EE369C: Class Projects

You can choose any project that is related to the subject of the class. This can be something related to your Ph.D. work, some problem you found interesting, or one of the problems listed below. The scope of the problem should be something beyond what you have done in the homework. However, it should also be restricted in scope, to fit the limited time available. One good choice is the implementation of one of the algorithms that we have discussed, that haven’t appeared in the homework.

The projects will be assessed based on the difficulty and importance of the problem, and on how well you do with it. You can do well either by doing a thorough job on a well understood problem, or by making progress on a more difficult or new problem. Additional credit will be given for reports that are in the form of a homework assignment for the course.

There are web resources for several of the projects suggested below. Jeff Fessler from the University of Michigan has his “Image Reconstruction Toolbox” web site

http://web.eecs.umich.edu/~fessler/code/

that includes his widely used nuFFT package, along with links to other image reconstruction software packages. Miki Lustig provides an excellent package that implements all of the SPIRiT variations, and compressed sensing more generally.

http://www.eecs.berkeley.edu/~mlustig/Software.html

You are welcome to use these packages, but please state this in your report. You will then need to do something beyond what is in the demos. You can also implement the algorithms yourself, in which case duplicating the results in the demo is sufficient.

In the next week, submit a short description of the problem, what approaches you will look at, and what resources you need (references, data, etc). The entire description should only be a paragraph or so. The projects are due Dec 15th, which is the last day of finals week. Present your project by writing a 10 page report of your project. This is similar in length and scope to the assignment write-ups you have been doing.

Possible Project Topics

1. Least Squares Reconstruction

   In class we talked about how the gridding reconstruction is essentially a weighted least squares solution to the reconstruction problem. Show that directly solving the least squares problem is also tractable using iterative solvers. This is one component of the non-Cartesian SENSE reconstruction in part 3. You will need an inverse gridding algorithm with is available in the m-files directory as igridkb.m and kb_deap.m. The Jeff Fessler toolbox also contains an implementation, if you would prefer to do this.

2. Off-Resonance Correction: Autofocus Metrics

   In the homework assignment we minimized the magnitude of the imaginary component of the image as a focus metric. This was based on the Noll et al. paper,

where they used a fractional power of the magnitude of the imaginary component

\[ f(x, y) = \sum_A |m(x, y)|^\alpha \]

where \( \alpha < 1 \), and \( A \) is a local neighborhood of \( x, y \).

Many different metrics have been proposed for quantifying motion blurring. A survey of several of these was given in


Study whether one or more of these can be extended to the off-resonance correction problem. The main issue is that motion correction is usually based on magnitude image, where we have access to the complex image (although we could just use on the magnitude).

For this project you can use the data from Assignment 3, and also the high-resolution spiral coronary data set 3T_Coronary.mat available in the data directory of the web site. A description of the data set is in 3T_Coronary.txt.

3. Non-Cartesian Parallel Imaging

There are a number of ways to do parallel imaging with non-Cartesian data sets. The first method is described in the paper by Klaas Prüssmann,


This was the first well known paper to use a conjugate gradient algorithm for parallel MR image reconstruction, and has a nice, simple description of how to implement it. This is a good place to start.

Another method is SPIRiT, as described in the Lustig paper you have already studied. This is a little more difficult to implement because it solves for all of the individual coil images, and that makes some of the operators more complex. However, being autocalibrating, it is preferred.

A variable-density spiral four coil data set is available on the web site, spiral_sense.mat. A description of the data is in spiral_sense.txt. This is a simulation, so we have the actual sensitivities if you would like to use them. Implement either of these approaches. For both of them you will need the adjoint of the gridding operator which is available in the mfiles directory as ikbgrid.m and kb_deap.m.

The data set has 21 spiral interleaves, and four coils. Try reconstructions with acceleration factors of 2, 3, and 4 by subsampling in the interleaf dimension.

4. Eigenvector Approaches to Parallel MRI

The SPIRiT algorithm is the first of a broader class of parallel imaging algorithms known as null space or eigenvector approaches. The basic idea of SPIRiT is that if \( x \) is the true k-space data, then operating on it with the SPIRiT kernel should do nothing

\[ Gx = x. \]

If we collect terms on the left

\[ (G - I)x = 0 \]
Hence the solution $x$ is in the null space of $(G - I)$. The operator $(G - I)$ is determined by calibration. The vector $x$ consists of known and unknown elements. The reconstruction problem then is reduced to finding the unknown elements of $x$ such that $x$ is in the null space of $(G - I)$. This is described in the paper


This perspective allows the sensitivity maps to be derived from the calibration data, and provides the direction connection between SENSE and GRAPPA. ESPIRiT is an autocalibrating algorithm that uses an image domain SENSE reconstruction. There are many possible projects starting from the paper, and the source code available on Miki’s web site. You can implement the algorithms yourself, study their performance, or develop your own extensions.