COSC 4372-6370 Medical Imaging
Image Synthesis - Human Brain

Background-Objective: A critical issue in medical machine learning is the limited number of available data for training and synthesis is extensively used. In this project you create a piece of software to synthesize ***MRI of the human brain*** based on the physics of image formation. This software will generate any number of brain MRI images. You will use data from the OASIS (Open Access Series of Imaging Studies) data set. As shown in figure 1, each data includes an MRI as well as the corresponding maps or segmented regions of interest of the White Matter (WM), Grey Matter (GM) and Cerebrospinal Fluid (CSF). You will begin by loading the provided 3D OASIS dataset maps in NIfTI (nii) format for WM, GM, and CSF. This dataset is located under the **Data** folder attached with this assignment, including samples from 2 patients. From each patient, **only select slice number 90** in the **axial** plane. In the loaded slice, voxel values are as follows: 1 and 2 for GM, 3 for WM, and 4 for CSF.

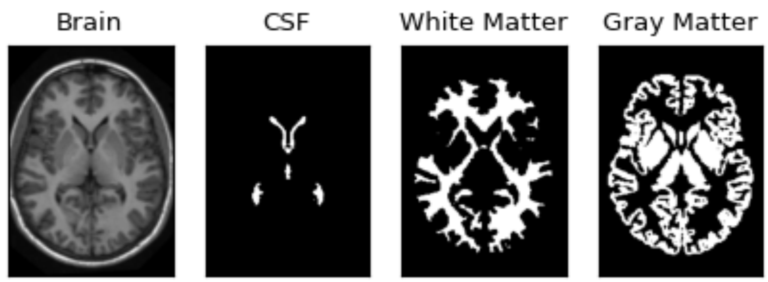

Figure 1: Example data from the OASIS data base

Overview: The image synthesis pipeline will include:

- For each tissue type assign a T1, T2 and P based on given distributions.
- Create the base generation of synthetic T1, T2 and P maps.
- Calculate the images generated by specific pulses sequences.
- Analyze images and extract metrics.

Table 1 shows T1, T2 and P distribution for each tissue.

Table 1	T1 (s)	T2* (ms)	P
GM	1.62 ± 0.26	85.00 ± 12.00	105.00 ± 10.00
WM	0.92 ± 0.08	80.50 ± 9.75	80.00 ± 5.00
CSF	10.4 ± 4.8	1055.00 ± 472.50	150.00 ± 40.00

- For each tissue assign **T1, T2*,** and **P**.
- The **T1**, **T2*, and P** come from a Gaussian distribution.

For variable TR, TE, and, when present, flip angle, and TI, calculate the signal intensity for three pulse sequences: **Spin Echo**, **Gradient Recalled Echo** (GRE), and **T1 Inversion recovery**. The signal intensity equation for each pulse sequence is given in the below table.

Table 2	*SI Formula*
Spin Echo (SE)	$S = P\,(1-\exp(-TR/T_1))\,\exp(-TE/T_2)$
T1 Inversion recovery	$S = P\,(1-2\exp(-TI/T_1)+\exp(-TR/T_1))\,\exp(-TE/T_2)$
Gradient Recalled Echo (GRE)	$S = P\,(1-\exp(-TR/T_1))\,\mathrm{Sin}(\alpha)\,\exp(-TE/T_2^*)\,/\,(1-\mathrm{Cos}(\alpha)\,\exp(-TR/T_1))$
For this project we will assume T2 = T2*	

For each pulse sequence, for each pair of parameters given below, generate the SI map and **represent them within their corresponding table cell (30 pts)**. Report your observation **(10 pts)**. Make sure to mention below the table what T1 and T2 values were selected for each tissue **(5 pts)**.

Spin echo	***TE (ms)***			
	20	***40***	***60***	***80***
TR (ms)				
250				
500				
750				
1000				
2000				

T1 Inversion Recovery (TE=0)	***TR (ms)***	
	1000	***2000***
TI (ms)		
50		
100		
250		
500		
750		

Gradient Recalled Echo (TE=5ms)	***TR (ms)***			
	25	***50***	***100***	***200***
α (degrees)				
15				
30				
45				
60				
90				

MRI Generation

For each patient at different pulse sequences, generate 100 MR image by variating T1 and T2 (within the range given in Table 1). The other necessary parameters for each pulse sequence are given in the following tables. For each pixel, add Gaussian noise, the standard deviation of which equals %5 of the peak signal calculated for that MRI **(10 pts)**. For each patient, select

one out of the 100 generated MRIs and put them into the following tables (You will need to have 6 tables for this part) **(10 pts)**. Report your observation **(10 pts)**.

Spin echo	***TE (ms)***			
	20	***40***	***60***	***80***
TR (ms)				
250				
500				
750				
1000				
2000				

T1 Inversion Recovery (TE=0)	***TR (ms)***	
	1000	***2000***
TI (ms)		
50		
100		
250		
500		
750		

Gradient Recalled Echo (TE=5 ms)	***TR (ms)***			
	25	***50***	***100***	***200***
α (degrees)				
15				
30				
45				
60				
90				

Verifying Distributions along the entire synthetic dataset

In your code incorporate a routine to analyze the T1, T2*, P and SNR distributions across synthetic images at tissue level. For each type of tissue, calculate and report mean and standard deviation of T1, T2*, P, and SNR for all pulse sequences. **(25 pts)**