BME 427: ADVANCED MRI

QUARTER OFFERED
Spring: MW 5:00-6:30, Chicago Campus; Markl

PREREQUISITES
BME 327

DESCRIPTION
Theory, design, and applications of pulse sequences and Magnetic Resonance Imaging.

WHO TAKES IT
Doctoral and Masters Degree students. Advanced Undergraduate students may register with permission of the instructor.

WHAT IT'S ABOUT
This is a project based course in the use of MRI for imaging living tissue. The flexibility of MRI to determine image contrast through altering pulse sequences results in MR being used in a broad range of clinical applications. This course will develop an understanding of the use and design of MR techniques and pulse sequences, image reconstruction, and advanced MRI data analysis concepts. The course will be split into three sections: The first section will revisit fundamentals and basic concepts of MRI and their applications to disease diagnosis. The second section will cover the some of the more widely used MR image acquisition strategies and applications areas. The state of the art in MRI will be present by faculty guest lectures. Finally, each student will select a project (Matlab based development or literature review). The course will culminate with a series of student presentations that will consist of 40-minute project presentations which will count as a final project.

MINISYLLABUS
- Revisit Fundamentals of MRI
- MRI Image Formation and Pulse Sequences
- Hands-on MR Imaging on Human MRI Systems
- Fast Imaging, Imaging Acceleration and Reconstruction
- Flow and Motion
- Cardiovascular MRI
- Functional MRI

TEXTBOOK
The following books are good references, but are NOT required for the course.
- “Magnetic Resonance Imaging, Principles and Sequence Design”, Haacke et al.
- “Magnetic Resonance Imaging”, by Vlaardingebroek and den Boer.
BME 427: ADVANCED MRI

2018 Spring Quarter

- Time: Mondays and Wednesdays, 5:00pm - 6:30pm
- Location: Conference Room, 737 N. Michigan Avenue Suite 1600, Chicago 60611 (downtown NU Campus, entrance the the building is on Chicago Avenue)

First class: Wednesday, April 4, 2018

Instructor
Michael Markl, PhD
Lester B. and Frances T. Knight Professor of Cardiac Imaging
Professor of Radiology & Biomedical Engineering
Director Cardiovascular Imaging Research
E-mail: mmarkl@northwestern.edu
737 N. Michigan Avenue Suite 1600

Who takes it: Doctoral and Master Degree students. Advanced Undergraduate students may register with permission of the instructor.

Prerequisite
General Physics and
BME 305 (Biomedical Signals Analysis)
BME 327 (Magnetic Resonance Imaging)
or permission of instructor

Physics and math background: vectors, rotation matrices, 1st order differential equations, complex numbers, exponential functions, Fourier Transform, magnetic moment and magnetic field, electromagnetic fields and waves, induction

Required Textbooks / Matlab

No text book, reading materials will be provided during class
Project work will require Matlab for MRI image reconstruction, analysis, and display.
Familiarity with Matlab is an important prerequisite for this course.

References
The following books are good references, but are NOT required for the course.

- “Magnetic Resonance Imaging, Principles and Sequence Design”, Haacke et al.
- “Magnetic Resonance Imaging”, by Vlaardingebroek and den Boer.
Grading System

<table>
<thead>
<tr>
<th>Item</th>
<th>% of final grade</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Attendance / Participation</td>
<td>30%</td>
<td>Project – presentations (midterm, final)</td>
</tr>
<tr>
<td>Project</td>
<td>40%</td>
<td>Project – written report</td>
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<tr>
<td>Project</td>
<td>30%</td>
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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 Attendance**: The design of this course is built around student participation in a small group (see also grading system above). Class attendance is thus mandatory.

**Canvas** will be used for passing out assignments, solutions, class notes, handouts, and announcements.

**Course Description**: This is a project based course in the use of MRI for imaging living tissue. The flexibility of MRI to determine image contrast through altering pulse sequences results in MR being used in a broad range of clinical applications. This course will develop an understanding of the use and design of MR techniques and pulse sequences, image reconstruction, and advanced MRI data analysis concepts. This will include an emphasis on understanding of the more widely used MR acquisition strategies, of image contrast mechanisms, and of data acquisition strategies (sampling, reconstruction, fast imaging and parallel acquisition concepts).

The course will be split into three sections: The first section will revisit fundamentals and basic concepts of magnetic resonance imaging and their applications to disease diagnosis (image formation, radiofrequency pulse excitation, magnetic field gradients, imaging equation, Fourier Transform, k-space, image artefacts, fast imaging methods, signal-to-noise, contrast-to-noise). The second section will cover the some of the more widely used MR image acquisition strategies and applications areas. The state of the art in MRI will be present by faculty guest lectures. Finally, each student will select a project (literature review or development of Matlab based MRI data analysis/manipulation/reconstruction). The course will culminate with a series of student presentations that will consist of 40-minute project presentations which will count as a final project.

**Lab**: The course will include hands-on lab work at MR systems at the Center of Translational Imaging (CTI) at the downtown Chicago campus. Sessions will include hands-on experience with MR imaging and data acquisition using CTI’s state-of-the art human MRI systems. MRI data collected during the lab session will be provide to students to conduct further image processing, analysis, and interpretation.
<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>04/04</td>
<td>Fundamentals of MRI: spin physics, magnetization, rf-excitation, T1, T2, T2* Relaxation, image formation, <strong>Introduce Course Projects</strong></td>
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<tr>
<td>04/09</td>
<td>MRI concepts: magnetic field gradients, spatial localization, frequency encoding, phase encoding, pulse sequence design, k-space</td>
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<tr>
<td>04/11</td>
<td>MRI concepts: MRI Pulse sequences: k-space, Fourier transform, finite sampling &amp; aliasing. <strong>Discuss Course Projects</strong></td>
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<tr>
<td>04/16</td>
<td>MRI Pulse sequences: Spin Echo and Gradient Echo MRI. <strong>Select Course Projects</strong></td>
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<tr>
<td>04/18</td>
<td>Interactive session: Matlab based MR image reconstruction &amp; Bloch simulations.</td>
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<tr>
<td>04/23</td>
<td>Advanced topics: Sequence parameter optimization and trade-offs, 3D imaging</td>
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<tr>
<td>04/25</td>
<td>Advanced topics: Fast imaging, multi-echo SE, EPI, parallel imaging, sparse sampling &amp; reconstruction</td>
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<tr>
<td>04/30</td>
<td><strong>Lab I</strong>: Hands-on MR imaging on human MRI systems</td>
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<tr>
<td>05/02</td>
<td>no class</td>
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<tr>
<td>05/07</td>
<td>no class</td>
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<tr>
<td>05/09</td>
<td><strong>Midterm presentations</strong>: State of the projects, preliminary results, project plan I</td>
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<tr>
<td>05/14</td>
<td><strong>Midterm presentations</strong>: State of the projects, preliminary results, project plan II</td>
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<td>05/16</td>
<td>Advanced topics: MR-signal phase, phase-contrast MRI, Fat-Water/Dixon</td>
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<td>05/10</td>
<td><strong>Lab II</strong>: Hands-on MR imaging on human MRI systems</td>
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<td>05/21</td>
<td>Advanced topics: MR angiography / cardiovascular MRI</td>
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<td>05/23</td>
<td><strong>Lab III</strong>: Hands-on MR imaging on human MRI systems</td>
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<td>05/28</td>
<td><strong>Memorial Day – no class</strong></td>
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<tr>
<td>05/30</td>
<td>Advanced topics: guest lecture</td>
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<tr>
<td>06/04</td>
<td><strong>Final presentations</strong> (project)</td>
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<tr>
<td>06/06</td>
<td><strong>Final presentations</strong> (project)</td>
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Lab: Hands on scanning & exercises at MRI system