BME 327: Magnetic Resonance Imaging
2017 Winter Quarter

Lecture Time and Room Tuesday & Thursday 9:30 am -10:50 pm, Tech M120

Instructors:
Daniele Procissi, PhD, Research Associate Professor of Radiology & BME

Tel: 312-503-2247
E-mail: mailto:d-procissi@northwestern.edu
Office hours: Tuesday, Thursday 9:30-10:50 am
Room: Tech-LG68
Guest-Lectures: To be Announced

Prerequisites:
General Physics & BME 305 (Biomedical Signals Analysis) or permission of instructor.

Reference Textbook:

- *Principles of Magnetic Resonance Imaging* -
by D. G. Nishimura
(*Available for purchase in Norris Center Bookstore*)

Suggested Textbooks (not required):

- *Handbook of MRI Pulse Sequences* -
by M. A. Bernstein, K. F. King & X. J. Zhou

- *Applied Medical Image Processing. A Basic Course*. –
by W. Birkfellner

- *Principles of Magnetic Resonance Imaging. A Signal Processing Perspective* -
by Z. Liang, P. C. Lauterbur

- *Magnetic Resonance Imaging: Physical Principles and Sequence Design* –
by E. Mark Haacke, et al.
(*Engineering Library*)

Suggested Readings:

- *Naked to the Bone. Medical Imaging in the 20th Century* -
by B. H. Kevles

Grading System:

ITEM	% OF FINAL GRADE	COMMENTS
Homework	30	Weekly Assignment (0-10)
Midterm	20	LAB REPORT Open Book (0-100)
Final	30	Open Book (0-100)
Project & Presentation	20	Open Book (0-100)

Grading Scale:

>= 93 → A
90-93 → A-
87-90 → B+
83-87 → B
80-83 → B-
77-80 → C+
73-77 → C
70-73 → C+

Course Management System (CMS) will be used for passing out assignments, solutions, class notes, handouts, and announcements.

Course Description & Main Takeaways:

MRI was initially developed in the 1970s and 1980s and has now become an integral part of the clinical diagnosis and monitoring of diseases affecting the entire human body. It also has the potential to provide a variety of information about the human body, including anatomy, function, blood flow, and metabolism and plays an important role in the development and implementation of modern paradigm of personalized medicine. This course will provide fundamentals and basic concepts of magnetic resonance imaging and their applications to disease diagnosis and will prepare those students who plan on taking the advanced MRI course offered at Northwestern.

This course will first introduce the basic physics of MRI, including nuclear spin, magnetic moments, interactions with external magnetic fields, and relaxation processes. The second portion of the course will discuss basic concepts of image formation, including radiofrequency pulse excitation, magnetic field gradients, imaging equation, Fourier Transform, k-space, and two-dimensional spatial encoding. The third portion of the course will introduce practical imaging methods and applications, such as image artifacts, fast imaging methods, signal-to-noise, contrast-to-noise, resolution, and MR imaging of the heart and blood vessels. Finally, students will have the opportunity to translate their gained knowledge and understanding of MRI physics and technology into a practical application by submitting an individual or group project.

At the end of the class, students will gain:

- A basic but systematic understanding of the MRI fundamentals
- A basic understanding of major technical issues in MRI;
- General knowledge of clinical and research applications of MRI.
- The ability to design, develop and implement an advanced MR research experiment.

A more detailed description of the objectives is given below

<u>Specific Objectives of BME 327 Course:</u>

The course will provide students with:

1. **An understanding of the physics of magnetic resonance including:**
   i) *nuclear spin interactions with applied, time-dependent and static magnetic fields*
   ii) *magnetic resonance*
   iii) *magnetic relaxation: Bloch Equations*

2. **An Understanding of the fundamentals of image formation, including:**
   i) *radiofrequency pulse excitation*
   ii) *phase of nuclear magnetization as a function of magnetic field gradients*
   iii) *frequency and phase encoding*
   iv) *Fourier Transform* relationship between image and k-space: Imaging equation
   v) *basic signal sampling requirements for magnetic resonance imaging and image artifacts if the Nyquist sampling rate is not met (aliasing)*
   vi) *spatial resolution of acquired images*
   vii) *contrast modalities (T_1, T_2 & spin density weighted imaging)*

3. **An understanding of the main factors affecting images, including:**
   i) *magnetic resonance signal and contrast as functions of tissue parameters*
   ii) *effects of field inhomogeneities on images*
   iii) *sources of image noise (i.e. how sensitiveß is MRI)*
   iv) *effects of contrast agents on image signal intensity*
   v) *definition and formation of echoes in spin-echo and gradient-echo sequences*

4. **The knowledge necessary to determine k-space trajectories from magnetic field gradient waveforms and vice versa.**

5. **The ability to analyze changes in signal-to-noise and contrast-to-noise ratios as functions of imaging parameters.**

6. **An understanding of the technical challenges and opportunities of MRI**

7. **A general perspective and understanding of the basic research and clinical applications of MRI in oncology, cardiology and neurology.**

IMPORTANT NOTE
This course will provide you with the basics of MRI and introduce you to applications of this technology in biomedical research. Prof Michael Markl will be offering an Advanced MRI course which will held in the Spring Quarter 2017. Please email Michael Markl <mmarkl@northwestern.edu> for additional questions

	Date	Topic	Materials
1	Tu - 3rd January 2017	Introduction, overview, basic concepts of MRI & historical perspective	slides
2	Th - 5th January 2017	Mathematics related to MRI, Introduction to Matlab programming for	slides handout: Fourier
3	Tu - 10th January 2017	Spin physics: Nuclear Spin, interactions with applied magnetic	slides handout: Physics of MRI
4	Th- 12th January 2017	Spin physics: T1, T2, T2* Relaxation, Bloch equations	slides handout: Relaxation
5	Tu - 17th January 2017	Imaging principles: magnetic field gradients, spatial localization, frequency	slides
6	Th - 19th January 2017	Imaging principles: Fourier transform, slice selection, phase encoding, echoes,	slides
7	Tu - 24th January 2017	Imaging principles: rf-excitation revisited, finite sampling, pulse sequence	slides
8	Th - 26h January 2017	Fundamental MRI techniques: Spin echo	slides handout: Spin Echo MRI
9	Tu – 31st January 2017	Guest lecture	slides
10	Th -2nd February 2017	Fundamental MRI techniques: Gradient echo	slides handout: GRE imaging
11	Tu – 7th February 2017	Imaging considerations: Image contrast, steady state, diffusion	slides
12	Th – 9th February 2017	Imaging considerations: SNR, Image Quality,	slides handout: Artifacts
13	Tu – 14th February 2017	**Lab I: Hands-on MR imaging on human and ultra-high field small**	lab report counts as midterm exam
14	Th – 16th February 2017	**Lab II: Small student groups split between CTI & CAMI both** days	lab report counts as midterm exam
15	Tu – 21th February 2017	Imaging considerations: Field inhomogeneity, Susceptibility, T_2*, Contrast agents	slides handout: Fat-water MRI
16	Th – 23rd February 2017	Guest lecture	slides
17	Tu – 28th February 2017	Advanced Application 1 : TBD	slides handout:
18	Th – 2nd March 2017	Advanced applications 2 : TBD	slides
19	Tu – 7th March 2017	Student presentations	Papers and/or project
20	Tu – 9th March 2017	Student presentations, final review	Papers and/or project
	Th 16th March 2017	**Final Exam**	

Lab: Introduction to MRI hardware, hands on scanning & exercises at MRI system
Shaded Lectures → *homework issued (due following week)*
Hands On Lab → *Takes place in Evanston and Chicago*

NOTES:

1) *The content for each lecture may vary as class progresses.*
2) *Some changes to content may change depending on specific interest of class participants.*
3) *Guest Lectures will be scheduled.*
4) *Advanced Applications will cover research applications of MRI*
5) *The laboratory will be divided in two sessions: 1) In Evanston at CAMI (Silverman Hall) you will be introduced to the high field preclinical imaging MRI (7, 9.4 Tesla). 2) In Chicgao at CTI (Olson Pavilion) you will be introduced to a clinical MRI. We will divide the class in subgroups and assign a time for the hands-on experience*