Quantitative and Functional Imaging

BME 4420/7450

Project #5

**Measuring cerebral blood volume**

The goal of this project is to measure cerebral (capillary) blood volume using dynamic contrast perfusion data. As in the previous projects, you are free to get your results in some other way—these procedures are just one (not necessarily optimal) method. Matlab commands are given in *italics* for easy reference. Use *help <command>* (for example, *help roipoly*) or the Matlab Help pages for more details on any Matlab function.

1. Load the data file proj5data\_qfi.mat into your Matlab workspace. There are six variables in the file:

image\_3d An array (128 x 128 x 46) of pixel values for 46 time points in a dynamic contrast perfusion study.

nRows Number of image rows (128).

nCols Number of image columns (128).

nTimes Number of times at which images were acquired (46).

tr Repetition time (time between image acquisitions, in seconds).

te Echo time (in seconds).

The indices of the array image\_3d are (row, column, timeIndex). The individual images (the pages of the 3D array) are given in time order, i.e., image\_3d(:,:,1) is the first image, image\_3d(:,:,2) is the second, and so on.

1. Create a movie (cine loop) to display all the images in sequence. Do you see any regions of unusual signal variation (across time)?
2. Make a binary mask (a matrix of 1’s and 0’s) showing where the mean image intensity (mean over all times) is at least 10% of the maximum pixel intensity. Call this matrix ‘headMask\_m’.
3. As the contrast agent flows into the image slice, pixel intensities drop then slowly increase toward their original (baseline) values. For every pixel with high mean signal (defined by headMask\_m), calculate the time at which the pixel takes on its lowest value. This is the time when the contrast agent concentration is highest in the tissue. Store these values in the matrix ‘timeOfMin\_m’. Display the time-of-minimum as a map (i.e., as an image), and include a color scale (using the *colorbar* command). Is the flow abnormality more obvious in this image than in your movie?
4. Prompt the user of your program to define a region of interest (ROI) covering the slow-flow region in your time-of-minimum map. Use *roipoly* to define the ROI. The output of *roipoly* is a binary mask with 1’s inside the ROI—name this matrix ‘slowRoiMask\_m’. Use the *line* command to draw the boundary of the ROI on the image. Make sure the ROI mask does not include low-intensity pixels by multiplying by headMask\_m:

*slowRoiMask\_m = slowRoiMask\_m .\* headMask\_m;*

1. Prompt the user to define an ROI covering the homologous region in the other hemisphere (i.e., a region of approximately the same size, reflected across the midline of the brain from the slow-flow ROI). Use *roipoly* again, but now name the output matrix ‘controlRoiMask\_m’. Again, use the *line* command to display the ROI boundary on the image. Make sure the ROI mask does not include low-intensity pixels by multiplying by headMask\_m:

*controlRoiMask\_m = controlRoiMask\_m .\* headMask\_m;*

1. Use a *for* loop to calculate the mean signal in both ROIs at all time points:

*slowRoiMean\_v = zeros(1, nTimes);*

*controlRoiMean\_v = zeros(1, nTimes);*

*for timeIndex = 1:nTimes*

*image\_m = squeeze(image\_3d(:, :, timeIndex));*

*slowRoi\_m = image\_m .\* slowRoiMask\_m;*

*controlRoi\_m = image\_m .\* controlRoiMask\_m;*

*% Enter your own code here to calculate the mean signal*

*% in each ROI at the current time:*

*slowRoiMean\_v(timeIndex) = <…>*

*controlRoiMean\_v(timeIndex) = <…>*

*end*

Use the *plot* command to display slowRoiMean\_v and controlRoiMean\_v as functions of time. You can display two (or more) curves in the same plot axes by appending one plot specification after another—the general format is *x coordinate array, y coordinate array, line specification (i.e., color and line type)*:

*figure*

*time\_v = tr \* (0:(nTimes-1));*

*plot(time\_v, slowRoiMean\_v, 'r-', time\_v, controlRoiMean\_v, 'b:')*

*title('ROI mean signal')*

*xlabel('Time [s]')*

*legend(‘Slow flow region’, ‘Control region’)*

1. Using the *input* command, prompt the user to enter the duration of the baseline period (i.e., time before contrast arrival in the ROI’s), based on the RoiMean plots:

*baselineTime = input('Enter the duration of the baseline (in seconds): ');*

*baseIndex\_v = find(time\_v < baselineTime);*

*slowBaseSignal = mean(slowRoiMean\_v(baseIndex\_v));*

*controlBaseSignal = mean(controlRoiMean\_v(baseIndex\_v));*

1. Find the R2\* change in both ROIs as a function of time. Use the relation



taking the baseline signal for *S0* and the echo time for *TE*. Note that Matlab’s *log* function calculates the natural logarithm. Name the R2\* arrays slowR2\_v (for the slow-flow ROI) and controlR2\_v (for the control ROI). Plot the two functions together as in step 7. Note that each curve is proportional to the concentration of contrast agent in the corresponding ROI.

1. Calculate and display the relative cerebral blood volume (CBV) in the slow-flow region (expressed as a ratio of slow-flow CBV to control CBV). Use the relation



where the constant *c* is the same for both ROIs.

# Questions

1. How does the R2\* curve differ between the two regions (in terms of amplitude, width, and time delay)? What physiological properties might these differences reflect?
2. A stroke is a sudden brain injury caused by impaired blood supply (due to a blood clot blocking a vessel, for example). If the perfusion deficit is severe and prolonged, brain cells die due to *hypoxia* (insufficient oxygen). How could you use your measurements to evaluate the extent and severity of stroke?
3. What is the relative CBV in the slow-flow region? Does this seem low enough to affect a patient?
4. What are some possible sources of error in your measurement? Briefly describe what you could do to improve the accuracy of the relative CBV estimate.

# Assignment

Create a Word document that includes

1. A figure showing the time-of-minimum map with your ROIs. Be sure to add a color bar to display numerical values.
2. Your plot of signal intensity versus time for both ROIs.
3. Your plot of R2\* change versus time for both ROIs.
4. Your answers to the questions above.
5. Your Matlab code.

Please save your report as a PDF file, name it “Project5…” (adding your name), and submit it on Brightspace by Thursday, Nov. 10. Each group can submit one report—just make sure all group members are named on the report.