EE591: Magnetic Resonance Imaging and Reconstruction
Fall 2016

Instructor: Prof. Justin P. Haldar

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Objectives: Magnetic Resonance Imaging (MRI) technology is a powerful, safe, and nontrivial tool for investigating the anatomy, physiology, and metabolism of living subjects. After multiple Nobel prizes (spanning Physics, Chemistry, and Physiology or Medicine) and more than 40 years of development, MRI techniques have given rise to a multi-billion dollar global industry and have revolutionized various biomedical research fields and modern medical practice.

This course is intended to teach students the fundamental principles of MRI from an engineering perspective, with a particular emphasis on signal processing aspects. Course topics will include: basic physical principles (MRI hardware, magnetized spin systems, signal generation and detection; signal characteristics); imaging principles (selective excitation, spatial encoding techniques); image reconstruction principles and techniques (concepts of ill-posedness and point spread function, Fourier transform, Radon transform, and algebraic reconstruction methods); image contrast, resolution, signal-to-noise, and artifacts; fast-scan techniques; applications; advanced topics.

Prerequisites: EE 483 (Introduction to Digital Signal Processing)
Familiarity with MATLAB

Credit: 3.0 Units

Required Text: Z.-P. Liang and P. C. Lauterbur, *Principles of Magnetic Resonance Imaging: A Signal Processing Perspective*, Wiley-IEEE Press, 2000.

Schedule:

Lectures:	9:30am-10:50am Tue,Thu Location TBA
Office Hours:	2:00pm-3:30pm Mon 2:00pm-3:30pm Thu
First Class:	Tue, August 23rd
Midterm:	Thu, October 6th 2:00pm-3:20pm (in class)

Last Class:	Thu, December 1st
Final Exam:	Thu, December 8th 11:00am-1:00pm

Additional References:

M. A. Bernstein, K. F. King, X. J. Zhou, *Handbook of MRI Pulse Sequences*, Elsevier Academic Press, 2004.

E. M. Haacke, R. W. Brown, M. R. Thompson, R. Venkatesan, *Magnetic Resonance Imaging: Physical Principles and Sequence Design*, Wiley-Liss, 1999.

Grading and Course Policies:

25% Homework Assignments
35% Midterm Exam
40% Final Exam

All exams are cumulative and closed book – please mark the scheduled exam times on your calendars, and inform me as soon as possible if you have any conflicts.

Written homework assignments must all be turned in by the beginning of class on the due date. Late homeworks will not be graded and will receive a score of zero. The final homework grade will be based on your average score after discarding the lowest.

You are allowed (and encouraged!) to discuss homework assignments with your classmates, but are expected to complete your homework assignments individually. USC's recommended sanction for plagiarism, unauthorized collaboration, and/or cheating on any course work is an F for the course, with a possibility for further disciplinary action.

Several of the homeworks will require MATLAB programming. It is your responsibility to make sure that you know how to access the software and read/write/debug MATLAB code.

Websites:

All course materials will be distributed through the USC blackboard website: https://blackboard.usc.edu/. It is your responsibility to check the website regularly for updates (notes, assignments, due dates, etc.).

We will be using Piazza for class discussion. The system is aimed at getting you help fast and efficiently from classmates and instructors. Rather than emailing questions to us, I encourage you to post your questions on Piazza so that everyone in the course can benefit from the discussion. The Piazza page for the course can be found at: https://piazza.com/usc/fall2016/ee591/home.

Course Timeline (subject to change):

Week 1 (8/23, 8/25)	Introduction, History, Context
(Book: Ch. 1 and 3.1)	Magnetized Nuclear Spin Systems
Week 2 (8/30, 9/1)	Bloch Equation
(Book: Ch. 3.2)	Resonance and RF Excitation
Week 3 (9/6, 9/8)	Free Precession and Relaxation
(Book: Ch. 3.3-3.4)	Signal Detection
Week 4 (9/13, 9/15)	Signal Characteristics
(Book: Ch. 4.1-4.3)	RF Echoes
Week 5 (9/20, 9/22)	Signal Localization
(Book: Ch. 5.1)	Slice Selection
Week 6 (9/27, 9/29)	Gradient Echoes
(Book: Ch. 4.4, 5.2)	Frequency and Phase Encoding
Week 7 (10/4, 10/6)	Basic Imaging Methods
(Book: Ch. 5.3)	Midterm
Week 8 (10/11, 10/13)	Sampling of k-Space
(Book: Ch. 5.4)	
Week 9 (10/18, 10/20)	Image Reconstruction
(Book: Ch. 6)	
Week 10 (10/25, 10/27)	Image Contrast
(Book: Ch. 7.1-7.2)	
Week 11 (11/1, 11/3)	Steady State Sequences
(Book: Ch. 7.3-7.6, 8.1)	Resolution
Week 12 (11/8, 11/10)	Noise and Artifacts
(Book: Ch. 8.2-8.3)	
Week 13 (11/15, 11/17)	Fast Imaging
(Book: Ch. 9, 10.2)	Support-Limited Extrapolation
Week 14 (11/22)	Partial Fourier Reconstruction
(Book: Ch. 10.1)	Parallel Imaging

Week 15 (11/29, 12/1) Advanced Applications
Review

Final Exam (12/8)

Suggestions:

My goal is to teach you and your fellow students as much as possible about MRI, while simultaneously inspiring your interest, excitement, and curiosity about the material. This will be easier if you:

- Come to class on time and pay attention.
- Do all of the assignments.
- Ask questions and participate in classroom discussion.
- Make use of office hours.
- If you're struggling with the material, don't wait until the last minute to talk to me about it.
- Don't violate USC's academic integrity standards – you won't enjoy the consequences.

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism - presenting someone else's ideas as your own, either verbatim or recast in your own words - is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions/. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct/.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu/ or to the *Department of Public Safety* http://capsnet.usc.edu/department/department-public-safety/online-forms/contact-us. This is important for the safety whole USC community. Another member of the university community - such as a friend, classmate, advisor, or faculty member - can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage sarc@usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more.

Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* http://emergency.usc.edu/ will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.