Introduction

M229 Advanced Topics in MRI

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UCLA

Department of Radiological Sciences
David Geffen School of Medicine at UCLA

Introduction

- Your instructor: Holden

- Your TAs: Wenqi, Elif

- Guest lecturers
  - Dr. Kyung Sung, Shu-Fu Shih, Dr. Anthony Christodoulou, Dr. Jingwen Yao, Dr. Fei Han, Dr. Lea Azour

- You

MRI Research

Technical Developments

Physics
Contrast mechanisms
Mathematical models
Hardware
Data acquisition
Data reconstruction
Data processing
Quantitative analysis
Data integration
Software

Clinical Applications

Anatomical imaging
Functional imaging
Multi-modal imaging
Quantitative imaging

for
Diagnosis / screening
Treatment planning
Procedural guidance
Treatment assessment
Monitoring

MRI Research

- MRI provides powerful information

- MRI is slow …
    - develop new acquisition and reconstruction methods

Goals of M229

- Understand state-of-the-art MR image acquisition and reconstruction

- Understand impact of MR technical developments on clinical applications

- Prepare for research in MRI

Prerequisites

- M219 or equivalent

- Strong interest in MRI research

- Some programming experience

Course Topics

- Pulse Sequences

- RF Pulse Design

- Fast Imaging Trajectories

- Parallel Imaging

- Compressed Sensing

- Deep Learning Recon

- Motion in MRI

- Susceptibility Imaging

- Invited Speakers

  - Body MRI

  - Lung MRI

Course Logistics

- Textbook: Handbook of MRI Sequences
  - Digital copy available through UCLA library

- Course website:

  https://mrrl.ucla.edu/pages/m229
  - Materials and links
  - Sample code and data

- Web resources
  - Past ISMRM education talks

- Mailing list: m229@lists.ucla.edu
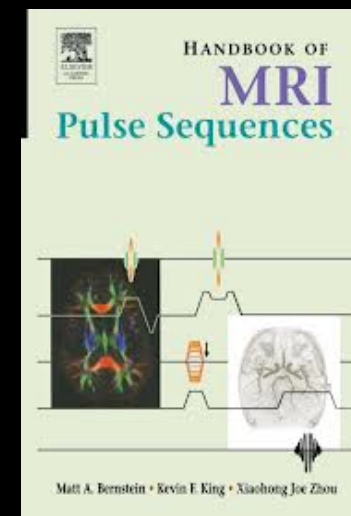
Course Logistics

- Office hours
  - Instructor: Fri 10-11 am; appointment
  - TAs: TBD
  - Send email

- MATLAB
  - available through UCLA

- SpinBench
  - available for free (Mac only)
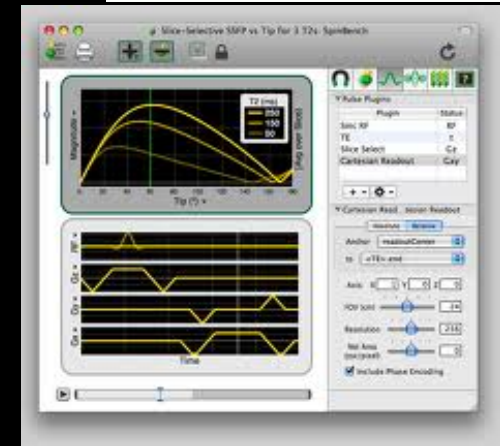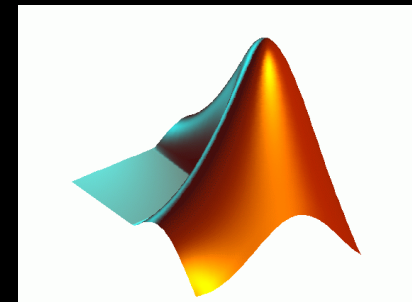
Course Logistics

- Grading
  - Participation (10%)
  - Homework (30%)
  - Final Project (60%)

- Homework
  - 2 MATLAB programming assignments
  - Turn in electronically (PDF and code)

Final Project

- Have ~6 weeks; start thinking now!
  - Take advantage of office hours

- Can be your own research

- Can be from list of ideas

- Components
  - Proposal (1 page), due in May
  - Abstract (1 page), due in early June
  - Presentation, in mid June

2023 Projects

- Random Matrix Theory-Based Image Domain Denoising for Diffusion-Relaxation Correlation Spectrum Imaging

- Comparison of T1-T2 Fitting Strategies Based on Multitasking Framework

- Universal Sequence-Invariant Deep Learning for CMR Multitasking Image Reconstruction

- Fractional Myocardial Blood Volume Estimation using Ferumoxytol-Enhanced Magnetic Resonance Imaging: Early Findings in Human Subjects

- A Novel Local Shim Array for B0 Shimming of the Prostate

2023 Projects

- MRI-based Radiomics Feature Analysis for Clinically Significant Prostate Cancer Diagnosis

- Myocardial Scar Detection in Ferumoxytol-Enhanced Cardiac MRI: A Dictionary Learning Approach Using LGE-Labeled Ferumoxytol-Enhanced MOLLI Images

- Deep-Learning Based Parametric Maps Generation for Undersampled CEST MRI Data

- The Influence of Undersampling Schemes on Compressed Sensing Reconstruction in Brain MRI

- 5D Cardiorespiratory Resolved Imaging with Ferumoxytol for Pediatric Congenital Heart Disease

2022 Projects

- Multicomponent T2 Mapping with DESS

- Pseudo-Resting-State Functional MRI from Dynamic Susceptibility Contrast Perfusion MRI Reveals Functional Networks

- T2-Weighted Dual Echo Steady State Knee MR Image Reconstruction Using Low Rank Modeling of Local k-Space

- Simultaneous Multi-Slice vs. In-Plane Acceleration: Comparison of Reconstruction Results Using ESPIRiT for Radial Golden Angle Abdominal MRI

- Multi-Slice Mask R-CNN for Needle Feature Detection and Segmentation in 3D T1 VIBE MR Images

2021 Projects

- Using Feed-Forward Neural Network to Generate Amide Proton Transfer Maps from Field Corrected Undersampled Z-Spectrum in the Brain at 3T

- Technique Development for Motion-Resolved Quantitative Imaging and Quantitative Susceptibility Mapping for Heart Chamber Oxygenation

- Coronary MR Image Reconstruction Using Convolutional Neural Networks

- Dynamic MR Reconstruction from Undersampled Data: A Comparison between KWIC and GRASP Reconstruction

- Effect of Attention Mechanisms on Prostate Segmentation in MRI

2020 Projects

- Ferumoxytol Relaxometry at 0.35 T to Investigate Optimized T1-weighted Imaging

- Evaluation of Spiral-Cartesian Sampling for 4D Real-time MR Multi-contrast Imaging Using Digital Motion Phantom

- A Deep Learning Method for Undersampled MRI Reconstruction

- Hyperpolarized ^{13}C MRI Cellular Metabolism and Transport Modeling with Parameters Estimation

- Probabilistic Tractography

- Evaluation of T2-weighted MRI Pulse Sequence for Visualization and Sparing of Urethra with MR-guided Radiation Therapy (MRgRT) on-board MRI

2020 Projects

- Image Synthesis in Multi-contrast MRI with Deep Neural Network

- An Investigation on the Flip Angle Dependence of Diffusion-Weighted Steady-State Free Precession using Monte-Carlo Simulations

- Deep Learning based Cardiac MRI Cine Super Resolution

- Automatic Segmentation of Myocardium in First-pass Cardiac MRI Datasets Using a Patch-Based Convolutional Neural Network Approach

2019 Projects

- Semi-Quantitative Low-Field DCE Perfusion Analysis: A Proof of Concept

- Brain Connectivity Study of Bipolar Disorder Based on fMRI

- Improved Correlation of Prostate Multi-Parametric MRI with Histologic Findings using Deep Learning

- Investigation of Robustness of Two Myocardium Segmentation Models to Training Datasize and Shifts on Training Masks

- Anisotropic Super-Resolution in Prostate MRI using Deep Learning

2019 Projects

- Assessment of Time Optimal Simultaneous Multi-Slice Excitation Pulses with Low Peak RF Power

- Myocardial Blood Volume Measurement using MOLLI Sequence and Water Exchange Model

- Accelerated Volumetric Free-Breathing Liver Fat Quantification using Low-N-Rank Tensor Reconstruction

- A SPIRiT-Like Deep Learning Network with Better Robustness for Diverse Sampling Trajectories

- T1 Mapping with Flow Effect

2018 Projects

- Dynamic Magnetization Evolution Visualizer

- CEST Fingerprinting Using Low-Rank Constraint

- Prostate Cancer Lesion Prediction using Multi-Parametric MRI via Deep Convolutional Neural Network

- Contrast Optimization of T1-Weighted Inversion Recovery in Cardiac MRI for Chronic Myocardial Infarction Detection without Contrast Agent

- Undersampled MR Image Reconstruction Using Convolutional Neural Network

- Glioma Segmentation in Multimodal MRI Scans using 3D Convolutional Neural networks

2018 Projects

- Dynamic Myocardial Hyper-Intensity in FLASH Cardiac Cine Imaging: Is it an Artifact?

- Optimizing Parameters to Enhance T2 Mapping Accuracy and Efficiency with Fast Spin Echo

- Plug and Play ADMM with Deep CNN Prior for MRI Reconstruction from Under-Sampled Data

- Using Prospectively Trained Artificial Neural Networks to Improve Cardiac Diffusion Tensor Reconstruction

- Implementation of Magnetic Resonance Image Example-Based Contrast Synthesis Method

- Prospective Single Self-Gating for Bulk Motion Correction

2017 Projects

- Magnetization Preparation: Enhancing T1 Contrast in Infarcted Myocardium

- Compressed-Sensing Phase-Contrast MRI with Hybrid One and Two-Sided Flow-Encoding and Velocity Spectrum Separation

- Optimization of Magnetic Resonance Fingerprinting Acquisition Scheme

- Estimating Diffusion Time for CODE Optimized Monopolar Diffusion Weighted MRI EPI Sequence

- Estimation of Non-Excitable Area Around Ferromagnetic Objects in MRI

2017 Projects

- Efficient Super-Resolution in Magnetic Resonance Imaging Based on Deep Neural Networks

- High Resolution Distortion Reduced Diffusion Prostate MRI with Minimal Echo Time using ENCODE (Eddy Current Nulled Convex Optimized Diffusion Encoding)

2016 Projects

- Evaluation of Polynomial Surface Fitting for In Vivo Eddy Current Correction of PC-MRI Data Sets

- Prospective Motion Tracking by Using Multiple Temporal Resolution Imaging Navigators

- Automated Tissue Segmentation Using MRI Fingerprinting

- Evaluation of Rapid Cardiac Imaging Using a bSSFP Pulse Sequence at 0.345 T

- Evaluation of Sparsifying Transforms for Low-Rank Tensor Imaging

- NUFFT-Based CLEAR Algorithm for Non-Cartesian MRI

2016 Projects

- Comparison of Various Sampling Trajectories for Accelerated Cardiac DTI Reconstruction Using Joint Low-Rank Model Sparsity Constraint

- Parameters Analysis and Image Quality Assessment in k-t SLR Method

- Validation of Using 3D Stack-of-Stars with Dixon Fat-Only Signal for Respiratory Motion Detection in DCE-MRI

2015 Projects

- Design and Validation of a Minimum Time VERSE Pulse for 4D Flow MRI

- Polymer Drug Delivery Release Study: Modeling In Vivo Drug Release Using Contrast Agent

- T2-Prepared Gradient Echo for Simultaneous T2-Thermometry Imaging

- 2D Multi-Slice Background Suppression for Brain Arterial Spin Labeling Perfusion Imaging

- Motion Compensation with Localized Translations for High Respiratory Gating Efficiency

- Toward Improved Respiratory Self-Gating: From SI Projection Acquisition to Motion Extraction

2014 Projects

- Evaluation of Temporal Blurring Effect in Dynamic MRI using Golden Angle Radial Acquisition and K-Space Weighted Image Contrast (KWIC)

- Phase Contrast MRI with Flow Compensation View Sharing (FCVS)

- Motion Sensitivity of Diffusion Encoding Gradient Schemes in Cardiac Diffusion MRI

- Comparison of TSE and SSFP for Myocardium T2 Mapping

- Diffusion of Contrast Agent in Dynamic Contrast Enhanced (DCE)-MRI

2014 Projects

- Effects of T1/T2 and B1 on bSSFP Catalyzation

- Real Time MR Imaging Using Dynamic Golden Angle Radial Acquisition with SPIRiT Reconstruction

- Comparing Fat-Water Separation for Radial and Cartesian Acquired Data

- Partially-Dephased SSFP: with Applications in fMRI

- Accelerated left ventricular twist measurement using CAIPIRINHA

- Effects of Under-sampling Pattern on GRAPPA, SPIRiT and ESPIRiT
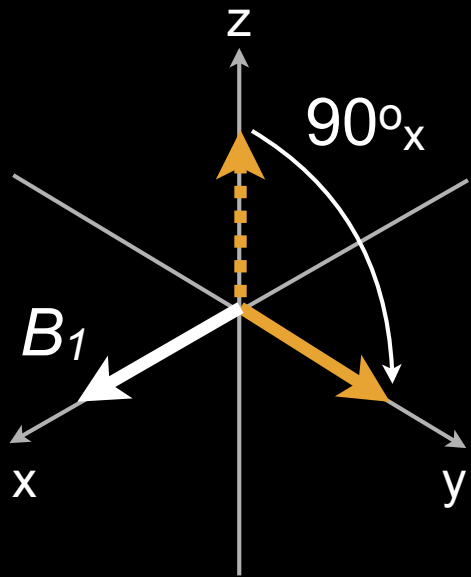
Questions?

Notation and Conventions

- $\omega = \gamma B$

  - $|B| = B_0 + G_x x + G_y y + G_z z + B_1 + \Delta B$

  - $\omega_0 = \gamma B_0$

- RF pulse

  - flip angle θ
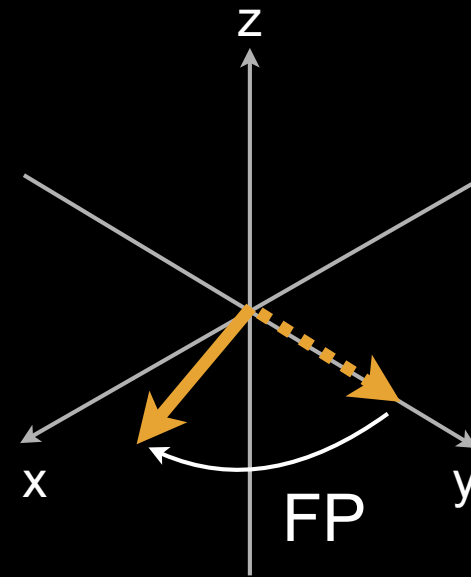
  - phase ϕ (=0 along x)

    $$\vec{B} = B_0 \hat{k} + B_1(t)[\cos \omega t \hat{i} - \sin \omega t \hat{j}]$$

Notation and Conventions

- Left-handed rotation and precession

rotating frame at ω_0

rotating frame at ω_0

Preview

- Closer look at course schedule
  - https://mrrl.ucla.edu/pages/m229_2024

Preview: RF Pulse Design

- Adiabatic Pulses

- Multi-dimensional Excitation

- SLR

- RF Pulse Design Tool (MATLAB)

Preview: Pulse Sequences

- Rapid Gradient Echo

- Fast (Turbo) Spin Echo

- Bloch Simulation (MATLAB)

- Extended Phase Graphs (MATLAB)

Questions?

- Related courses of interest
  - PBM 222 MR Spectroscopy
  - PBM/BE M236 MR Contrast Mechanisms

Thanks!

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http://mrrl.ucla.edu/wulab