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HST.583 Functional Magnetic Resonance Imaging: Data Acquisition and Analysis
Fall 2008

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HST.583

October 3, 2008

Problem Set #2

Problem 1: Understanding K-space

Describe what you would see AND explain why when you look at a T1 image of the mid-sagittal slice through the brain after:

- a) discarding the LOW frequency k-space information
- b) discarding the HIGH frequency k-space information

You may include images, but a verbal description is required.

Problem 2: Factors that affect the spin level populations

The difference in level population in a two level system is denoted by $\Delta n = N_\alpha - N_\beta$, where N is the number of spins and the levels are denoted by α or β . The time rate of change of Δn is given by $d(\Delta n)/dt = -(\Delta n - \Delta n_0)/T1$, where T1 is the spin-lattice relaxation time and Δn_0 is the population difference at equilibrium.

- a) Find the equation for the population difference at some time, t, after placing the sample in the magnet?
- b) How long does it take for the distribution to get to 90% of the Boltzmann distribution if the T1 is 800 ms?

Problem 3: Playing with T1 and T2 contrast

Using the table of tissue parameters below, we will investigate how the choice of pulse sequence parameters can change the contrast in the image. We will assume that the pulse sequence is the following: $[\pi/2 - t1 - \pi/2 - (t1+t2) - \pi/2 - t1 - \text{acquisition}]$, a stimulated echo, and make use of the relationship: $S = (\rho/2)(\exp^{-(t1+t2)/T1}) \exp^{-2t1/T2}$, where S is the MR signal strength, ρ is the proton spin density, $t1=TE/2$ and $t1+t2=TM$.

Tissue	T1	T2	ρ
Gray matter	1.2 s	70 ms	.98
White matter	800 ms	45 ms	.80

- a) Plot the signal equation versus t1 for both white matter and gray matter assuming $t2 = 50$ ms.
- b) In another figure, plot the signal difference between white matter and gray matter as $t2$ is changed. Assume $t1 = 25$ ms.

Problem 3: Calculation of Imaging Gradients

Assuming a 10 cm field of view, a 10 ms phase encoding gradient, and 8 phase encoding steps, what are the phase angles for each phase encoding step?

Problem 4: Human safety in MRI

The goal of this problem is to make you aware of human safety issues when using fast brain imaging sequences. Consider the following two pulse sequences: single shot gradient-echo EPI (i.e., one 90° RF excitation pulse followed by a train of gradient recalled echoes), and a single shot spin-echo sequence (i.e., one 90° RF excitation pulse followed by a train of 180° RF refocusing pulses that form spin-echoes).

- a) Find an expression for the specific absorption rate (SAR) for both sequences.
Hint: make a simple model that considers the RF power deposited for a single RF pulse and weight it by the duty cycle for the train of RF pulses. The duty cycle is the amount of time the RF is turned on per TR, thus it contains information about each RF pulse duration, the number of slices acquired and the number of RF pulses per TR. Does the weight of the patient matters?
- b) Based on the expression found in the previous point, compare the two sequences and discuss their limitations in terms of SAR. Which of the two sequences would be likely to induce more peripheral nerve stimulation?

Problem 5: Considerations in pulse sequence acquisition parameters

Which parameter(s) would you keep the same to ensure that the degree and direction of distortion between two different pulse sequences were the same? Why?

Problem 6: More on Pulse Sequence Acquisition Parameters

For each of the two pulse sequences shown below:

- Calculate the Total Acquisition Time
- Calculate the Voxel Size
- State whether it is a structural or functional scan (and how you know)
- State whether it is a 2D or 3D scan

SEQUENCE ONE

Scanner SIEMENS MAGNETOM TrioTim

Routine

Slab group: 1

Orientation: Sagittal

Phase encode direction: A >> P

Readout direction: R >> L

Slices per slab: 160

FoV read: 220 mm

FoV phase: 220 mm

Slice thickness: 1.20 mm

TR: 2300 ms

TE: 2.94 ms

Averages: 1

Contrast

Magnetization preparation: Non-sel. IR

TI: 1100 ms

Flip angle: 9 deg

Reconstruction: Magnitude

Measurements: 1

Resolution

Base resolution: 256

Phase resolution: 192

Slice resolution: 256

PAT mode: GRAPPA

Acceleration factor: PE 2

Geometry

Multi-slice mode: Single shot

Series: Interleaved

Sequence

Bandwidth: 240 Hz/Px

Echo spacing: 7 ms

RF spoiling: On

SEQUENCE TWO

Scanner SIEMENS MAGNETOM TrioTim

Routine

Slice group 1

Slices: 30

Dist. Factor: 25 %

Orientation: Transversal

Phase encode direction: A >> P

Read encode direction: R >> L

FoV read: 220 mm

FoV phase encode: 220 mm

Slice thickness: 4.0 mm

TR: 2000 ms

TE: 30 ms

Averages: 1

Contrast

MTC: Off

Flip angle: 77 deg

Measurements: 142

Resolution

Base resolution: 64

Phase resolution: 64

PAT mode: None

Matrix Coil Mode: Triple

Geometry

Multi-slice mode: Interleaved

Series: Ascending

Sequence

Bandwidth: 2298 Hz/Px

Free echo spacing: Off

Echo spacing: 0.5 ms

EPI factor: 64

Dummy Scans: 3