ISBI 2020 Tutorial proposal on
Computational MRI: Beyond Compressed Sensing
Organizers: Sajan Lingala, and Mathews Jacob

OVERVIEW:
The goal of this tutorial is to provide a survey on emerging computational magnetic resonance imaging (MRI) topics beyond compressed sensing. This will involve six speakers with 30 minute lectures (including Q/A). Specific details of the topics covered are listed below:

30 mins: Physics based models for MR image reconstruction (*Mariya Doneva*)
30 mins: Optimization methods for MR image reconstruction (*Jeffrey Fessler*)
30 mins: Accelerating dynamic MRI using learned representations (*Sajan Lingala*)
30 mins: Multi-contrast and quantitative MRI methods (*Jonathan Tamir*)
30 mins: Structured low rank algorithms for computational MRI (*Mathews Jacob*)
30 mins: Deep learning reconstruction for parallel MRI (*Mehmet Akcakaya*)

SPECIFICS OF EACH TALK:
Talk 1: Physics based models for MR image reconstruction
Speaker: *Mariya Doneva*

- Short description and relevance to ISBI audience:
  - The signal measurement model is the link between data acquisition and image reconstruction. Simple models are tempting, and in MRI the Fourier model has been predominantly used because of its simplicity and efficiency. However, this simple model ignores many factors and is often insufficient. This lecture will give an overview of modern techniques for model-based reconstruction that apply an extended signal model to better describe the data acquisition process.

- Description of the expected audience participation:
  - No hands-on computer-exercises will be involved. If there is an audience response system, we would add few questions to better engage the audience

- Description of the course-packs (including slides and other tutorial material) that will be provided to the audience in hardcopy and/or electronic format. All such material must be free from copyright issues.
  - Slides

- Description of the expected audience, especially prerequisite knowledge and skills
  - The talk would be suitable to the broad ISBI audience with technical background in signal processing.

- Contact information
  Mariya Doneva,
  Affiliation: Philips Research Hamburg
  Email: mariya.doneva@philips.com
  Mailing address: Roentgenstrasse 24-26, 22335 Hamburg, Germany

- Two-page Bio-sketch
  Please see appendix

Talk 2: Optimization methods for MR image reconstruction
Speaker: *Jeffrey Fessler*

- Short description and relevance to ISBI audience:
  This tutorial will summarize several key models and optimization algorithms for MR image reconstruction, including both the type of methods that have been recently FDA approved for clinical use, as well as more recent methods being considered in the research community that use data-adaptive regularizers. Many algorithms have been devised that exploit the structure of the system model and regularizers used in MRI; this talk will collect such algorithms in a single survey. Many of the ideas used in optimization methods for MRI are also useful for solving other inverse problems.

- Description of the expected audience participation:
  - Will be in lines with my ISBI 2019 tutorial. Python and julia codes exemplified by jupyter notebooks will allow the participants/attendees to test the codes and practice by themselves.

- Description of the course-packs (including slides and other tutorial material) that will be provided to the audience in hardcopy and/or electronic format. All such material must be free from copyright issues.
  - Slides

- Description of the expected audience, especially prerequisite knowledge and skills
  - Basic understanding of signal processing, linear algebra, MR physics.

- Contact information
  Jeffrey A. Fessler
  William L. Root Collegiate Professor
  Electrical Engineering and Computer Science
  The University of Michigan, Ann Arbor, Michigan
  Mailing Address: 4431 EECS Bldg., 1301 Beal Ave.
  Ann Arbor, MI 48109-2122
  Email: fessler@umich.edu

- Two-page Bio-sketch
  Please see appendix

Talk 3: Accelerating dynamic MRI using learned representations

Speaker: *Sajan Lingala*

- Short description and relevance to ISBI audience:
  - In this tutorial, we will offer a unified view of several different approaches to dynamic MRI using learned representations, focusing on the signal processing aspects which make each class of learning methods so powerful. These methods include low-rank methods, blind compressed sensing methods, higher-order multidynamic methods, explicit motion estimation compensated recovery methods, and manifold regularized recovery methods. Over the past five years or so, these schemes have revolutionized dynamic MRI for many applications, offering exciting new capabilities in biomedical imaging. We expect this tutorial to benefit the ISBI audience who are interested in learning on recent trends in dynamic MRI.

- Description of the expected audience participation:
  - Interactive question and answers. No hands-on computer-programming will be involved.

- Description of the course-packs (including slides and other tutorial material) that will be provided to the audience in hardcopy and/or electronic format. All such material must be free from copyright issues.
  - Slides in electronic format

- Description of the expected audience, especially prerequisite knowledge and skills
  - A basic understanding of MRI physics, and MRI reconstruction is desired. These will will already be covered by our previous speakers.

- Contact information

Sajan Lingala
Assistant Professor
Roy J Carver Department of Biomedical Engineering
University of Iowa
Mailing Address: 5609 Seamans Center for the engineering arts and sciences
Iowa city, IA, USA 52242
Email: sajangoud-lingala@uiowa.edu

- Two-page Bio-sketch

  Please see appendix

Talk 4: Multi-contrast and Quantitative MRI methods
Speaker: *Jonathan Tamir*

- Short description and relevance to ISBI audience:
  - This tutorial will introduce physics-based modeling constraints in MRI and shows how they can be used in conjunction with compressed sensing for image reconstruction and quantitative imaging. We describe model-based quantitative MRI, as well as its linear subspace approximation. We also discuss approaches to selecting user-controllable scan parameters given knowledge of the physical model. We will present MRI applications that take advantage of this framework for the purpose of multi-contrast imaging and quantitative mapping. We expect this tutorial to benefit the ISBI audience who are interested in learning on recent trends in multi-contrast and quantitative MRI.

- Description of the expected audience participation:
  - Interactive question and answers. No hands-on computer-programming will be involved.

- Description of the course-packs (including slides and other tutorial material) that will be provided to the audience in hardcopy and/or electronic format. All such material must be free from copyright issues.
  - Slides and links to open-source demonstration code will be provided.

- Description of the expected audience, especially prerequisite knowledge and skills
  - This talk will be suitable to a broad audience with knowledge in signal processing and optimization. A basic understanding of MRI physics and MRI reconstruction is desired. These will already be covered by the previous speakers.

- Contact information
  Jonathan Tamir
  Assistant Professor
  Electrical and Computer Engineering
  The University of Texas at Austin (UT Austin)
  Mailing Address: EER 7.872, 2501 Speedway, Austin, TX 78712
  Email: jtamir@utexas.edu

- Two-page Bio-sketch
  Please see appendix

Talk 5: Structured low-rank algorithms for computational MRI
Speaker: *Mathews Jacob*

- Short description and relevance to ISBI audience:
  - We will provide a review of recent advances in the recovery of continuous domain multidimensional signals from their few non-uniform (multichannel) measurements using structured low-rank matrix completion formulation. This framework is centered on the fundamental duality between the compactness (e.g., sparsity) of the continuous signal and the rank of a structured matrix, whose entries are functions of the signal. This property enables the reformulation of MRI signal recovery as a low-rank matrix completion of the structured matrix, which comes with performance guarantees. We will also review fast algorithms that are comparable in complexity to current compressed sensing methods, which enables the application of the framework to large-scale magnetic resonance (MR) recovery problems. The remarkable flexibility of the formulation enables us to exploit signal properties that are difficult to capture by current sparse and low-rank optimization strategies. We will discuss the framework's utility in a wide range of MR imaging (MRI) applications, including highly accelerated imaging, calibration-free acquisition, MR artifact correction, and ungated dynamic MRI.

- Description of the expected audience participation:
  - Mostly in the form of question and answers. No hands-on computer-work will be involved.

- Description of the course-packs (including slides and other tutorial material) that will be provided to the audience in hardcopy and/or electronic format. All such material must be free from copyright issues.
  - Slides in electronic format. We will leverage slides from similar tutorials presented at ISBI 2017, ISBI 2018, ISMRM 2017, ICASSP 2018.
  - Eg. see https://research.engineering.uiowa.edu/cbig/content/presentations

- Description of the expected audience, especially prerequisite knowledge and skills
  - Prior understanding of compressed sensing, MR image formation would help. However, the talk will be made self descriptive.

- Contact information
  Mathews Jacob
  Professor
  Department of Electrical and Computer Engieering
  University of Iowa
  Mailing Address: 3314 Seamans Center for the engineering arts and sciences
  Iowa city, IA, USA 52242
  Email: Mathews-jacob@uiowa.edu

- Two-page Bio-sketch
  Please see appendix

Talk 6: Deep learning reconstruction for parallel MRI
Speaker: *Mehmet Akcakaya*

- Short description and relevance to ISBI audience:
  - Parallel imaging is the most commonly used strategy for accelerating MRI acquisitions. These techniques utilize the redundancies in the data acquired by multiple receivers in coil arrays. In this talk, we will overview the recent machine learning approaches that have been proposed specifically for improving parallel imaging. This talk will provide an extensive overview of deep learning methods for parallel MRI. We expect that this survey will be of significant interest to researchers in related fields, and those interested in learning more about improved parallel imaging techniques, building on the clinical standard for accelerated MRI.

- Description of the expected audience participation:
  - Mostly in the form of question and answers. No hands-on computer-work will be involved.

- Description of the course-packs (including slides and other tutorial material) that will be provided to the audience in hardcopy and/or electronic format. All such material must be free from copyright issues.
  - Slides in electronic format

- Description of the expected audience, especially prerequisite knowledge and skills
  - A basic understanding of linear algebra and statistics is a prerequisite. An understanding of how MRI data is acquired would be helpful for further appreciating the subtleties, but this will also be briefly covered in the talk.

- Contact information
  Mehmet Akcakaya,
  Affiliation: McKnight-Land Grant Assistant Professor,
  Department of Electrical and Computer Engineering, and Center for Magnetic Resonance Research
  University of Minnesota
  Mailing Address: 200 Union Street SE Keller Hall Rm. 5-159
  Minneapolis, MN, USA 55455
  Email: akcakaya@umn.edu

- Two-page Bio-sketch
  Please see appendix