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Homework #8

due Tuesday, December 1st, 2009

Reading:

- Blaimer et al., "SMASH, SENSE, PILS, GRAPPA: How to Choose the Optimal Method", *Topics in Magnetic Resonance Imaging*, 15(4):223-236, August 2004.

Assignment:

This is the first of four programming assignments. We will be grading your answers and your code. 25% of the points will awarded based on good programming style: using matix/vector operations, adequate comments, and meaningful variable names. You should submit at TAR or ZIP file containing your code (without the datafiles), and a master script that steps through each of the problems, similar to `mrdemo`.

1. **Simple 2DFT SENSE reconstruction**. The following data is for a simulated resolution phantom, where the sensitivies are known exactly. This represents a 24 cm FOV acquisition, with coils directly above and below the object (along the y-axis).

   http://ee369c.stanford.edu/mr_data/sense_2dft.mat

   (a) **g-Factor.** The g-factor tells you how well conditioned the SENSE reconstruction problem will be. The two sensitivity maps are stored in `s1` and `s2`. Assume that the noise covariance matrix is $\sigma^2 I$, meaning that the noise is uncorrelated between coils, and is of equal intensity.

      ii. Make an image of the g-factor if the the phase encode is along the y axis. Show the image with the range of g-factors limited to 1 (the minimum possible) to 4. Plot a cross section along the y axis. Where is the largest g-factor? What is it?

      iii. Repeat the calculation for phase encoding along the x axis. Show the image, and plot a cross section along the x axis. Again, limit the g-factor image to a range of 1 to 4. Notice that the g-factor is large in specific places. What is it about the coil sensitivities there that cause this to happen?

   (b) **SENSE Reconstruction.** Two acceleration factor 2 aliased images are in the matlab variables `im1a` and `im2a`. Write an mfile that performs the SENSE decomposition. Show the resulting image. *Note: write your own code from scratch*.

   (c) **Averaging**. One of the tradeoffs with SENSE is that it reduces SNR in exchange for speed. Occasionally, the SNR will be too low, and the operator will decide to average multiple SENSE acquisitions to get the SNR back. Assume that the acquisition has been accelerated by a factor R, and then averaged R times. In this amount of time, we could have simply acquired a fully encoded data set. Find an expression for the ratio of the SNR's of the two alternatives. When would acceleration and averaging be a reasonable thing to do?

   (this is based on a problem provided by John Pauly, Stanford University)

2. **Parallel Imaging of the Brain using an 8-channel Coil.** The following data (also simulated) represents an axial slice of the brain imaged using 8 coils, with known sensitivities.

   http://mrel.usc.edu/class/591/data/head_8ch.mat

   (a) **SENSE reconstruction**. Coil sensitivity maps are provided in `coil_sens`, and fully sampled data is provided in `raw_data`. Subsample the raw data, and perform SENSE reconstructions with R=2 and 4. Reconstruct images and g-factor maps. Discuss image features and artifacts. Compare the images with each other and the fully-sampled sum-of-squares reference image. Comment on differences in SNR. If necessary, you may add realistic noise to the raw data.

   (b) **Coil sensitivities.** Estimate the coil sensitivities using a fully-sampled central portion of k-space. Compare these estimates with the ground truth that is provided in `coil_sens`. How much of k-space should be sampled in order to produce reasonable SENSE reconstructions?

   (c) **GRAPPA**. Write an mfile that performs GRAPPA reconstruction. Consider the case where the periphery of k-space is undersampled by a factor of 2, and the central fully-sampled region contains N phase encode lines (also known as ACS lines). Perform GRAPPA reconstructions and vary the number of ACS lines. Comment on what happen when N is too small.

   (this problem is based on data provided by Fa Hsuan Lin, National Taiwan University)

3. You may earn **extra credit** by going beyond the call of duty on any of these problems. Feel free to suggest ideas to me, and I will approve them over e-mail. For example, you could: 1) implement 2D SENSE and/or 2D GRAPPA, where k-space is undersampled along two axes, and apply this to 3DFT data, or 2) Compare SENSE and GRAPPA when the imaging FOV is smaller than the coil sensitivity (i.e. coil sensitivity maps are aliased).