EE 591
MAGNETIC RESONANCE IMAGING AND RECONSTRUCTION
SPRING 2024 SYLLABUS

Instructor	Prof. Krishna Nayak Office Hours: *TBD* Office: EEB 400C, (213) 740-3494 Virtual: https://usc.zoom.us/my/krishusc knayak@usc.edu (include EE591 in the Subject)
Sessions	Tuesdays and Thursdays 2:00 - 3:20pm KAP 158 (Zoom during travel)
Website	https://piazza.com/usc/spring2024/ee591 Handouts and Homework will be posted here Discussion and Q/A will happen here
Prerequisites	EE 483 Digital Signal Processing Familiarity with MATLAB

Magnetic resonance imaging (MRI) is a powerful tool for imaging structure, function, metabolism, and other properties of soft tissues (e.g. organs, diseased tissue) within the body. Modern healthcare relies heavily on non-invasive imaging, and roughly 100 million MRI scans are performed each year for this purpose. MRI is also used extensively in biomedical and neuroscience research.

Acquisition and reconstruction of MRI images is rooted in Fourier transforms, sampling, and linear systems, making it an excellent application for concepts in signal processing, optimization, data science, and machine learning.

This course will cover the physics of MRI, selective excitation, acquisition, linear image reconstruction, image contrast, volumetric imaging, and system imperfections; and will then cover advanced topics such as ultra-fast imaging, quantitative mapping, artifact correction, non-linear reconstruction, reconstruction from sparse data, and entrepreneurship. Class will meet twice per week for 80 minutes. There will be weekly homework assignments, and three demo days at the scanner. Upon completion, you will be able to: 1) understand how ~95% of clinical and research MRI scans are performed, and 2) follow the latest trends in MRI research.

Required Text

- DG Nishimura, *Principles of Magnetic Resonance Imaging*
  http://tinyurl.com/usc-ee591-text

Additional References

- ZP Liang and PC Lauterbur, *Principles of Magnetic Resonance Imaging: a Signal Processing Perspective*, Wiley-IEEE
- MA Bernstein et al., *Handbook of MRI Pulse Sequences*, Academic Press
- EM Haacke et al., *MRI: Physical Principles and Sequence Design*, Wiley
- RN Bracewell, *The Fourier Transform and it's Applications*, McGraw Hill

Software

- MATLAB™ Mathworks, Inc., South Natick, MA
- SpinBench™ HeartVista, Inc., Menlo Park, CA (MacOS only)

Grading

- Homework 60%
- Exams 40%
- Participation (bonus up to 5%)

Schedule

Week	Topics	Reading	HW
1	MRI System Overview; Equipment Tour Comparison of Imaging Modalities; Review of Requisite Math	Nish 1,2,3 Pencasts 1,2,3	-
2	NMR and MRI Physics; Role of B0, B1, and G magnetic fields Free induction decay, T1 & T2 relaxation	Nish 4 Pencast 4,5	1
3	Bloch Equation Deriving the Signal Equation (2 different ways)	Nish 5.1-5.5 Pencast 6,7	2
4	2D Imaging, k-space Sampling Considerations (and aliasing)	Nish 5.5-5.8 Pencast 8,9	3
5	Review + **MIDTERM**		-
6	Bloch Equation in the Rotating Frame Selective Excitation, Small-Tip Approximation	Nish 6 Pencast 10,11	4
7	Excitation continued, Simulation in Matlab (or SpinBench), Reconstruction in Matlab w/ Normalized Coordinates	Nish 6 Pencast 12	5
8	Image Contrast (most common pulse sequences) Off-resonance and Spin Echoes	Nish 7.1-7.4 Pencast 13,14	6
9	Noise in MRI 3D imaging, 2D multi-slice imaging	Nish 7.5, 8	7
10	Review + **MIDTERM**		-
11	MRI Industry, Market Segments, Application Segments Companies, Innovation Areas, Growth		8
12	Adoption of Machine Learning + Artificial Intelligence: Reconstruction, Artifact Correction, Workflow		9
13	High-Field (B0 ≥ 7 Tesla), Low-Field (B0 ≤ 1 Tesla), and Ultra Low-Field (B0 < 0.1 Tesla)		10
14	Body Imperfections: Flow & Motion, Off-Resonance. System Imperfections: Gradient, RF, Maxwell fields.		11
15	Manipulating Contrast: Preparation Pulses, Steady-State Sequences, Contrast Agents		-
16	**NO FINAL** (May 6, 2-4pm)		-

Discussion

This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com.

Find our class page at: https://piazza.com/usc/spring2023/ee591/home

Suggestions

My primary interest is that you learn as much as possible, that you find the material interesting, and that you finish the course wanting to know more about this subject. There are a few important things you can do: (i) ask questions, (ii) actively respond to questions posed in class, (iii) make use of office hours, (iv) read about applications of the course material, (v) learn to use MATLAB (and SpinBench if you use MacOS), (vi) remember that exams, grades, and degrees are a means to an end and not an end in itself.

We will be using Piazza for class-related discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. I will give up to 5% extra credit for active participation in class and online, which includes asking questions and answering questions from your peers in a timely, clear, and coherent fashion.

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 accommodations can be obtained from DSP. Please be sure the letter is delivered to me 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.

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. 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/.