Course homepage: https://pages.ucsd.edu/~msereno/neuroimaging

Foundations of Neuroimaging

Professor:

Marty Sereno -- email: msereno@ucsd.edu
example time: MWF 9:00-9:50 AM, grad/advanced: F 8:00-8:50
take hand-written notes for better memory consolidation!
take-home exams, final/paper based on lecture content

Course Content:

Sereno Lectures:
https://pages.ucsd.edu/~msereno/neuroimaging/lectures.html
Sereno Lecture Notes PDF (single-page links on homepage)
https://pages.ucsd.edu/~msereno/neuroimaging/notes.pdf
Background reading:
Huettel, S., A.W. Song, and G. McCarthy (2014) *Functional Magnetic Resonance Imaging*, 3rd ed. (also 2nd ed.)
Additional background readings, references:
https://pages.ucsd.edu/~msereno/neuroimaging/readings.html

Assignments:

Homework #0 (practice, not due)
Homework #1 (due end of 6th week)
Homework #2 (due end of 12th week, test img here)
Final Paper: 5(ugrad)/10(grad)-page literature review on narrow methodological topic (~1 paper) (start search in *Magnetic Resonance in Medicine*, *Neuroimage*, *Human Brain Mapping*)

Learning Objectives:

Students will be able to do the following:
(1) explain precession/excitation/recording/contrast of magnetic resonance signals and echoes using the Bloch equation
(2) compute Fourier transform, use it to explain how RF simulation, gradients, and RF coil signals generate k-space data and how brain images are reconstructed from that data
(3) diagram main classes anatomical/functional pulse sequences
(4) describe diffusion, perfusion, and spectroscopic imaging
(5) describe origin/localization of EEG/MEG signals, cortical surface-based methods, and how to combine them w/fMRI

Lecture Topics (e.g., Fall semester course):

Week 1 (MWF) -- Introduction
Introduction to Neuroimaging -- MRI, fMRI, EEG, MEG
MRI hardware
Spin and Precession

Week 2 (MWF) -- Bloch Equation
Bloch Equation
Dot/Cross/Complex Products
Precession solution
Initial-Value Solutions to Differential Equation
T1, T2 solutions
Bloch Equation/Solution -- matrix version

Week 3 (WF) -- Signal Equation
[no class: Mon]
RF Excitation
Signal Equation
Phase-Sensitive Detection

Week 4 (MWF) -- Echoes
Free Induction Decay
Spin Echo
Spin Echo Equations
Stimulated Echo, Spin Echo Trains
Gradient Echo, Gradient Echo Trains

Week 5 (MWF) -- Using the Bloch Equation
Saturation-Recovery Signal
Inversion-Recovery Signal
Spin Echo Signal
Gradient Echo Signal
Gray-White Contrast
Signal-to-Noise

Week 6 (MWF) -- Fourier Transform
Complex Algebra
Fourier Transform
Negative Exponents, Orthogonality
Spatial Frequency Space (k-Space)
One k-Space Point -- 3 representations

Week 7 (MWF) -- Gradients, Slice Selection
Gradient Fields
Gradient Combination
Slice Selection
RF Pulse Details

Week 8 (MWF) -- MRI Image Formation
1st Take-Home Exam Due
Frequency-Encoding -- A Misnomer
Frequency-Encoding -- Incorrect and Correct Intuition
Imaging Equation (1D)
Phase Encoding
3D Imaging
Spin Phase in Image Space
Gradients Move Signal in k-Space

Week 9 (MWF) -- Image Reconstruction
Image Reconstruction
Aliasing and FOV
Under/Over Sample
Replicas, FTs
General Linear Inverse for MRI Reconstruction

Week 10 (MWF) -- Practical Pulse Sequences
Fast Spin Echo
Fast Gradient Echo
Quantitative T1/PD/T2* Methods
Gradient Echo EPI, Spin Echo EPI, Single-Shot Spiral
SENSE, GRAPPA, Simultaneous Multi-Slice, 3D EVI

Week 11 (MWF) -- Image Artifacts
Fourier Shift Artifacts
EPI vs. Spiral Artifacts
Image-Space View Localized B0 Defect
Effect Local B0 Defect on Reconstruction
Shimming, B0-Mapping, Navigators
Gradient Non-linearities
RF Field Inhomogeneities

Week 12 (MW) -- Diffusion and Perfusion Imaging
Diffusion-Weighted Imaging and Tract Tracing
Perfusion Imaging (Arterial Spin Labeling)
[no class: Fri]

Week 13 (MWF) -- Phase-Encoded, Block Design
Phase-Encoded Stimulus for Mapping
Convolution
General Linear Model and Solution, Geometric Picture
Cluster Correction -- 3D and Surface-Based
Normalize, Strip Skull, Non-Isotropic Filtering
Region-Growing, Tessellation: 3D -> 2D
Cortical Unfolding and Flattening
Sulcus-Based Alignment

Week 14 (M) -- Cortical Surface Methods
2nd Take-Home Exam Due
Cortical Thickness Measurement
Mapping Cortical Visual Areas
[no class: Wed, Fri]

Week 15 (MWF) -- Source of EEG/MEG
Intracortical Source of EEG/MEG
Grad, Div, Curl
1D/2D/3D Current Source Density
Why We Can Ignore Magnetic Induction

Week 16 (MWF) -- Neuroimaging EEG/MEG
Forward Solution
Minimum Norm Linear Inverse
Noise-Sensitivity Normalization

Week 17 (M)
Spatiotemporal Covariance Filters
Final Paper Due