

HST.583

LAB4: Cortical and Subcortical Parcellation with MRI

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1. Goals of lab4

This Lab examines ways in which different brain anatomical structures can be classified based on the signal intensity of high spatial resolution anatomical MR images acquired with different contrast weightings.

2. Organization of the lab

Here is an outline (details are below):

- You will run a matlab program that loads some images (T1 and proton density maps).
- You will be asked questions about these images.
- To answer these questions you will have to process the images using simple matlab functions that you will have to write for this purpose.

3. Getting started

- i) **login** your athena account
- ii) **attach hst.583**
- iii) If you don't have one, create a matlab directory in your home directory: **mkdir ~/matlab**
In this directory you should write the matlab functions that you can use for solving the exercises.
- iv) **source /mit/hst.583/bin/lab4-init.csh** (this changes your directory to that of lab4)
- v) **matlab &** (start matlab)
- vi) In the matlab window: **add_lab4**
This adds the paths for matlab functions used in lab4 and also for the ones that you may use from your own ~/matlab directory.
- vii) In the matlab window: **load_lab4_data**
The matlab file load_lab4_data.m will load 3 volumes:
 - T1vol - map of T1 values across the brain
That is, this is a 3D volume image of the brain where the value of each voxel is the T1 (in ms) of the tissue in that voxel.
 - PDvol - map of proton density values across the brain.
As for the T1 map but now the value in each voxel is the proton density (arbitrary units) in that voxel.
 - LABELvol - volume of labels of all neuroanatomical structuresIt will also define some symbolic constants for structure names including amygdala, hippocampus, pallidum, putamen, cerebral_white_matter and cortical_gray_matter.
- viii) If you type **whos** you will get a list of the variables hold in memory.
- ix) You can use the additional tool show_slice (see below) to look at the images you just loaded.

- x) **Now read carefully the exercises.** To answer the questions write matlab functions in your home matlab directory.

4. Additional matlab tools

The following matlab files have also been provided:

```
load_lab4_data.m - load the data needed for this lab.
load_mgh.m       - load a volume in 'mgh' format.
radians.m       - convert degrees to radians
save_mgh.m      - save a volume in 'mgh' format
show_slice.m    - show a (coronal) slice from a volume.
```

If you want to save images, do so in your own directory. For example:

```
save_mgh(my_image, '~/hst-583/lab4/my_image.mgh')
```

Note that to display a 2-d slice of a volume, you can use the function `show_slice(volume, sliceno)`. This will display coronal slices, but you should be able to modify it to view slices along any other cardinal axis easily enough.

5. Exercises

EXERCISE 1a:

Write a matlab script that will use the T1 and PD maps to synthesize a new image volume using a flip angle of 30 degrees (remember to use radians) and a TR of 20 msec (assume that TE is short relative to T2 and can therefore be neglected). Call this new volume `synthesized_vol`. You will need to use the equation for the signal intensity that you derived in the second problem of Problem Set 1 (Ernst angle calculation). What is the primary 'weighting' of this image? That is, what tissue parameter is primarily responsible for the contrast in the image? Why?

EXERCISE 1b:

Compute the contrast to noise ratio of each of the following pairs of structures using the synthesized volume obtained in the previous point.

```
amygdala and hippocampus
pallidum and putamen
cortical_gray_matter and cerebral_white_matter
```

You may find the matlab function 'find' useful in this context. For example:

```
amygdala_indices = find(LABELvol == amygdala);
amygdala_mean = mean(synthesized_vol(amygdala_indices));
amygdala_var = var(synthesized_vol(amygdala_indices));
```

would compute the mean intensity (`amygdala_mean`) and the variance (`amygdala_var`) of all voxels labeled amygdala in the volume you have synthesized.

Generate a table with these contrast to noise values and turn it in.

EXERCISE 1c:

Turn in a plot of the empirical distribution of the signal intensity of voxel in each structure using the synthesized image (hint: use matlab function `hist` to get the histogram. If you don't know how to use this

function type 'help hist' in your matlab window). Remember to normalize the empirical distributions so they sum to 1. Please use the following colors:

amygdala	'c'
hippocampus	'y'
cortical_gray_matter	'g'
cerebral_white_matter	'k'
putamen	'm'
pallidum	'b'

Comment on your results with regard to building an automated segmentation procedure based on this type of intensity image.

EXERCISE 1d:

Compute the optimal discriminant between gray matter and white matter assuming that the classes have a normal distribution with equal variances. Plot the empirical distributions of each on the same plot, together with a line representing the decision boundary. Compute the percentage of voxels of each class that would be misclassified using this decision rule. How well placed is the discriminant based on the Gaussian models?

EXERCISE 1e:

Now compute the contrast-to-noise ratio for a subset of cortical gray matter and white matter. Use a single horizontal slice near the center of the 30 degree flip angle volume (use slice 90, meaning `vol(:,90,:)`). Compare it to the gray/white contrast-to-noise ratio for the entire volume. Speculate on the cause of the disparity between the two (hint: you may want to take a look at this data at different horizontal slice planes). Recalculate the discriminant as in 1d and percent voxels misclassified using just this slice. How well placed is the discriminant based on the Gaussian models?

EXERCISE 2a:

Change the flip angle to 5 degrees and synthesize a new volume. Use this volume to recalculate the contrast-to-noise ratio of the same pairs of structures (neglecting T2 effects again). What is the primary 'weighting' of this image? Why is it different from the 30 degree image of exercise 1a?

EXERCISE 2b:

Compute the contrast to noise ratio of the same structures as 1b using this synthesized volume. Compare them to your results in 1b. Which type of volume would you choose for segmentation purposes for each structure pair?

EXERCISE 2c:

Plot the empirical distribution of each structure using this volume with the same colors as done in 1c.

EXERCISE 2d:

Compute the optimal discriminant between gray matter and white matter assuming that the classes have a normal distribution with equal variances. Plot the empirical distributions of each on the same plot, together with a line representing the decision boundary. How well placed is the discriminant based on the Gaussian models? Compute the percentage of voxels of each class that would be misclassified using this decision rule. Compare this to your results in 1d. Which volume is more useful for gray/white classification?