生醫影像導論

Introduction to Biomedical Imaging

(11020EE 441000)

Homework #2: MRI and k-space

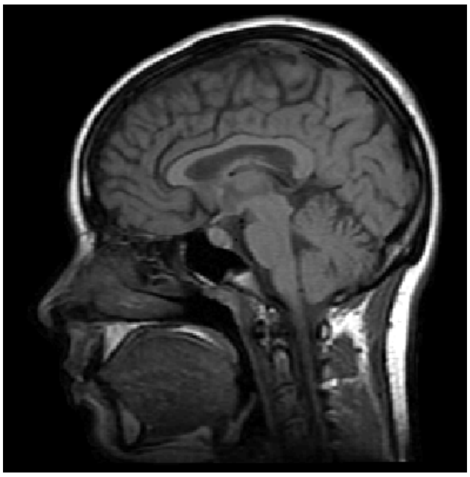
Due: 24:00, 05/19/2022

1. Given 2 MRI raw data files from spin-echo pulse sequence, 256x256 data points for each, corresponding to the real (hw2_r.dat) and imaginary (hw2_i.dat) components in k-space. The data files are provided with binary format and all data points contain 4-byte integers. Ideally, you can reconstruct the MRI image by 2D inverse Fourier transforming the provided k-space data.

(a) Show the real and imaginary components, respectively (by Matlab instruction: imagesc()), and check the data range (by Matlab instructions: colorbar, max() and min(), and mean2()). By checking the data range, supposedly, you should be able to find out that the data suffer a constant DC offset, which comes from the electronics.

(b) Discuss the effects on the image when the receiver channel has a constant DC offset caused by the electronics. You can apply 2D inverse Fourier transform to the given k-space data, and see the effects directly from the reconstructed image. Justify your findings.

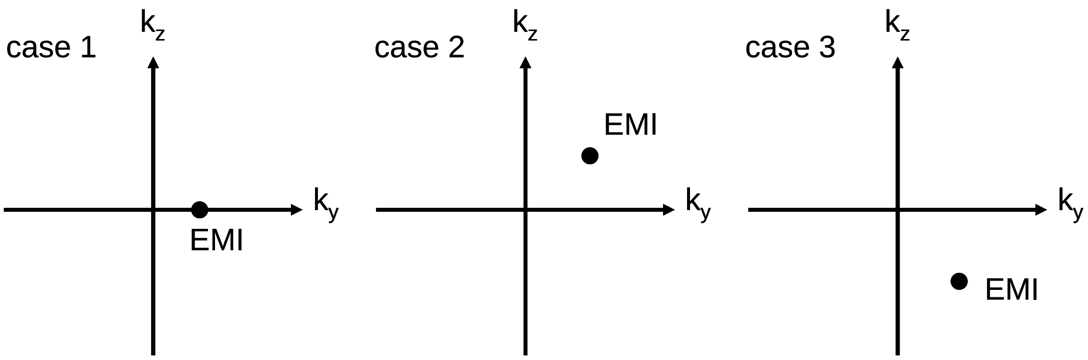
(c) Follow (b). How could you retrospectively correct it? Could you test your proposed method successfully on it? Discuss how you make it or why you are unsuccessful. If you were successful, you will see a sagittal-slice image similar to the following image.



(d) Use the same set of data to verify the effects of sampling interval in k-space on the image. Make sure to include DC offset correction in your reconstruction program. Reconstruct the image by using only the even samples along the k_y direction (note that the x y z coordinates follow the definition used in our lecture slide). Explain your findings and discuss why you obtain such an image. If you have troubles in removing the DC offset, you can load the DC removed k-space data from the provided file – KspaceData_DCRemoved.mat for this and the following questions.

(e) Use the same set of data to grasp more sense on the relationship between the k-space and the reconstructed image. Make sure to include DC offset correction in your reconstruction program. Reconstruct the image when the middle (#129) phase encoding value has been arbitrarily set to zero and also reconstruct the image when the first (#1) phase encoding value has been arbitrarily set to zero. Compared with the image reconstructed with the full MRI k-space data in (c), explain the results in the two images. In particular, contrast the artifacts in the two images and discuss why they are different. Note that y direction is the phase encoding direction.

(f) Use the same set of data to verify the effects on the image if the receiver channel suffers strong electromagnetic interference (EMI) while acquiring certain k-space data point. Make sure to include DC offset correction in your reconstruction program. Note that "strong" means the EMI is larger than or equal to the original k-space data and at least try the following three cases. Describe how you make it, and justify your findings on the reconstructed image.



(g) Use the same set of data to implement half Fourier imaging which saves you about half of the scan time. Make sure to include DC offset correction in your reconstruction program. Does it work well? Why or why not? Note that almost all the commercial MRI systems in the world have the half Fourier imaging function in their standard package. So there must be some way to make it work. (halfFourier imaging: acquire half of k-space data, then use the conjugate-symmetry property of Fourier transform for a real signal to build the full k-space and reconstruct the MRI image). Note that y direction is the phase encoding direction and you should use half of k-space data in the proper spatial frequency corresponding to phase encoding direction.

(h) Based on the image you reconstruct in (c), please tell what weighted image (e.g., T1 weighted or T2 weighted) it is, and justify your answer.

(i) A technician has accidentally reversed the wires to the slice selection gradient coil such that the gradient is reversed. Must you change the current waveform delivered to this gradient coil for the same slice selection as a result of this error? Explain.

2. (a) For gradient echo pulse sequence, please elaborate in MRI what is the contrast source and what factors determine the time resolution and spatial resolution in x, y, and z, respectively, and their relationship with the gradient echo pulse sequence.

(b) Since I never mentioned during our MRI lectures and I have no idea, either :Q, please help me to find out the VALUEs of the pulse duration and bandwidth of the B1 magnetic pulse, magnetic gradients (including x, y, and z gradients), and the other required physical quantities commonly used in clinical MRI and use these values to estimate the resolutions mentioned in (a). Note that please include the citation links where you find the values in your report.

Notice:

1. To have a better sense about k-space or spatial frequency domain concept, you may go through the following links.
   (a) https://www.cs.auckland.ac.nz/courses/compsci773s1c/lectures/ImageProcessing-html/topic1.htm
   (b) https://en.wikipedia.org/wiki/K-space_(magnetic_resonance_imaging)
2. Please hand in your solution files to the LMS elearning system, including your word file of the detailed solutions, the associated Matlab codes, and all the related materials. It would be nice that you can put your codes with comments side by side along with your answer in the word file.
3. Name your solution files "BioMedImg_HW2_StudentID.doc" and "BioMedImg_HW2_StudentID.m", and archive them as a single zip file: BioMedImg_HW2_StudentID.zip.
4. The first line of your word or Matlab file should contain your name and some brief description, e.g., % EE 441000 王小明 u9612345 HW2 05/05/2022