

## EE369C: Assignment 3

Due Oct 25

For this assignment you will refine your gridding reconstruction routine that you started developing in the last class. You may base your answers on the matlab routine you developed for the previous homework, or use `grid2w.m` which is available from the directory

<http://www.stanford.edu/class/ee369c/mfiles>.

This does a pre-density compensated 2X gridding reconstruction using a triangular kernel. This only performs the gridding operation, and does not do the `fft2c`, or the deapodization. You will have to add these elements.

**1. Improved Kernel** Many kernels work well on a 2X grid. One of the most widely used kernels is the Kaiser-Bessel window. Its shape is dependent on a single parameter  $\beta$ , which makes it easy to describe. Also, there is an analytic expression for the inverse transform that is required for the deapodization function. Modify your gridding routine to use the Kaiser-Bessel kernel, given a value of  $\beta$ , and a kernel width. Use the expressions from the Beatty paper.

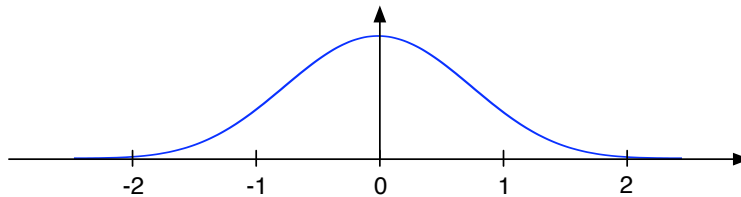
Reconstruct the data set `rt_spiral_03.mat` from last time. Fully correct for apodization, based on the analytic expression in the paper. Assume a width of 5 grid samples on the 2X grid, and choose the optimal value of  $\beta$  from Eq. 5 of the paper (which is listed in Table III). As a reality check, the kernel should look like Fig. 1. The function  $I_0(x)$  used in computing the kernel is the zero order modified Bessel function of the first kind, and is implemented in matlab as `besseli(0,x)`.

You will want to pre-compute the kernel. Assume that we will allow the maximum error due to kernel sampling to be  $10^{-3}$ , choose either nearest neighbor or linear interpolation for the kernel, and choose an appropriate kernel sampling density.

Display images of the full 2X FOV, and the central 1X FOV that would normally be displayed. Also, plot a cross section through the middle of the phantom to demonstrate that the deapodization is correct.

**2. Non-Integer Oversampling** Modify your gridding routine to reconstruct at non-integer oversampling factors. Use an oversampling ratio of 1.25, and choose a kernel size to achieve a reconstruction error of  $10^{-3}$ . Find the optimum  $\beta$  for the Kaiser-Bessel kernel. Use an interpolation method for the kernel to give you a  $10^{-3}$  maximum error.

Reconstruct the data set `rt_spiral_03.mat`. Fully compensate for apodization using the analytic expression. Show images of the 1.25X FOV, the central FOV that would normally be displayed, and plot a cross section to show that the deapodization is working correctly.



**Figure 1:** Optimum Kaiser-Bessel Kernel for a 2X grid, with a kernel width of 5 samples on the 2X grid.

**3. Density Calculation** For this problem, we will use a variable density spiral data set of a simulated phantom. This has twice the sampling density near the origin. The data is in `var_dens.mat`, also in the `mr_data` subdirectory. This contains the k-space trajectory `k`, and the complex data `d`. The acquisition has 2048 points per spiral interleave, and 6 interleaves. The image matrix size is 128 by 128. Use a 2X grid for the reconstruction, and the kernel from question 1. Fully correct for the apodization.

1. Implement post-density compensation by gridding unity to estimate and correct the density on the grid points. Display the resulting post-density compensated image.
2. Use the `voronoidens.m` routine from the `mfiles` subdirectory to estimate the density on the data points using the Voronoi diagram. This routine returns the area associated with each sample, which is the weighting function (*i.e.*  $1/\text{density}$ ). You also need to devise a method for assigning reasonable values to the k-space samples at the edge of the sampled region, since the `voronoidens.m` routine returns areas of NaN for these samples.  
Display the resulting pre-density compensated image.
3. Plot a cross-section through the middle of each image to compare the two methods. Which produces a more accurate reconstruction? Note that the background inside the circular ring of the phantom has a DC level of 20% of the peak, and is not zero (*i.e.*, this is not an artifact!).

*Note:* There are a few streaks in the reconstruction of this data set that may not go away. These are subtle, but still noticeable.