

Syllabus
Faculty of Biomedical Engineering
Advanced topics in Biomedical Engineering 2:
Deep learning applications in MRI
336016
Spring 2021
(2 credit points)

Description

Deep-learning is now the state-of-the-art machine learning model across a variety of areas. These developments have a huge potential for Magnetic Resonance Imaging (MRI) technology, slowly being realized. This course will provide an overview of recent advances in deep learning applied to Magnetic Resonance Imaging.

We will give a brief introduction to the theoretical and practical aspects of deep learning and discuss how deep learning has been applied to the entire MRI processing chain including acquisition, reconstruction, restoration, registration, segmentation, and diagnosis.

Instructor: Dr. Moti Freiman, Silver 239, moti.freiman@bm.technion.ac.il,

Reception hour: see below.

T.A.: Samah Khawaled, ssamahkh@campus.technion.ac.il

Reception hour: Wed. 15:30-16:30 (Pre-arrangement by email)

Course location:

Due to the coronavirus outbreak and per the updated guidelines, the course will be delivered online until further notice. We will use the Technion's zoom online meeting system for both lectures and reception hours. Please schedule reception hour meetings by email. To facilitate communication, email subject must be: deep-mri: <your subject> where <your subject> is the topic you would like to discuss with us.

The online meeting details are available at the course website.

Prerequisites

1. עבוד וניתוח תמונות 046200
2. מערכות לומדות או 336546 מערכות לומדות בתחום הבריאות 046195
3. עקרונות הדמיה או 336504 עקרונות תהודה מגנטית

Textbook

There is no textbook that we will follow. Recommended reading includes:

1. <http://www.deeplearningbook.org/>
2. <https://www.sciencedirect.com/book/9780128104088/deep-learning-for-medical-image-analysis>
3. <https://arxiv.org/abs/1811.10052>

List of papers covering course topics to read and discuss as part of the course duties will be provided and the beginning of the course.

Course Objectives

1. To introduce the main concepts of deep-learning algorithms
2. To introduce the main challenges in the domain of clinical Magnetic Resonance Imaging (MRI)
3. To understand how to solve clinical MRI challenges with deep-learning algorithms including:
 - a. Segmentation
 - b. Registration
 - c. Reconstruction/Restoration
 - d. Disease prediction
 - e. Quantitative MRI analysis (specifically, Diffusion-Weighted MRI)
4. To be familiar with up-to-date literature in deep-learning for MRI
5. To gain hands-on experience in developing deep-learning algorithms for MRI using the python programming language and PyTorch or tensor-flow2.0 as the deep-learning software libraries.

Learning outcomes:

At the end of the course, students will know:

1. How to formulate a challenge in MRI processing pipeline by a neural network.
2. How to implement a deep-neural-network to solve a given challenge such as:
 - a. Segmentation
 - b. Registration
 - c. Reconstruction/Restoration
 - d. Disease prediction
 - e. Quantitative MRI analysis (specifically, Diffusion-Weighted MRI)
3. How to train and evaluate a deep-neural network.

Course Topics

The course will cover the following topics:

A theoretical and practical introduction to the fields of deep-learning, clinical MRI, and the applications of deep-learning for MRI. Specifically, we will discuss the perceptron, logistic regression, back-propagation, activation functions, hyper-parameters, convolutional neural networks, auto-encoders, regularization, residual-networks, generative adversarial networks, weakly and unsupervised deep-learning. In addition, we will discuss MRI-related applications, such as segmentation, image restoration, image reconstruction, sparse sampling, image synthesis, quantitative MRI, MRI super-resolution, MR fingerprinting, image registration.

Assignments & Readings

1. Each student is expected to get prepared for the class by reading at least one paper from the list related to the class topic.
2. Each pair of students is expected to present a selected topic during the class based on several papers provided for the selected topic.
3. Each pair is expected to implement a deep-learning algorithm for a specific MRI problem.
4. At least 90% attendance on course lectures unless justified reason with lecturer permission.

Course grade: 50% presentation + 50% project.

Online resources

1. Course website on the Technion's moodle:
<https://moodle.technion.ac.il/course/view.php?id=7085>
all lecture notes/supplementary material/slides are available there.

MRI fundamentals:

1. <https://www.coursera.org/learn/mri-fundamentals#syllabus>
2. <https://www.edx.org/course/fundamentals-of-biomedical-imaging-magnetic-resona>
3. <https://ucrfisicamedica.files.wordpress.com/2010/10/mri.pdf> (MRI book available online)
4. http://eprints.drcmr.dk/37/1/MRI_English_a4.pdf
5. https://www.weizmann.ac.il/chemphys/assaf_tal/lecture-notes (very detailed and comprehensive, only for those who are interested in a depth understanding of MRI)

Intro to deep-learning (theory):

1. <http://introtodeeplearning.com/> (lectures 1, 3)
2. <http://cs231n.stanford.edu/>
3. <https://www.coursera.org/specializations/deep-learning?>
4. <https://www.deeplearningbook.org/>

Intro to deep-learning (programming)

1. PyTorch: <https://pytorch.org/tutorials/>
2. Tensorflow: <https://www.tensorflow.org/tutorials>
1. General machine-learning website: <https://machinelearningmastery.com/>
More specifically within it:
 - a. <https://machinelearningmastery.com/understand-machine-learning-algorithms-by-implementing-them-from-scratch/>
 - b. <https://machinelearningmastery.com/implement-perceptron-algorithm-scratch-python/>
 - c. <https://machinelearningmastery.com/implement-backpropagation-algorithm-scratch-python/>