Computational MR imaging
Laboratory 1: MRI pulse sequences and image contrast

Code submission is due by Sunday 23:55 the week of Tuesday session. Please upload your code to StudOn in a described format. Late submissions will not be accepted.

Learning objectives

- Recall and improve familiarity of the MR contrast generation process.
- Recall and improve familiarity with MR pulse sequences and the k-space concept.
- Simulate image contrasts from generated by pulse sequences using a numerical brain phantom.

1. Inspect the digital brain phantom (Aubert-Broche, Neuroimage 2006)

1.1. Load the file digital_brain_phantom.mat by calling load_data method. T1, T2, and PD values were simulated. Therefore, their values for one region is the same.

1.1.1. Label (mat['ph']['label'][0][0])

1.1.1.1. 1: Cerebrospinal Fluid (CSF)

1.1.1.2. 2: Gray Matter (GM)

1.1.1.3. 3: White Matter (WM)

1.1.2. T1_map (mat['ph']['t1'][0][0])

1.1.2.1. Predefined T1 values

1.1.3. T2_map (mat['ph']['t2'][0][0])

1.1.3.1. Predefined T2 values

1.1.4. PD_map (mat['ph']['sd'][0][0])

1.1.4.1. Predefined proton density(PD) values

1.2. Display the regions Cerebrospinal Fluid (CSF, label=1) Gray Matter (GM, label=2) and White Matter (WM=3).

1.2.1. Implement methods, get_[csf,gm,wm]_mask(). Consider their labels.

1.3. Display the predefined T1, T2 and Proton Density (PD) values for these three regions.

1.4. Print unique values of T1_map, T2_map, and PD_map.

1.5. Print T1, T2, and PD for CSF, GM, and WM, respectively.

1.5.1. Implement methods, get_[T1,T2,PD].

2. Simulate MR image contrast from pulse sequences

2.1. Implement spin_echo method. Use the Spin-Echo signal equation from Bernstein eq 14.57.

2.1.1. Assume a 90º excitation and a 180º refocusing pulse.

2.2. Spin Echo Proton density weighted (PDw):

2.2.1. Choose repetition time (TR) and echo time (TE) accordingly and define them as a list format in self.PDw_TRTE in Lab01_op class. Hint: Consider the T1 and T2 values of GM and WM.

2.3. T1-weighted

2.3.1. Do the same as PDw and define self.T1w_TRTE.

2.4. T2-weighted

2.4.1. Do the same and define self.T2w_TRTE.

2.5. Plot PDw, T1w, and T2w images.

3. **K-Space trajectories**

Consider three popular k-space acquisition trajectories. Cartesian, radial and spiral (see **Figure 1**). Sketch the gradient waveforms that generate these k-space trajectories. Hint: Remember that:

$$k_y = \int_0^t G_y d\tau$$
$$k_x = \int_0^t G_x d\tau$$
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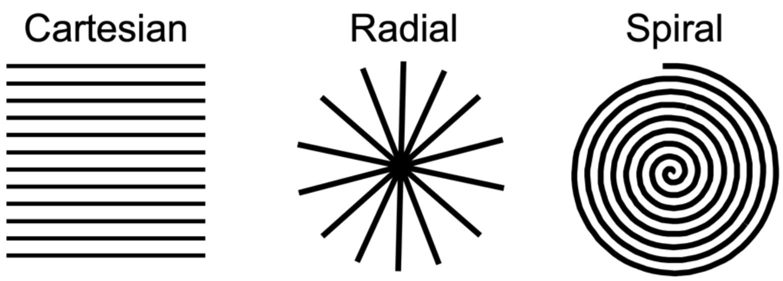

Figure 1: Cartesian, radial and spiral k-space trajectories

Appendix: Equations from Bernstein book:

Spin Echo signal equation (section 2.1.2)

$$S = M_0(1 - 2e^{-(\mathrm{TR}-\mathrm{TE}/2)/T_1} + e^{-\mathrm{TR}/T_1})e^{-\mathrm{TE}/T_2} \qquad (14.57)$$