Introduction to Biological Imaging

Homework 4

Date: 16.01.2019

Deadline: 30.01.2019, 23:59 CET

Submit your work to: ivan.olefir@tum.de

Email title: MAT{your matrikelnummer #} HW{homework #} 201819 {your name}

Example: MAT12345678 HW4 201819 IVAN OLEFIR

Acceptable formats: .pdf, .doc, .docx

Report guidelines:

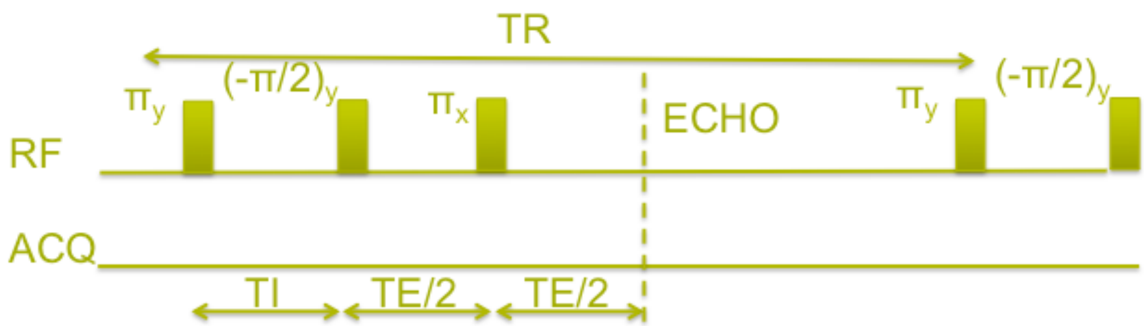
- Do not be too elaborate in your answers unless you are asked to. 1-2 sentences are usually enough to answer the questions.
- Every figure should have a number and a title. In the text refer to figures by their number. Every plot should have titled axes. If the figure consists of several subplots, each one should have a self-explanatory title.
- Include the commented code as shown below either at the beginning or at the end of the document
- Do not only include your code in your report – show the images you have obtained and answer the questions.

Code Example:

```
 %% Assignment 1
============================================================
%============================================================================

% 1)    Create a phantom for simulating XCT measurements. The phantom
should
% contain ellipses and polygons of varying intensity (use radon() and
augment
% the resulting image). Show an image of your phantom.

solution = pressxtowin(1); % create phantom by pressing X to win

% 2)    Compute the views (projections) with spacing of 1, 5 and 10
degrees.
% Show the projections at 0°, 30°, 45° and 90° (in one axes).
% Show the sinogram with the most angles.

solution = pressxtowin(2); % compute projections by pressing X twice

% 3)    Implement the backprojection algorithm (i.e. inverse radon
transform)
% according to slide 16 of the Tutorial slides. You are not allowed to use
iradon().

...

%% Assignment 2 =================================================================
%============================================================================
```

Problem 1: Bloch equation

The pulse sequence diagram of an inversion-recovery spin echo sequence is given below. The sequence is composed of a π_y pulse, a $(-\pi/2)_y$ pulse and a π_x pulse and it uses the following parameters TE = 40 ms, TI = 300 ms and TR = 1500 ms, The sequence is employed to image a tissue with T_1 = 1000 ms and T_2 = 80 ms.



(a) Consider a spin that precesses with off-resonance frequency equal to 1 Hz. Plot the evolution of the angle of the transverse magnetization for the above spin for the 2nd TR. Show that the spin echo is formed at time TE from the $(-\pi/2)_y$ RF pulse.

(b) Plot the evolution of longitudinal and transverse magnetization for 5 TRs. How many TRs are required in order to establish a steady-state in the magnetization evolution?

(c) Based on the numerical simulation of the Bloch equation, determine the signal of the spin echo at the 5th TR (assume M_0=1). Compare the signal of the formed spin-echo at the 5th TR to the following analytical expression (depending on T_1 and T_2 relaxation times):

$$S = M_0[1 - 2exp(-TI/T_1) + 2\exp(-(TR - TE/2)/T_1) - \exp(-TR/T_1)]\exp(-TE/T_2)$$

(d) The above equation can be simplified for TE<<TR:

Based on the analytical above expression, it is possible for a given TR to select the inversion time TI to null the signal of a tissue with a given T_1. Assume that the inversion-recovery spin echo sequence will be used to null the signal from fat (T_1=360 ms). Find the inversion time required to null the fat signal.

Problem 2: Reconstruction from k-space

The k-space data of a T_1-weighted sagittal brain image can be loaded from the workspace braint1data.mat.

Reconstruction of k-space data

(a) Reconstruct the brain image using the given complex k-space data. Is it possible to reconstruct the MR image using only the magnitude or the phase of the measured k-space data? Show the corresponding images.

(b) Assume that only every other k-space point along the horizontal direction has been sampled. Reconstruct the MR image. What type of artifacts do you observe? Why?

(c) Raw k-space can be corrupted with noisy spikes of various origins. Introduce a spike artifact in k-space, by setting the complex signal at the pixel location (160,160) equal to 10^4. Reconstruct the MR image. How do k-space spike artifacts appear in image space?

(d) Introduce a stripe artifact in k-space, by setting the complex signal for all pixels at column 160 equal to 10^2. Reconstruct the MR image. How do k-space stripe artifacts appear in image space?

<u>SNR versus spatial resolution</u>

(e) Measure the noise by computing the standard deviation in a signal-less region in the image. Display the image in SNR units, and add a colorbar to show the SNR scale.

(f) Zero-fill the k-space data to a 512x512 matrix by symmetrically adding zeros around the data. This will interpolate the image to a larger matrix size. Reconstruct the image, compute the SNR, and display in SNR units.

(g) Windowing: Multiply the data by a 2D Hanning window. Reconstruct the image, compute the SNR, and display in SNR units. How has the SNR changed? How has the image changed? How are these changes related?