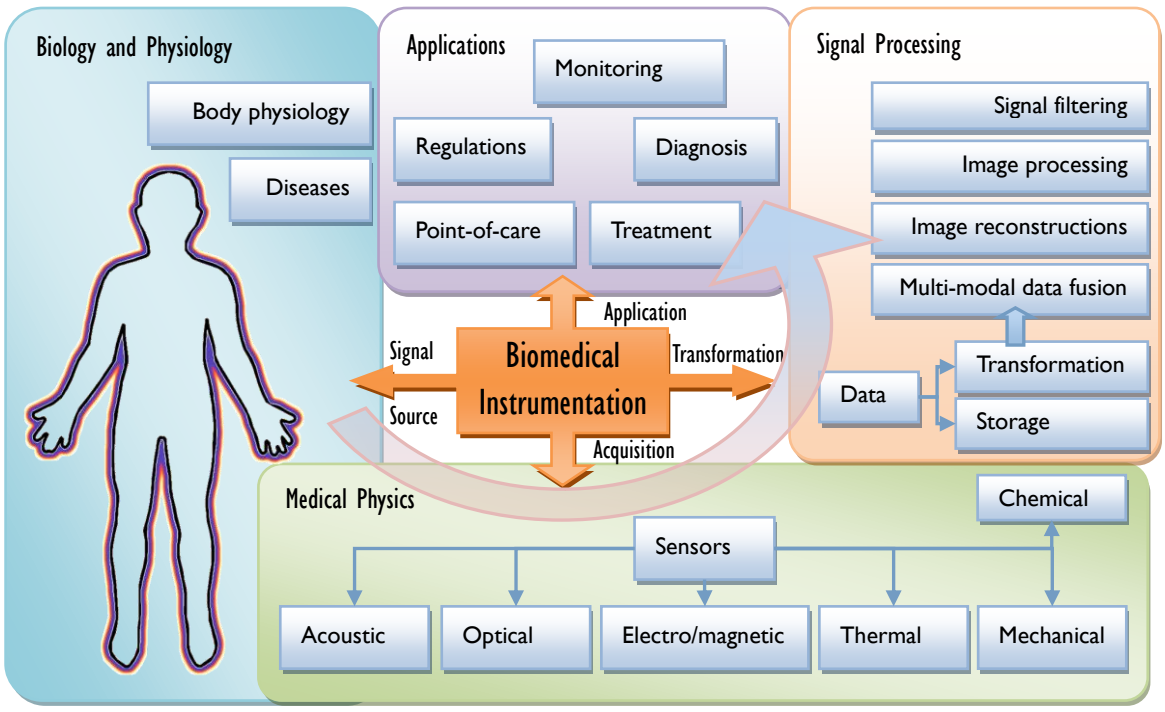
Course Time: Tuesday/Friday 3:25-5:05 PM | Hastings 100 | Jan. 10 – Apr. 21 2017
Office Hours: Monday 3:00-5:00PM, (additional office hours by appointment)

(**Note**: this syllabus was last updated on Feb. 20, 2017)

Course Materials (Recommended)

- *Medical Instrumentation: Application and Design (4th Edition)* - by John G. Webster (**recommended**)
- *The Essential Physics of Medical Imaging* - by J. T. Bushberg, etc
- Course handouts (available on Blackboard)

Visual Syllabus



In this course, the principles of biomedical instrumentation designs are explained in four interconnected aspects – the basics of human physiology (the source of the biomedical signals), the physics and designs of biomedical sensors (with which we acquire the signals), signal and image processing methods (the transformation and interpretation the acquired information) and a wide range of applications and their associated practical issues such as regulations, ethics and safety concerns.

Course summary

In this course, we introduce our students to a world of modern biomedical instrumentation systems, and guide them in understanding the essential aspects of biomedical instrumentation design, including the source of biological signals, medical data and image acquisition, recording, and processing methods. Through the introductions to a list of real-world medical applications, we teach students the fundamentals of bio-sensors, modern medical imaging methods, biomedical circuit designs, and medical image processing techniques. Students will have opportunities to gain hands-on experience on a number of medical systems, building simple bio-sensor circuitry and processing measured data/images. The class not only introduces conventional medical instrumentation, but also exposes the students to the cutting-edge of medical imaging and medical signal processing techniques. Advanced medical instrumentation design concepts, such as multi-modal imaging, as well emerging medical device segments, such as mobile-health, or mHealth, will be discussed in the class.

The course is roughly divided into **3 segments**. In the first segment (Weeks 1-6), we discuss the **fundamental steps of biomedical instrument design** – from the origins of the biological signals, to sensors, circuits, signal processing, filter and amplifier designs, and data acquisition. Through the lab and discussions, student will learn the skills needed to develop a simple instrument. In the second segment (Weeks 7-10), we focus on **medical imaging** under the context of advanced biomedical instrumentation designs. We will explain the underlying physics, imaging system designs, image acquisition and analysis. In the last segment, we will fill it with **various special topics related to biomedical instrumentation design** via a number of guest lectures. Invited speakers from industry as well as academia will share their unique experiences and perspectives on regulations, global health challenges, instrumentation development in industries, as well as intellectual properties.

Calendar and Course Outline (Tentative)

WEEK	TOPICS	NOTES
1	**Lecture 1**: Introduction 01/10 (Discussion 1 topics)	**Objectives**: Understand the overall structure of the course; understand the key elements in biomedical instrumentation design.
	Lecture 2: Basic body physiology, vital signs and diseases 01/13 (Homework 1)	**Objectives**: Understand the source of biomedical signals, what the common vital signs are and how they are measured.
2	**Lecture 3**: MATLAB warm-up 01/17	**Objectives**: Learning basic MATLAB commands and programming skills.
	Lecture 4: Basics of biomedical sensors - I **Lecture 5**: Basics of biomedical sensors - II 01/20 (Homework 2)	**Objectives**: Explain various commonly used sensors, including mechanical, thermal and optical sensors, and their pros and cons.
3	**Lecture 6**: Characteristics of sensors 01/24	**Objectives**: Understand the basic characteristics of sensors, including gain, range, zero-offset, drift, accuracy, resolution, and precision.
	Lecture 7: Principles of circuits **Lecture 8**: Amplifier circuit design 01/27 (Homework 3)	**Objectives**: Resistors, capacitors, inductors, DC and AC network analysis and op-amps; various amplifiers, buffers, adders, and filters built with op-amps.
4	**Lecture 9**: Basic sensor signal processing - I **Lecture 10**: Basic sensor signal processing - II 01/31	**Objectives:** Frequency domain analysis of a circuit/system, transfer functions, zeros and poles, Bode plot, block diagrams, filter design with MATLAB.

	Lecture 11: Signal digitization and data acquisition 02/03 (Homework 4)	**Objectives:** Understand how ADC and DAC work; data quantization and errors; data acquisition protocols: GPIO, I^2C
5	**Lab 1.1**: Building a simple heart-rate detector using photoresistors and op-amps 02/07	**Objectives:** Gain hands-on experience on circuit prototyping, and take steps towards building a simple instrument.
	Lab 1.2: Building a simple heart-rate detector using photoresistors and op-amps 02/10	**Objectives:** Continuation of Lab 1.
6	**Lab 1.3**: Building a simple heart-rate detector using photoresistors and op-amps 02/14 (Lab report 1)	**Objectives:** Continuation of Lab 1.
	Discussion 1: Student presentations (pick one topic in Week 1, study the current practices, instruments, principles, and review challenges, emerging techniques and future directions) 02/17	**Objectives**: Self-motivated research on selected topics relevant to the course, perform extended reading and critical thinking.
7	**Lecture 12**: Medical Imaging I – Radiation and Interactions with Matters **Lecture 13**: Medical Imaging II – X-ray, CT and mammography 02/21	**Objectives**: Understand the physics and data processing methods for x-ray based imaging modalities; understand Radon transform.
	Lecture 14: Medical Imaging III - MRI, PET, SPECT 02/24	**Objectives**: Can explain the basic physics behind MRI, PET and SPECT; understand the mathematical models associated with each imaging modality.
8	**Lecture 15**: Medical Imaging IV – Medical Ultrasound 02/28	**Objectives**: Understand the physics of ultrasound imaging; key instrument parameters and limitations.
	Midterm Exam 03/03	**Objectives**: In-class test of the student learning for the first half of the class.
9	03/07	Spring break
	03/10	Spring break
10	**Lecture 16**: Medical Imaging V – Near-infrared optical imaging 03/14 (Discussion 2 proposal topics)	**Objectives**: Understand fundamentals of light-tissue interactions; understand the basics of non-linear tomographic imaging
	Guest Lecture 1: Global health and point of care devices – Solomon Mensah, Co-founder & CEO, Therapeutic Innovations, TBD 03/17	**Objectives**: Meet our local entrepreneur, and listen to his stories and experience on developing devices for global health market; gain insights into the current global health challenges; understand what are needed for entrepreneurship.
11	**Lecture 17**: Biomedical image processing I – Filtering, Registration and segmentation **Lecture 18**: Biomedical image processing II – Registration and segmentation 03/21	**Objectives**: Understand Fourier representations of images and common image filtering techniques; Explore medical image segmentation, registration, and 3D object modeling;
	Lab Tour 1: MRI, PET and optical imaging instruments (Martinos Center, MGH)	**Objectives**: See MRI, PET, and optical imaging instruments in action in research labs; understand the basic operating steps,

	03/24	and obtain sample data.
12	**Guest Lecture 2**: Functional optical neuroimaging using fNIRS, history and current status – Dr. Juliette Selb, Instructor, Martinos Center, MGH, TBD **03/28**	**Objectives**: Understand the basic principles of optical brain functional imaging, pros and cons, related instruments, and can identify a number of related applications.
	Guest Lecture 3: Intellectual properties and patents – Heonick Ha, Senior Licensing Manager, Partners RVL, TBD **03/31**	**Objectives**: Understand how patent works and what are intellectual properties.
13	**Lab 2.1**: Biomedical computing lab **04/04** (Lab 2 Report)	**Objectives**: Use the previously learned image processing methods to analyze a set of medical images.
	Lecture 19: Clinical trials and performance assessment **04/07**	**Objectives**: Understand the definitions of clinical trials; understand ROC curves and AUC; aware of common sample selection biases in a clinical study design.
14	**Guest Lecture 4**: Patient safety and regulations – Joel Kent, GE/NEU, TBD **04/11**	**Objectives**: Understand the key regulations (FDA, ANSI standards, and clinical trials) that govern the development of medical instrumentation; understand the ethical rules for human studies; know the patient safety measures.
	Discussion 2: Presentations of student research proposals on developing a point-of-care medical device. **04/14**	**Objectives:** Prepare the students for future research career through a mock research proposal competition.
15	**Discussion 2:** Presentations of student research proposals on developing a point-of-care medical device. **04/18**	**Objectives:** Continuation of Discussion 2.
	Final Exam **04/21**	**Objectives:** Evaluate the learning goals set for the entire course.

Notes: For each week, homework will be assigned on Friday, and the due date is the following Friday at the end of the class. All Labs will be performed in Dr. Fang's (temporary) lab, Mugar 310. Each "Discussion" session requires student presentations and a written report. The lab tour happens at the location near Boston. Students need to arrange their own transportation. For students who can complete the TRACE survey before its deadline will be receiving a 5 point credit for Discussion 2, which has a total point of 20.

Condensed Course Calendar Map (15 weeks, 30 slots)

Jan 10								*Week 1-4*
Feb 7 Lab 1.1	Lab 1.2	Lab 1.3	Discu. 1				Midterm	*Week 5-8*
Mar 7			Guest 1		Tour 1	Guest 2	Guest 3	*Week 9-12*
Apr 4 Lab 2		Guest 4	Discu. 2	Discu. 2	Final			*Week 13-16*

Legend: each cell in the above chart represents a class time slot; two slots per week. Color code: - Regular Lecture; - Discussions and presentations; - Lab tours; - Lab exercise; - Exams; Guest - Invited speakers; Empty – No class.

Course Policies

Grading

Assignments in this course are divided into these general categories, which carry the following weight in your final grade calculations:

Midterm Exam	15%
Final Exam	15%
Homework	20%
Lab Reports	20%
Discussion Presentations	10%
Discussion Written Report	20%

Some of the homeworks will include Bonus questions. The total point (used to compute the percentage score) for each homework **will include** the points from the Bonus questions. All students are encouraged to complete the bonus questions. Successfully completing those questions will help advance the overall ranking of the student in the class.

Report, Presentation and Student Proposal Grading Guidelines

If an assignment is a report, it will be graded according to the following criteria: 1). comprehensiveness, 2). technical accuracy, 3). use of reference, 4). writing and language, and 5). relevance to the assignment topic.

If an assignment involves presentation and slides, the grading considerations will include 1) organization of the materials (introduction, transition, logical orders etc), 2) clarity of the points, 3) oral delivery and audience engagement, 4) oral and visual styling, and 5) question handling.

If an assignment involves a short proposal, the grading considerations will cover 1) innovation (is this idea new?), 2. feasibility (are the promises real?), 3) approach (can you actually do it?) 4) grantsmanship (story telling).

Receiving Grades & Instructor Feedback

Assignment grades and feedback are provided generally ***1 week*** after the assignment is due and always before an assignment of the same type is due. Unless otherwise stated, grades and feedback will be

available via the ***Grades*** area of the online course site.

Accepting Late Work

Late work may be accepted for extenuating circumstances. These include family emergencies, sickness, and various other unforeseen circumstances. All work must be submitted by the last day of the course; no extensions or late work will be accepted beyond that date. Please plan ahead.

Communication

Feel free to ask questions by phone, email, or scheduling meetings in my office (during office hours or another scheduled time), or by video conferences (skype). I will try to respond to your question within a day or two.

Minimum Technical Skills

Students are expected to be comfortable accessing the online course site and downloading files such as Microsoft Office documents, YouTube videos, and PDFs. In addition, students should be able to use Microsoft Office to compose written documents, spreadsheets, and PowerPoint presentations. A basic knowledge of MATLAB is required.

Academic Integrity

The University views academic dishonesty as one of the most serious offenses that a student can commit while in college and imposes appropriate punitive sanctions on violators. The Student Handbook contains more information on what is considered academic dishonesty and is available here. A first offense will result in a grade of zero on the assignment. A second offense will result in a failing grade for this course and disciplinary action through Northeastern University's student judicial committee.

University Policies

Students with Disabilities

Students needing disability accommodations should visit the Northeastern University Disability Resource Center (DRC).

Student Privacy (FERPA)

The Family Educational Rights and Privacy Act (FERPA) affords students certain rights with respect to their education records. For information about these rights, visit the Northeastern University Office of the Registrar.

Diversity

Northeastern University is committed to providing equal opportunity to its students and employees, and to eliminating discrimination when it occurs. For more information, including grievance procedures, please visit the Northeastern University Office of Institutional Diversity and Inclusion.