Homework 3: DOC 2023, Biomedical Imaging

Due: June 1^{st}, 2023. Version 1.0

Instructions

Please show work for all problems, and email solutions to ***hall.er@northeastern.edu*** as ***"Homework_#_Group_#.pdf"***.

1 Weighted Images

The signal intensity, S, after outputting a spin echo sequence can be described by the equation:

$$S = k\rho(1 - e^{-T_R/T1})e^{-T_E/T_R}$$

Working through each variable, we find that k is the scaling factor, ρ is the proton density, T_1 is the spin-lattice relaxation time, and T_2 is the spin-spin relaxation time. If a radiologist wanted modify the contrast, they could modify T_R, the pulse repetition rate, and/or T_E, the echo pulse time.

1. For this homework, we will focus on 3 different ways of constructing MRI images:

   - $T1$-Weighted
   - $T2$-Weighted
   - Moderately Weighted

   For each method, show how to achieve this using Equation 1 (Hint: think about the situations we looked at in class!)

2. Generate a relative density phantom (representative of ρ) using the MATLAB function *phantom*. Set all values below zero to 0.5. Scale the image so that it represents a $10cm \times 10cm$ square with a resolution of $100um$.

3. Using the table below, create a $T1$ and $T2$ map based on the relative densities created by part 2.

Relative ρ (unitless)	T_1 (ms)	T_2 (ms)
0	0	0
0.1	838	74
0.2	827	80
0.3	1322	110
0.4	1392	104
0.5	1356	102
1	752	106

4. Modify T_E and T_R to create $T1$-Weighted and $T2$-Weighted, and Moderately Weighted images. Using the magic of the world wide web, find an example of a contrast agent that is good for $T1$-Weighted and and example for $T2$-Weighted images. For the Moderate Weighted image, choose values between these two values. Name the contrast agent and cite your source when you submit your homework.

2 MRI Images

Using the website old.mridata.org, find a fully sampled dataset to use for this problem. The *.ZIP* file you want is the *"Acquired Raw Kspace Data"*. These files can take quite a while to download (sometimes longer than 30 minutes), so be patient! You will also need the *readReconData.m* file provided on the website.

1. Start by getting to know your data by reading the *params.txt* and *your_filename.hdr* files. Find the following information:

    (a) x, y, and z resolution

    (b) Number of channels (Hint: this one is in the .hdr file)

    (c) x and y field of view, and z slice thickness

    (d) TR and TE

2. Voxel size is a term often used to describe MRI imaging capabilities, and is the 3D-equivalent of pixel size in two dimensional images. Using the information you gathered above, what is the voxel size of your dataset?

3. Open the *readReconData.m* and carefully read the instructions. It can take a while to load the data, so be patient. What is the variable type created when the data finishes loading?

4. Perform an inverse Fourier Transform to convert your k-space data into an image. Choose a Z-slice from one channel, and plot it using *imagesc*. Now, for the same slice, average all the channels together and show that image alongside the original.

5. Signal to Noise Ratio (SNR) is defined as:

$$SNR = S/\sigma$$

    σ is the variance of the dataset. Calculate the SNR for the two images you found in part 4. Which image has the better SNR?

6. Find the SNR for images of incremental averages of channels (single image, 2, 3, 4, 5, 6, 7, 8...) and plot the result. How does the SNR change as you increase the number of averaged channels? What is the shape of the graph?

7. The 3 primary planes we look at for MRI images are the Sagittal, Coronal, and Transverse, as seen by Figure 1. Pull a slice from each of these planes (single channel) and plot them on the same figure side by side.

    For an example about how this can be done, see this link here. Be cautious of the axis in the example vs your dataset! (This isn't the only way to achieve this, just an example of one).

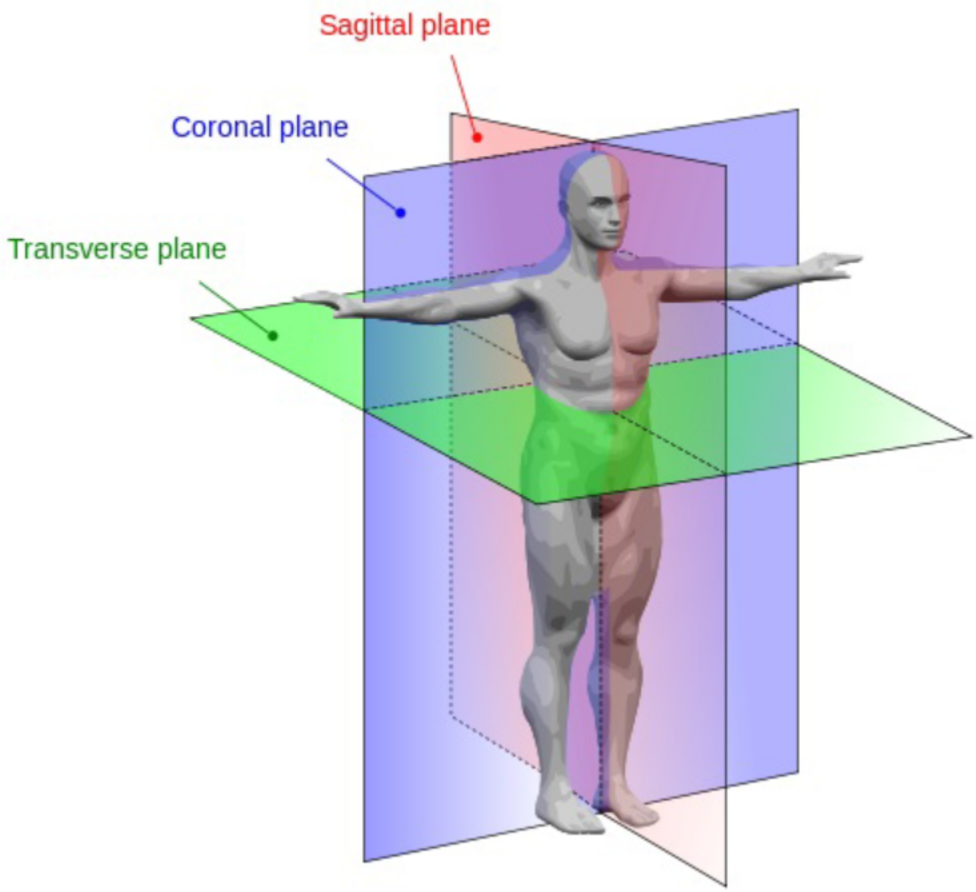

Figure 1: The Three Primary Imaging Planes