BENG280A, Principles of Biomedical Imaging 10/24/12
Fall Quarter 2012

HOMEWORK #4
Due at 5 pm on Wednesday 10/31/12

Homework policy: Homeworks can be turned in during class or to the TA's mailbox in the Graduate Student Lounge. Late homeworks will be marked down by 20% per day. If you know that you need to turn in a homework late because of an emergency or academic travel, please let the TA know ahead of time. Collaboration is encouraged on homework assignments, however, the homework that you submit should reflect your own understanding of the material.

Readings: Section 7.1 to 7.4.

Problem 1

Consider the object $m(x,y) = rect(x+1, y+1) - rect(x-1, y-1)$ that you already examined in Homeworks 2 and 3. To answer the questions below, you will find it useful to sketch the object and its Fourier transform (using what you found from prior homeworks).

(a) Determine the values of Δk_x and Δk_y needed to avoid aliasing.

(b) Assume that the desired resolution in both the x and y directions is $\frac{1}{4}$ cm. Determine $k_{x,\max}$ and $k_{y,\max}$ and also the number of voxels in the x and y directions. Assuming a spin-warp acquisition with one phase-encode line per repetition, what is the total scan-time for TR = 100 ms?

(c) Assume that the readout time (i.e. time to cover one line in k-space) is much smaller than TR = 100ms. Develop and describe a simple solution that takes advantage of the geometry of the object to reduce total scan time by roughly a factor of 2, while keeping the TR at 100 ms.

Problem 2

Consider the 2D object: $f(x,y) = \cos(2\pi x - 2\pi\sqrt{3}y)rect(x/4)rect(\sqrt{3}y/4)$ that you examined in Homework 3. . To answer the questions below, you will find it useful to sketch the object and its Fourier transform (using what you found from Homework 3).

a) Determine the values of Δk_x and Δk_y needed to avoid aliasing.

b) Assume that the desired resolution in the x and y directions is given by ½ cm and $\frac{1}{2\sqrt{3}}$ cm. Determine $k_{x,\max}$ and $k_{y,\max}$ and also the number of voxels in the x and y directions.

c) Draw and label gradient waveforms that will provide sufficient coverage of k-space, according to the specifications in parts a and b. Assume a spin-warp trajectory, a maximum available gradient of 4 G/cm, and a sampling rate of 10 micro-seconds. Where possible, minimize the duration of the gradients. Note: due to an error in the original assignment, you may use a gradient > 4 G/cm for the readout gradient. Use the 4 G/cm limit for the initial dephasers.

Problem 3.
Do problem 4.3 from Nishimura (in other words, show that Eqn 4.15 is a solution to Eqn 4.14) ; In addition, use MATLAB to plot out the solution for initial conditions of (a) $M_z(0) = 0$; (b) $M_z(0) = -M_0/2$; and (c) $M_z(0) = -M_0$. Assume a T_1 of 1 second. For each of the initial conditions, determine the time at which the magnetization recovers to $0.95M_0$. Is this time the same for all initial conditions? – explain your finding.

Problem 4. Problem 7.3 in Nishimura.

MATLAB exercise. In this exercise you will experiment with how different imaging parameters alter the contrast of an image. First download the file BE280A08_hw6.mat from the course website. In this file you will find three matrices labeled csf, gm, and wm, which are the partial volume maps for cerebral spin fluid, gray matter, and white matter, respectively. Assume the values shown in the table below. Assume that your MRI system can have a minimum echo time (TE) of 3 ms and a maximum TR of 15,000ms. Finally, assume that you are using a saturation-recovery sequence. Come up with sequence parameters that yield proton-density, T1-weighted, and T2-weighted images and use the partial volume maps to generate corresponding images. For the T1-weighted image, choose parameters that maximize the contrast between gray and white matter -- you may want to use MATLAB to search over possible TR values.

Tissue	Proton Density	T1 (ms)	T2 (ms)
Csf	1.0	4000	2000
Gray	0.85	1350	110
White	0.7	850	80