BM525: Biomedical Imaging Systems
Spring 2013

Department of Biomedical Engineering
&
Ming Hsieh Department of Electrical Engineering
University of Southern California

Time:	11.00am - 12.20pm TuTh
Location:	DEN
Instructor:	Richard M. Leahy, Professor, Electrical Engineering, Biomedical Engineering and Radiology
Office Hours:	TuTh 12.30-2.00pm
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Midterm:	Tuesday, March 19th, 11.00am-12.00pm
Final:	Tuesday, May 14th 11.00am-1.00pm

Course Description: *Advanced scientific and engineering principles of biomedical imaging systems including magnetic resonance, X-ray computed tomography, ultrasound, and single photon and positron emission tomography.*

Prerequisites: BME513 or EE483

Intended Audience: This course is intended for graduate MS and PhD students in EE and BME who want a serious introduction to the major biomedical imaging modalities. It is differentiated from the undergraduate course (BME425) through a systems-oriented approach and a more mathematical treatment. The prerequisites (BME513 or EE483) ensure that students have a background in linear systems, Fourier transforms and signal processing.

Course Overview: this course provides a comprehensive introduction to the major 3D clinical imaging modalities: MRI, x-ray CT, ultrasound, PET and SPECT. The material will be presented from a systems perspective starting with a review of concepts in linear system theory, Fourier analysis and the sampling theorem. We will then describe the ways in which image quality is defined and measured and how we assess the relative performance of different imaging systems or protocols. We will then review the physical basis for each modality (MRI, x-ray CT, ultrasound, PET and SPECT), but with a stronger emphasis on the mathematical concepts underlying image formation and characterization. The material will be complemented by lectures from radiologists who will describe the way in which each modality is used in a clinical setting.

Learning Objectives: On completion, the students will be familiar with the physical principals underlying MRI, x-ray CT, ultrasound, PET and SPECT. They will have a basic understanding of the computational approaches (Fourier inversion, filteredbackprojection, model-based reconstruction) that are used to form images. Students will also understand how to assess image quality through resolution, contrast recovery, SNR, and detection metrics. Finally students will learn how these modalitites are used to explore different aspects of human anatomy, physiology and metabolism and how they are typically employed as a diagnostic and treatment planning tool in radiology.

Required Texts: Medical Imaging: Signals and Systems, JL Prince and JM Links, Prentice Hall, 2006. *ISBN 0-13-065353-5.* The main text will be supplemented with additional readings from tutorial articles/online resources for each of the major modalities studied.

Grading:
1*. Home Works 20%*
Weekly home works will be given for students to sharpen their understanding of concepts introduced in class, and deepen their understanding of each imaging modality.

2. *Mid-Term Exam: 30%*
A 60 minute midterm exams will be given in class during the 10th week. The exams will test student comprehension of concepts and techniques presented up to the date of the exam.

3. *Final Exam: 50%*
A 2 hour final exam will be given according the university's final schedule. The exam will be comprehensive, emphasizing core concepts introduced throughout the course.

COURSE OUTLINE

lec.#1. Introduction: medical imaging with x-rays, CT, MRI and ultrasound.
lec.#2. Signals and systems I: signals and images, linear and shift invariant systems, convolutions, finite dimensional representations of linear systems.
lec.#3. Signals and systems II: multidimensional Fourier transforms, properties, examples, rotations, Hankel transforms.
lec.#4. Signals and systems III: Sampling in 1D and 2D, aliasing, frequency sampling, image, discrete image transforms, image interpolation
lec.#5. Image quality assessment I: Contrast, modulation transfer functions, resolution
lec.#6. Image quality assessment II: Review of random variables, variance and correlation, noise in linear systems, signal to noise ratio.
lec.#7. Image quality assessment III: Hypothesis testing, sensitivity, specificity and accuracy, ROC curves
lec.#8. X-ray imaging – the EM spectrum, interactions of EM radiation with tissue, ionizing radiation, x-ray production, photo-electric effect, Compton scatter.
lec.#9. X-ray imaging - planar imaging: characterizing x-ray beams, Beer's law, linear attenuation coefficients, radiation dose, filtering and collimation, projection radiography, blurring and resolution, SNR.
lec.#10. X-ray computed tomography I: basic concepts, evolution of x-ray CT scanners, hardware
lec.#11. X-ray computed tomography II: CT measurement, CT numbers, line integrals and Radon transform. Projection slice theorem.
lec.#12. X-ray computed tomography III: Image reconstruction by filtered backprojection for parallel and fan beam data. Conbeam CT.
lec.#13. X-ray computed tomography IV: Sampling issues; resolution and noise in CT, beamhardening and scatter.
lec.#14. Nuclear medicine I: radioactive decay and radioisotopes. Types of radioactive decay, gamma rays and positrons. half life, Poisson model of decay. Common sources in nuclear medicine.
lec.#15. Nuclear medicine II: Radiopharmacy and kinetic modeling. The Anger camera and planar imaging. Collimators and imaging equations. Resolution and SNR.
lec.#16. Nuclear medicine III: SPECT imaging basics, imaging equation, reconstruction. Resolution and noise properties. Quantitation: scatter, background, sensitivity.

lec.#17. Nuclear medicine IV: PET imaging basics, imaging equation, reconstruction. Resolution and noise properties. Quantitation: scatter, randoms, sensitivity.
lec.#18. Clinical Perspectives I: Diagnostic clinical imaging with x-ray CT, nuclear medicine and ultrasound, *Professor Hossein Jadvar, MD PhD, Depts. Radiology and BME, USC.*
lec.#19. Midterm
lec.#20. Ultrasound I: wave equation, reflections and refractions, attenuation and absorption.
lec.#21. Ultrasound II: Ultrasound transducer design, A,M and B mode display.
lec.#22. Ultrasound III: Imaging signal model for pulse echo imaging
lec.#23. Ultrasound IV: Image formation, resolution and noise characteristics.
lec.#24. Guest speaker
lec.#25. Magnetic Resonance Imaging I: MR hardware, spin physics, Bloch equations
lec.#26. Magnetic Resonance Imaging II: Signal detection, spectroscopy, noise, RF excitation
lec.#27. Magnetic Resonance Imaging III: Spin echoes, relaxation, contrast
lec.#28. Magnetic Resonance Imaging IV: Spatial encoding, image reconstruction, resolution
lec.#29. Magnetic Resonance Imaging V: Artifacts, fMRI, diffusion MRI
lec.#30. Clinical Perspectives II: Neuroradiology, *Professor Meng Law, MD, Depts Radiology and BME.*

Statement for Students with Disabilities
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved haccommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity
USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one's own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/.