PHYS-760

CIBM translational MR neuroimaging & spectroscopy

Cudalbu Cristina Ramona, Invited lecturers (see below), Lanz Bernard, Wenz Daniel, Xin Lijing, Zerbi Valerio

Cursus	Sem.	Type
Biotechnology and Bioengineering		Opt.
Physics		Opt.

Contact language	English
Credits	3
Session	
Exam	Term paper
Workload	90h
Hours	**48**
Lecture	36
Practical work	12
Number of positions	**12**

Frequency

Every year

Summary

Magnetic resonance imaging (MRI) and spectroscopy (MRS) will be addressed in detail, along with experimental design, data gathering and processing on MRS, structural and functional MRI in humans and rodents, and hands-on experience with MRI scanners.

Content

Monday
08:15 -10:00 - Introduction: MRI and MRS in neurological and psychiatric disorders; the importance of translational aspects; main requirements for planning a successful study (Speakers: Lijing Xin and Cristina Cudalbu)
10:15 - 11:00 - Ethics for human study (Invited external speaker: E. Fornari)
11:15 - 12:00 - Ethics for animal study (Invited speaker: Stefan Mitrea)
Lunch Break
13:15-14:00 - Basics of nuclear magnetic resonance I: Hardware components (Magnets, Gradient coils, Shim coils, Transmit/receive chain); Radio frequency (RF) coils (Resonance circuits, Losses and decoupling, Surface coils, Phased arrays, Volume coils); High field MRI (High-field effects, Specific absorption rate, Electromagnetic field simulations, Parallel transmission, Advanced approaches in RF coil design for high field) (Speaker: Daniel Wenz)
14:15-15:00 - Basics of nuclear magnetic resonance II:The origin of magnetic resonance, nuclear spin and magnetic moment, basic terminology, interesting nuclei/isotopes; Energy levels, macroscopic magnetization, classical description and resonance frequency; Laboratory frame and rotating frame, magnetic excitation, RF pulses, precession; Relaxation(s), Bloch equations, basic pulse sequences (FID, spin-echo) (Speaker: Bernard Lanz)
15:15-16:00 - Basics of MRI : gradients, K-space (Speaker: Cristina Cudalbu)
16:15-17:00 - Basic of MR sequences (Invited external speak: Ruud B. van Heeswijk)

Tuesday
RF coil design (1/2) : The aim of this part of the course is to provide a theoretical and practical introduction to RF coil design for animal and human scanners. Participants should get an overview and hands-on experience on how to build basic RF coils for human (and animal) applications. The best design will be selected and used in MR phantom experiments.
08:15-09:00 - Theory: introduction & demonstration (Scattering parameter matrix, Impedance matching, tuning, decoupling, Vector network analyzer: calibration and demonstration, Lumped elements: capacitors, trimmers, inductors). Bench tools: soldering iron, pick-up loop, etc.
09:15-12:00 - Hands-on: RF coil construction and characterization at the bench (Surface coil for human (and/or animal) application, Construction of a single loop coil, Frequency tuning and impedance matching, Loading effect on the RF coil's performance, Quality factor measurement). Optional: two surface coils in quadrature, Geometrical decoupling: overlapping
Teacher: Daniel Wenz
Afternoon: FREE

Wednesday
8.15-9.30 - Brain structure & function I : an introduction to the MRI tools used to study whole-brain connectivity and brain-behavior interactions (Speaker: Valerio Zerbi)
9.45-10.45 - MRI sequences and applications of functional imaging, task and resting-state, introduction to large multi-site initiatives (EPI, GE, SE, www.humanconnectome.org/ and www.neurosynth.org) (Speaker: Valerio Zerbi)
11:00-12:00 - MRI sequences and applications of diffusion-weighted imaging (Invited external speaker: Ileana Jelescu)
Lunch Break
13.15 - 17:00 RF coil design (2/2) The aim of this part of the course is to provide a theoretical and practical introduction to RF coil design for animal and human scanners. Participants should get an overview and hands-on experience on how to build basic RF coils for human (and animal) applications. The best design will be selected and used in MR phantom experiments.
13:15-14:00 - Theory: introduction & demonstration (Scattering parameter matrix, Impedance matching, tuning, decoupling, Vector network analyzer: calibration and demonstration, Lumped elements: capacitors, trimmers, inductors). Bench tools: soldering iron, pick-up loop, etc.
14:15-17:00 - Hands-on: RF coil construction and characterization at the bench (Surface coil for human (and/or animal) application, Construction of a single loop coil, Frequency tuning and impedance matching, Loading effect on the RF coil'##s performance, Quality factor measurement). Optional: two surface coils in quadrature, Geometrical decoupling: overlapping
Teacher: Daniel Wenz

Thursday
08:15-09:00- Introduction of MRS: J-coupling, chemical shift, basic localization methods (Speaker Lijing Xin)
09:15:10:00 - Outer volume suppression, water suppression, shimming, spectral quality - (Speaker: Cristina Cudalbu/Lijing Xin)
10:15-11:00 - Basics of Magnetic Resonance Spectroscopic Imaging, MRSI vs SVS (Speaker Cristina Cudalbu)
11:15-12:00 - Fast Magnetic Resonance Spectroscopic Imaging and reconstruction techniques (External invited speaker: Antoine Klauser)
Lunch Break
13:15 - 17:00: Demonstration and hands on: MRI/MRS (Group 1 & Group 2)
Group 1: 6 persons on 7T
Group 2: 6 persons on 14T

Group 1: 7T MRI & MRS - Phantom/fruit/human experiment (demonstration: 1h, hands on: 3h)
The participants will get hands-on experience on a human 7T MRI scanner and perform experiments with a phantom and a fruit (or a human if there is volunteer). This part includes: basic safety aspects, operation of an MRI system, preparation of an experimental setup (RF coil loaded with a phantom/human), demonstration and optimization of common MRI and MRS protocols to get different imaging contrast and spectra.
Teacher: Lijing Xin and Daniel Wenz
Group 2: 14T MRI & MRS - Phantom, ex-vivo, in vivo rat (demonstration: 1h, hands on: 3h)
The participants will get hands-on experience on the 14.1T preclinical MRI system. The basic parameters, tips and tricks to obtain high-quality scans and we will look together at the meaning of several scan parameters. We will also present the environment for in vivo scanning at 14.1T with the animal holding equipment, anesthesia units and physiology monitoring capabilities to perform metabolic experiments in best conditions. We will show how to prepare and place the rat in a stabilized position in the magnet holder, with physiology monitoring setups and how to position an RF coil for best signal induction and reception. We will show how to run localizer images, perform coil and B0 shim optimizations, run anatomical images with acquisition parameters. For 1H MRS, we will show how to position an acquisition voxel in the area of interest, optimize the shim and water suppression to get a reliable 1H spectrum, and how to evaluate its quality.
Teachers: Valerio Zerbi, Cristina Cudalbu and Bernard Lanz

Friday: Demonstration and hands on: MRI/MRS (Group 1 & Group 2)
Group 2: 6 persons on 7T
Group 1: 6 persons on 14T
Group 2: 7T MRI & MRS - Phantom/fruit/human experiment (demonstration: 1h, hands on: 3h)
The participants will get hands-on experience on a human 7T MRI scanner and perform experiments with a phantom and a fruit (or a human if there is volunteer). This part includes: basic safety aspects, operation of an MRI system, preparation of an experimental setup (RF coil loaded with a phantom/human), demonstration and optimization of common MRI and MRS protocols to get different imaging contrast and spectra.
Teacher: Lijing Xin and Daniel Wenz
Group 1: 14T MRI & MRS - Phantom, ex-vivo, in vivo rat (demonstration: 1h, hands on: 3h)
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Teachers: Valerio Zerbi, Cristina Cudalbu and Bernard Lanz
Week 2
Monday
8:15-9:00 - X nuclei MRS (13C, 31P, 15N, 2H). Physical specificities, applications as in vivo tracers of metabolic pathways, specific acquisition schemes (Speaker Lijing Xin)
9:15-10:00 - Quantification: 1H, 13C MRS, 31P MRS, 15N MRS and 2H MRS (Speaker Cristina Cudalbu)
10:15-12:00 - Interpretation of dynamic X-nuclei experiments with metabolic modelling: biochemical network, infusion protocol, accessible metabolic pools, mathematical aspects of quantitative metabolic modelling (Speaker: Bernard Lanz)
Lunch Break
13.15-15.15 - 1H MRS quantification (demonstration 1h, hands-on 1h) (Teachers: Lijing Xin and Cristina Cudalbu)
15.30-17 :00 - X-nuclei data modeling (demonstration 1h, hands-on 1h) (Teacher: Bernard Lanz)

Tuesday:
8:15 - 12:00 - Theory of clinical MRI segmentation and registration for MP2RAGE. Introduction to surface and voxel based morphometry (VBM and SBM) and fMRI processing. (Invited external speakers: M B Cuadra & E. Fornari)
Lunch Break
13:15 - 17:00 - Lab for structure MRI processing (VBM and SBM) and fMRI. (Invited external speakers: M B Cuadra & E. Fornari)

Friday:
8:15-9:00 - Brain structure & function II: an introduction to rodent MRI; history, potentials, caveats & hardware (Speaker Valerio Zerbi)
9:15-10:00 - Rodent multimodal fMRI. Tools for manipulating neural activity (electrical stimulation, chemogenetics, optogenetics) & fMRI applications (Speaker Valerio Zerbi)
10:15-12:00 - Translational fMRI. Assessing (dys)similarities across species using fMRI and brain connectivity (Speaker Valerio Zerbi)

NB: the course is for now opened to only 12 participants due to the limitations related to the Hands-On/practice sessions. If requested 6 additional participants can be added, however additional Hands-On sessions will be organized for these 6 participants in the week after the course. Or/and an additional session can be organised in the automn if the demand is strong.

Note

Invited lecturers:
M B Cuadra, E. Fornari, I Jelescu, R. B. van Heeswijk, Stefan Mitrea

Keywords

Magnetic Resonance Imaging (MRI); Magnetic Resonance Spectroscopy (MRS); functional MRI; diffusion MRI; Imaging; MR Hardware; Coil Design;

Learning Outcomes

By the end of the course, the student must be able to:

- Know the essential elements in designing a translational study
- Understand the physical principles of MRI and MRS
- Know how to establish MRI and MRS acquisition protocols, to perform experiments independently on clinical and preclinical scanners, and to analyze results for the research topic of interest.
- Explain the basics of organizing a successful MRS experiment, processing/quantification, modeling, and preclinical image processing (volumetry and DWI, ...)

- Perform an MRI, MRS, DWI, ... and a simple quantification and modeling on provided data
- Read representative MRS, fMRI and DWI papers
- Discover the power of interdisciplinary interaction by working on questions and hands-on exercises in groups

Resources

Bibliography

n Vivo NMR Spectroscopy: Principles and Techniques (Robin de Graaf); Principles of Magnetic Resonance Imaging: A Signal Processing Perspective (Zhi-Pei Liang & Paul C. Lauterbur)

Websites

- https://www.youtube.com/playlist?list=PL471uBfQUs9qcODBkQGJTZkcblIKrjKry

Moodle Link

- https://go.epfl.ch/PHYS-760