Project Task 1

Applied Medical Image Analysis

(M2.03100.20.030)

22.04.2024

# Submission guidelines

* + One submission per team uploaded to Moodle
  + Deadline: May 27th, 3.00 pm.
  + A script RUN.m, which executes, computes all results, and plots them without user interaction. Supporting functions can be in separate MATLAB files.
  + The code has to be commented to briefly and clearly describe what the code does.
  + A PDF report that contains explanation and interpretation of all exercises (approximately 2 - 3 pages).
  + A front page of the report contains group number and team member names.
  + The report has to be short and precise, do not include code.
  + You can register for max. 2 project supervision sessions to answer any questions regarding the exercise, provide feedback to your code or parts of your report. No support outside these sessions will be provided.

# Assignment

Aim of this first project task is to exploit the gained knowledge on image filtering and restoration, image segmentation. The task is to generate Susceptibility-Weighted Images (SWI) and Quantitate Susceptibility Maps (QSM) from MRI images and do a quantitate evaluation in defined regions of interest.

**Data**

Two datasets are provided – one for SWI processing and one for QSM.

1. **SWI data**

* this are 7T MRI images of a healthy volunteer
* magnitude image (magnitude.nii), unwrapped phase image (phase\_unw.nii) and the brain mask (mask.nii) are provided

1. **QSM data**

* this is a simulated dataset generated by using the code and in-silico head phantom model created by *Marquez J et al. QSM reconstruction challenge 2.0: A realistic in silico head phantom for MRI data simulation and evaluation of susceptibility mapping procedures. Magn Reson Med 2021, doi:10.34973/m20r-jt17*
* data properties: B0\_dir = [0,0,1], voxel\_size = [0.64,0.64,0.64] mm
* magnitude image (magnitude.nii) and demagnetization field image (demagnetization\_field.nii) are provided
* chi\_model.nii represents the ground truth susceptibility maps for comparison.

**Helper functions**

Useful Matlab functions for this assignment:

* load\_nii, make\_nii and save\_nii
* fftn, ifftn, fftshift, ifftshift, real, abs
* strel, imfill, imerode, imclose, imdilate, bwconncomp, bwareaopen
* fspecial, imfilter, deconvwnr

Documentation and example usages of built-in Matlab functions can be accessed with the command doc function name.

Provided MATLAB function called create\_dipole\_kernel.m can be used to create the point-spread function (dipole response) of the QSM. It can be called to create the dipole in Fourier domain (parameter kernel\_in\_FD set to 1) or in image space (parameter kernel\_in\_FD set to 0)

* dipole\_FD = create\_dipole\_kernel(B0\_dir, voxel\_size, dims, kernel\_in\_FD);
* dipole\_im = create\_dipole\_kernel(B0\_dir, voxel\_size, dims, kernel\_in\_FD);

and dims in the size of the data matrix.

Nifty viewer, such as MRIcro (https://people.cas.sc.edu/rorden/mricro/index.html)) can be for display of the 3D images outside MATLAB.

## Tasks and grading

Maximum number of points per subtask are denoted in brackets (**20 in total**).

A script RUN.m should run through without any error, compute all the results, and display them without user interaction. The resulting processed 3D images can be instead of displaying in MATLAB saved as nifty images.

The code should be clean, organized and commented, to briefly and clearly describe what the code does **(2 points)**

**Generate an SWI image (7 points)**

* 1. Apply the mask to the unwrapped phase image (1 point)
  2. High-pass filter the phase data using unsharp masking (2 point)
  3. Generate an SWI mask following: (1 point)
  4. Generate and SWI image by n-times multiplying the magnitude image by the SWI mask (1 point)
  5. Generate a minimum intensity projection SWI image (2 point)

**Generate and evaluate QSM images**

1. **Brain mask generation (2 points)**
   1. Using thresholding of magnitude data and morphological operations, generate a brain mask (2 points)
2. **Perform image restoration (5 points)** 
   1. Apply the mask to the demagnetization field
   2. Generate a dipole field (the PSF of the system) using provided function called create\_dipole\_kernel.m (1 point)
   3. Generate a QSM using direct inverse filtering in Fourier domain (2 point)
   4. Generate a QSM using thresholded inverse filtering in Fourier domain and optimize the threshold (2 point)
   5. Compare the generated QSM to the ground truth susceptibility map.
3. **Assess the susceptibility values (4 points)**
   1. Use some segmentation approach (other than thresholding) to segment two deep gray-matter structures. Segmentation can be performed in 2D by choosing a certain slice. (2 point)
   2. Save the ROI and load it to the script so that the script can run without user interaction (but provide commented-out code you used to draw the ROI or describe in the protocol how you did it) (1 point)
   3. Calculate the mean susceptibility values in those two regions (1 point)
   4. Compare to literature values for the given region.