Assignment III

Biomedical Imaging & Analysis (ECE J1-791) - Fall 2014

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Instructions

Please show your solutions to each problem in full, writing explanations neatly along with mathematical justifications, as needed. For computer programs, please remember to turn in your code through the course's blackboard session, as well as any plots / figures that are requested. This assignment is due on **Tuesday, 7 Oct 2014** via Blackboard, including an a Report with explanations associated with each question in the assignment, as well as any associated code and result files. If you have collaborated with another student on solving this homework assignment please state so (e.g. "I helped John with question 1" etc.).

LEARNING GOALS:

- Working with 3D k-space data and visualizing the same.
- Reconstructing k-space: Fourier Transform.
- Input & Output of essential file-types
- Visualization of data using Visualization Tool Kit (VTK).

1. **(50 points)** Koay et al 2007 presented a method of generating a 2D and a 3D analytical MRI phantom in the Fourier domain [1,2] which was modeled based on the Shepp-Logan 1974 head phantom. This phantom consists of several ellipsoids of different sizes, orientations, locations, and signal intensities (i.e. gray levels). The uniqueness of this phantom is that it's k-space signal can be analytically expressed. Attached with this assignment is the 2D and 3D complex k-space of the 2D and 3D Koay phantom respectively, as .MAT files.
   a. Write separate Matlab scripts to read each of these Phantoms into the Matlab workspace and compute the image-space version of the k-space data (after appropriate Fourier-transform reconstruction

[1] Koay, C. G., Sarlls, J. E., & Özarslan, E. (2007). Three-dimensional analytical magnetic resonance imaging phantom in the Fourier domain. *Magnetic Resonance in Medicine*, *58*(2), 430-436.

[2] Shepp LA, Logan BF. The Fourier reconstruction of a head section.IEEE Trans Nucl Sci 1974;NS-21:21–43.

activities, based on the class lectures) . Visualize the 2D image space result, I2, using the "imshow" and "imagesc" functions in Matlab. Similarly, for the 3D image space result, I3, visualize it in a z-slice having the index given by `round(numel(I3(1,1,:))/2.3)`, in Matlab. In your reports, please insert screenshots of your results along with the steps taken to reconstruct the image data in each case, with the code.

Recall that we learned how to plot a matrix of complex numbers as an image by take the absolute value of the numbers. Plot the "real" and "imaginary" components of your reconstructed image results for the 2D and 3D (z-slice at `round(numel(I3(1,1,:))/2.3)`)cases and compare the results against the absolute value image … Insert plots and describe your observations.

b. Next, visualize the 3D image space version of the Phantom data in **ITK-SNAP** (based on the Insight Tool-Kit (ITK), www.itksnap.org/docs/viewtutorial.php?) or **Paraview** (based on the Visualiation Tool-Kit (VTK), www.kitware.com) – both the open source image visualization GUIs which you used in your previous assignments. In order to do this you will require to "write out" the VTK Volume file of your 3D phantom result. Please insert snapshots of any one slice through the image volume from each, ITK-SNAP and Paraview (using the "slice" filter), in your reports.
HINT: Consider spacing to be [1,1,1] while writing the file if you use "all" of the k-space data for reconstruction.

❖ ***Code is provided on Blackboard to help you get started:***
- Starter code to write VTK Volume Image is available from Assignmt 2: *write_vtk_Volume*

2. **(40 points)** Repeat the steps in Question 1 part (a) and (b) for the 3D k-space reconstructions this time using the following "sub-sets" of k-space and visualize your results in Paraview for each case, paying attention to the change in "Spacing" between voxels expected in each case (if any) before you write out your VTK volumes for visualization :

i) `squeeze (kspaceSignal(50:1:100,:,:) )`
ii) `squeeze (kspaceSignal(1:1:end/2,:,:) )`
iii) `squeeze (kspaceSignal(1:2:end/2,:,:) )`
iv) `squeeze (kspaceSignal(:,:,53)) )`

Note : "squeeze" is a function in Matlab (search in Matlab help for it does!) and kspaceSignal is the 3D k-space of the Phantom.

Please insert snapshots in your report of an "isocontour" of the 3D image volume resulting from each of the above cases viz. i, ii, iii, and iv.

Why are the four results different..? Explain your observations for each case based on your understanding of k-space after first visually comparing each result with slices through the image volume reconstructed and visualized in (b), in Paraview. Insert screenshots to support your observations.

3. **(60 points)** Please go over the reading assignment PDF uploaded to Blackboard:

   Moratal, David, et al. "k-Space tutorial: an MRI educational tool for a better understanding of k-space." *Biomedical imaging and intervention journal* 4.1 (2008).

   Now attempt to write a Matlab code to replicate the example of “low-pass” and “high-pass” filtering using the given 3D k-space Phantom, this time cropping a “sphere” from k-space instead of a 2D circle to demonstrate the filtering process.

   Please submit your code as well as a set of snapshots of your results as visualized in Paraview in slice-planes of your choice. Explain your observations based on your understanding of k-space.

   HINT: This reading assignment may help you with Q2 above, as well!