12/8/2022

BMB/BE 5810
Techniques of Magnetic Resonance Imaging

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Curriculum Summary

Detailed introduction to the physics and engineering of magnetic resonance imaging and its applications in medical imaging. Topics covered: Bloch equations, spatial encoding principles, Fourier analysis, spin relaxation, imaging pulse sequences, contrast mechanisms, chemical shift imaging, flow encoding, diffusion and perfusion, artifacts, motion compensation techniques, high-field MRI and a discussion of the most relevant clinical applications.

Weekdays and time: **Mondays and Wednesdays, 5:00 – 6:30pm**

Location: **Donner 2 Conference Room (just past the 2nd floor cafeteria)**
***** Donner/Grice Auditorium on 1/11, 2/8, and 4/12 *****

Grading: 20% Homework (4 problem sets), 35% Midterm, 45% Final

Reading: The course does not follow a specific textbook. However, you may find the following references to be useful (they are not required):

1. ***Principles of Magnetic Resonance Imaging***
   Nishimura, 2010, www.lulu.com (look for the softcover)
2. ***Magnetic Resonance Imaging: Physical Principles and Sequence Design***
   Haacke, et al, Wiley, 1999
3. ***Handbook of MRI Pulse Sequences***
   Bernstein, et al, Elsevier, 2004
4. Useful link: ***The Basics of MRI***
   Hornak http://www.cis.rit.edu/htbooks/mri/

In addition, supplementary reading material may be distributed prior to some of the lectures.

Schedule

Date	Topic	Description
Jan. 11 Wed (Wehrli)	Basics of NMR	Nuclear spin, magnetic moment, gyromagnetic ratio, nuclear precession, Larmor equation, bulk magnetization excitation and detection
Jan. 16 Mon	**No Class – MLK, Jr. Day**	
Jan. 18 Wed (Wehrli)	Bloch Equations and Signal Detection	Rotating frame, solutions for various initial conditions, time & frequency domain, Fourier transform
Jan. 23 Mon (Wehrli)	Fundamentals of spin relaxation: T1, T2, T1ρ	Correlation and power spectral density function, dipole-dipole and other relaxation mechanisms, chemical exchange
Jan. 25 Wed (Song)	RF Pulses and Excitation	Principle of resonance, pulse shape and excitation profile, nonlinearity problem, adiabatic inversion
Jan. 30 Mon (Song)	MR Hardware	Magnet, gradient system, siting issues, eddy currents/ compensation/shielded gradients; Principle of signal detection, resonant circuits
Feb. 1 Wed (Wehrli)	Signal and Contrast	Image signal intensity and contrast in MRI, role of relaxation times, techniques for measuring relaxation times (T1, T2, T1ρ), coherence pathways
Feb. 6 Mon (Wehrli)	Spatial Encoding and K-space	Gradient fields, gradient rephasing, k-space concept and properties, imaging equation, sampling
Feb. 8 Wed (Witschey)	Fourier Imaging Techniques I	Rectilinear sampling: spin warp imaging, gradient and spin echo embodiments, 3D spin-warp imaging, signal and contrast
Feb. 13 Mon (Witschey)	Fourier Imaging Techniques II	Introduction to echo-train imaging: EPI and RARE, contrast implications, point-spread function, artifacts
Feb. 15 Wed (Song)	Image Reconstruction	Fundamentals of Fourier transform, sampling theorem, field of view, resolution, modulation transfer and point spread function, partial Fourier
Feb. 20 Mon (Witschey)	Advanced Imaging Techniques I	Imaging with multiple receive coils, reconstruction issues, SNR, parallel imaging: SENSE and SMASH, image reconstruction artifacts
Feb. 22 Wed (Wehrli)	Flow Imaging Techniques	Time of flight and phase effects, gradient moment nulling, flow encoding methods, angiographic imaging techniques, vascular imaging and flow quantification
Feb. 27 Mon (Tisdall)	SNR in MRI	Properties of noise: Gaussian, Rayleigh and Rician, measurement of SNR, dependence on scan parameters
Mar. 1 Wed	**Mid-Term Exam**	
Mar. 6 & 8	**Spring Break**	

Mar. 13 Mon (Witschey)	Cardiovascular MRI	Dark/bright blood imaging, cardiac gating, cine imaging techniques, tagging methods, cardiac T1 mapping, tissue characterization using modified Look-Locker
Mar. 15 Wed (Detre)	Perfusion and Functional MRI	Physics of microcirculation, first-pass contrast methods, diffusible tracer methods (ASL), clinical applications; BOLD, fMRI acquisition techniques, processing of fMRI data, design of fMRI paradigms
Mar. 20 Mon (Song)	Advanced Imaging Techniques II	Fat/water separation, inversion recovery, rapid imaging techniques, keyhole technique, dynamic imaging
Mar. 22 Wed (Wehrli)	Spectroscopic Imaging	Chemical shift and spin-spin coupling, 2-component chemical shift selective imaging: saturation and selective excitation, echo offset techniques, PRESS, STEAM, spectroscopic imaging, conventional phase-encoding methods, high-speed EPI
Mar. 27 Mon (Song)	Alternative Image Acquisition Schemes	Radial scanning (UTE/ZTE), spiral, regridding and reconstruction, artifacts, PROPELLER/BLADE
Mar. 29 Wed (Wehrli)	Diffusion MRI	Pulsed gradient diffusion experiment, diffusion tensor imaging, fiber tracking, diffusion in background gradients, Q-space imaging
Apr. 3 Mon (Wehrli)	Magnetic Susceptibility	Fundamentals of induced magnetism, image artifacts, applications: bone, iron, measurement of hemoglobin saturation, Quantitative Susceptibility Mapping
Apr. 5 Wed (Rajapakse)	Other Reconstruction Strategies	Iterative reconstruction, regularized reconstruction, compressed sensing
Apr. 10 Mon (Tisdall)	Motion Reduction Techniques	K-space analysis of motion, respiratory gating, navigator echoes, retrospective motion correction, prospective compensation
Apr. 12 Wed (Song)	Steady State Imaging	Steady-state conditions and signal formation, balanced steady-state free precession, image contrast, transient period, clinical applications
Apr. 17 Mon (Song)	Imaging Artifacts and Compensation	Common artifacts (aliasing, ghosting, zipper, N/2, flow, etc.) and means for their reduction
Apr. 19 Wed (Song)	MR Safety	SAR, dB/dt, gadolinium CA, quenching, flying objects, pregnancy, implantable devices, RF coils and cables, imaging at high fields (>3T), etc.
Apr. 24 Mon (Walter)	Emerging Technologies	AI/deep learning, MR fingerprinting, ultra-high field >> 7T, etc.
Apr. 26 Wed (Song, Deshpande)	Review Session	
May 1-9	**Final Exam**	