Syllabus

Faculty of Biomedical Engineering

Deep learning applications in MRI

336028

Spring 2022

(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@technion.ac.il,

Reception hour: Mon. 16:30-17:30 (Pre-arrangement by email).

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

Reception hour: Tue. 12:30-13:30 (Pre-arrangement by email)

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 lecture recordings will be available on the course website.

Course locations and times:

Lecture: Silver 202, Wed. 10:30-12:30

Prerequisites

1. 046200 עבוד וניתוח תמונות
2. 046195 מערכות לומדות או 336546 מערכות לומדות בתחום הבריאות
3. 336502 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.

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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. Albert Einstein college of medicine course in MRI:
   https://www.youtube.com/watch?v=35gfOtjRcic
2. Stanford radiology course of MRI: https://www.youtube.com/channel/UCJgAoFeFMKQ-f1XVPrFBslQ/videos
3. https://www.coursera.org/learn/mri-fundamentals#syllabus
4. https://www.edx.org/course/fundamentals-of-biomedical-imaging-magnetic-resona
5. https://ucrfisicamedica.files.wordpress.com/2010/10/mri.pdf (MRI book available online)
6. http://eprints.drcmr.dk/37/1/MRI_English_a4.pdf
7. https://www.weizmann.ac.il/chemphys/assaf_tal/lecture-notes (very detailed and comprehensive, only for thus who 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/

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