Special Topics in Signals & Systems: Biomedical Imaging

ECEn 682R, Section 3

Fall 2009 Course Syllabus

Lectures:	TTh 12:05-1:20pm
Location:	406 Clyde Building
Instructor:	Neal K. Bangerter
Office:	469 Clyde Building
Office Hours:	TTh 1:30-3pm
Phone:	(801) 422-4869
Email:	nealb@ee.byu.edu
Course Website:	http://ece682rweb.groups.et.byu.net/
Textbook:	*Medical Imaging Signals and Systems* Jerry L. Prince and Jonathan M. Links Pearson Prentice Hall Bioengineering

COURSE OVERVIEW:

This course is a technical elective, and is designed as a first introductory course to the major biomedical imaging modalities. The course builds on fundamental signal processing (ECEn 380), basic electricity and magnetism, and the multivariate calculus needed in most engineering disciplines. However, the material fundamentally stands alone; while familiarity with certain topics common to an engineering undergraduate education is expected, the course is not part of a series.

Ideally, students will get the following out of the course:

(1) A familiarity with the basic biomedical imaging modalities and their history (x-ray, CT, ultrasound, MRI, and nuclear medicine);
(2) A working knowledge of the basic physics, engineering, and instrumentation principles underpinning each modality (with a signals and systems emphasis);
(3) An understanding of the typical applications for each modality, and an understanding of each modality's strengths and weaknesses;
(4) An overview of the state of the art for each modality, and current research directions.

Student learning will be assessed through a combination of homework sets, exams (midterm and final), and an in-class presentation towards the end of the semester. Homework sets will be designed to develop and assess understanding of the basic physics, engineering, and instrumentation principles underpinning each modality. A mixed-format (multiple choice and written) midterm and final exam will be given. The final in-class presentation will require each student to focus on one of the particular imaging modalities, give an overview of the technology and applications for that modality, and then dive deeply into the current state of the art and current

research directions. Final presentation grades will be based on instructor assessment of accuracy, clarity, presentation quality, and completeness, and feedback from fellow students.

GRADING:

While homework sets, exams, and the final presentation will represent a significant portion of the grade, I am including a not insignificant component for class participation. The breakdown will be:

- Homework (7 assignments): 35%
- Midterm: 15%
- Final: 15%
- Final Presentation: 25%
- Class Participation: 10%

Homework: Homework will be due on the Thursdays noted in the course schedule at 5pm, and will be assigned one week earlier. Some of the homework assignments will include Matlab exercises and other activities that can be done independently at any time before the homework is due. If you don't have access to a computer with Matlab, please see me so we can get a CAEDM account set up for you.

Midterm and Final: The midterm and final are weighted so as to encourage studying and review of the key course takeaways, while not making them an over-large component of the overall grade. They will be mixed format (written and multiple choice), and will be given in the testing center during the days noted in the course schedule.

Final Presentation: The final presentation represents a full quarter of the grade, as I believe that significant long-term learning comes from the process of researching and preparing to teach others. No homework will be assigned the final four weeks of class to allow adequate time for preparation. Details of the final project will be provided later in the semester.

Class Participation: Attendance and participation in class are strongly encouraged, and will represent 10% of your total grade. I expect students to:

- Attend scheduled classes;
- Bring the textbook and other course materials to class;
- Ask questions;
- Be prepared to provide a very brief summary (< 2 minutes) of the key takeaways from the previous lecture at the beginning of class.

Class participation scores will be assessed based on level of engagement, beginning of class cold-call summaries of previous lectures, and attendance.

COURSE SCHEDULE:

Date	Topic	Homework	Reading
8/31 – 9/4	Introduction to Medical Imaging (history, basic imaging principles), Signals & Systems Review (impulse response, sampling functions, exponential signals, separable signals, periodic signals)		p. 1 - 32
9/7 – 9/11	Signals & Systems Review (linear systems, properties of LSI systems), The Fourier Transform in 2D (properties, Parseval's theorem)		p. 32 - 49
9/14 – 9/18	2D Fourier Transform continued, Sampling (sampling signal model, Nyquist theorem, anti-aliasing filters)	HW 1 due 9/15	p. 49 - 55
9/21 – 9/25	Image Quality (contrast, resolution, noise, random variables, SNR, artifacts, distortion, quantitative and diagnostic accuracy measures)	HW 2 due 9/24	p. 63 - 95
9/28 – 10/2	Physics of Radiography (ionizing radiation, particulate radiation, EM radiation, Compton scattering, etc.)	HW 3 due 10/1	p. 106 – 131
10/5 – 10/9	Projection Radiography (x-ray tubes, film-screen detectors, basic x-ray imaging equation, blurring effects, film characteristics, SNR, quantum efficiency)	HW 4 due 10/8	p. 135-164
10/12 – 10/16	Computed Tomography (x-ray source and collimation, CT detectors, image formation, line integrals, CT numbers, parallel-ray reconstruction, fan-beam reconstruction, resolution, noise, artifacts)	HW 5 due 10/15	p. 181 - 218
10/19 – 10/23	Physics of Magnetic Resonance (magnetization, precession and Larmor frequency, transverse and longitudinal magnetization, NMR signals, rotating frame, RF excitation, relaxation)	**Midterm** (10/20 – 10/23)	p. 381 - 403
10/26 – 10/30	Magnetic Resonance Imaging (Bloch equations, spin echoes, contrast mechanisms, system components, gradient coils, RF coils)	HW 6 due 10/29	p. 409 - 430
11/2 – 11/6	Magnetic Resonance Imaging (data acquisition, encoding methods, image reconstruction, sampling, resolution, noise, SNR, artifacts)	Project proposals due 11/6	p. 430 - 455
11/9 – 11/13	Physics of Ultrasound (wave equation, 3D acoustic waves, plane waves, spherical waves, wave propagation, Doppler effect, beam pattern formation and focusing)	HW 7 due 11/12	p. 313 - 342
11/16 – 11/20	Ultrasound (transducers, probes, pulse-echo equation, transducer motion, ultrasound imaging modes, steering and focusing)	Project preparation	p. 347 - 371
11/23 – 11/24	NO CLASS (optional field trip to the U. of Utah)	Project preparation	
11/30 – 12/4	Review (Tuesday) and Final Presentations (Thursday)	Project preparation	
12/7 – 12/10	Final Presentations		
12/14 – 12/18	FINAL EXAMS	**Final Exam** (12/14 – 12/18)	

HONOR CODE:

I expect all students in the course to behave ethically and in keeping with the BYU Honor Code. All work submitted should be your own except where specifically stated otherwise. Cheating of any kind will result in a failing grade. If you have any questions about what comprises unethical behavior, please discuss with me.

PREVENTING SEXUAL HARASSMENT:

Title IX of the Education Amendments of 1972 prohibits sex discrimination against any participant in an educational program or activity that receives federal funds. The act is intended to eliminate sex discrimination in education. Title IX covers discrimination in programs, admissions, activities, and student-to-student sexual harassment. BYU's policy against sexual harassment extends not only to employees of the university, but to students as well. If you encounter unlawful sexual harassment or gender-based discrimination, please talk to your professor; contact the Equal Employment Office at 422-5895 or 367-5689 (24-hours); or contact the Honor Code Office at 422-2847.

STUDENTS WITH DISABILITIES:

Brigham Young University is committed to providing a working and learning atmosphere that reasonably accommodates qualified persons with disabilities. If you have any disability which may impair your ability to complete this course successfully, please contact the Services for Students with Disabilities Office (422-2767). Reasonable academic accommodations are reviewed for all students who have qualified documented disabilities. Services are coordinated with the student and instructor by the SSD Office. If you need assistance or if you feel you have been unlawfully discriminated against on the basis of disability, you may seek resolution through established grievance policy and procedures by contacting the Equal Employment Office at 422-5895, D-285 ASB.