Statistical Analysis Of MRI Data

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Project Motivation and Background

-Overall Goal: Determining locations of the brain responsible for various motor functions

-Brain split into voxels (volumetric pixel)

-Activation level measured in each individual voxel during times of activity and rest

-Determine whether there is a change in activation level during times of activity using linear regression and likelihood ratio test

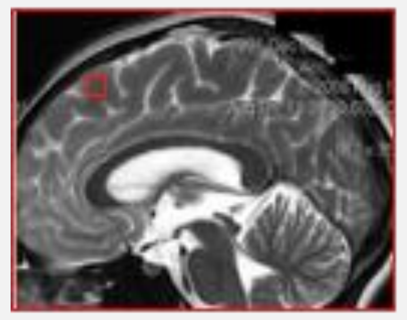
-Use this information to create colored maps of the brain indicating voxels responsible for given motor function

Raw Data: Brain Scans and Matrices

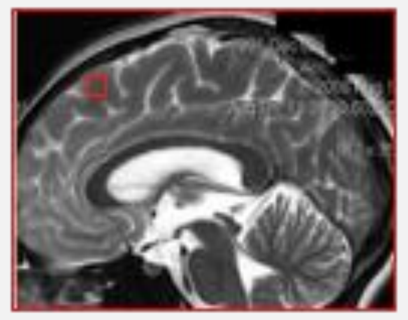
t=1

t=2

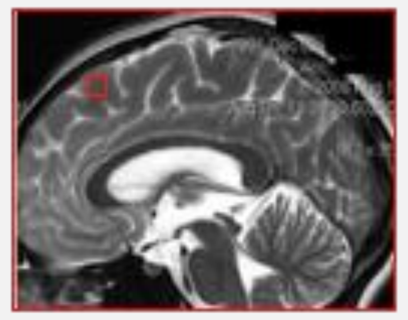
t=3



t=4



t=5



t=6

$$\begin{bmatrix} 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0.3 & \boxed{0.2} & 0.6 & \cdots & 0 \\ 0 & 0.4 & 0.5 & 0.8 & \cdots & 0 \\ 0 & 0.7 & 0.6 & 0.8 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

t=1

$$\begin{bmatrix} 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0.3 & \boxed{0.3} & 0.6 & \cdots & 0 \\ 0 & 0.5 & 0.5 & 0.7 & \cdots & 0 \\ 0 & 0.6 & 0.6 & 0.9 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

t=2

$$\begin{bmatrix} 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0.2 & \boxed{0.7} & 0.6 & \cdots & 0 \\ 0 & 0.4 & 0.5 & 0.7 & \cdots & 0 \\ 0 & 0.6 & 0.5 & 0.8 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

t=3

$$\begin{bmatrix} 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0.3 & \boxed{0.9} & 0.7 & \cdots & 0 \\ 0 & 0.3 & 0.5 & 0.7 & \cdots & 0 \\ 0 & 0.6 & 0.5 & 0.8 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

t=4

$$\begin{bmatrix} 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0.4 & \boxed{0.4} & 0.5 & \cdots & 0 \\ 0 & 0.4 & 0.5 & 0.6 & \cdots & 0 \\ 0 & 0.5 & 0.6 & 0.7 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

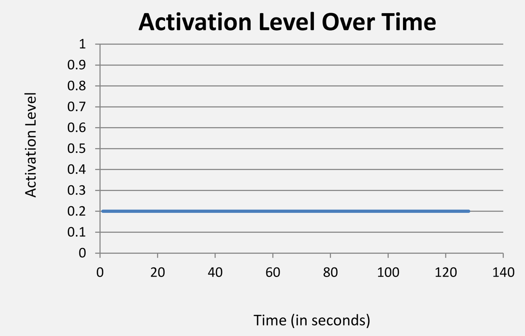
t=5

$$\begin{bmatrix} 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0.3 & \boxed{0.3} & 0.6 & \cdots & 0 \\ 0 & 0.4 & 0.5 & 0.7 & \cdots & 0 \\ 0 & 0.6 & 0.6 & 0.8 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 \end{bmatrix}$$

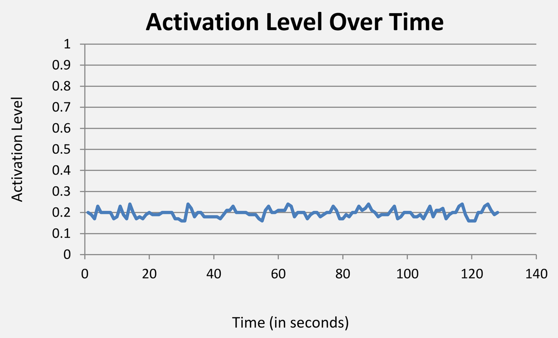
t=6

Looking for Changes in Brain Activity

Sample Graphs of Activation Levels in Voxels not Involved in Given Motor Function

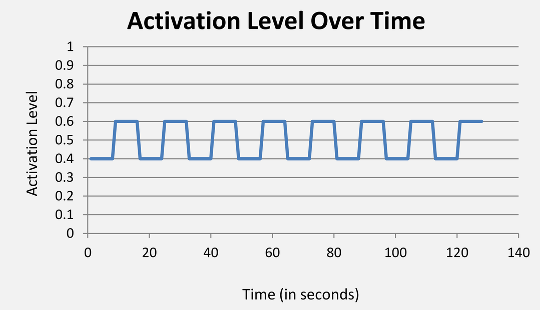


Ideal Data

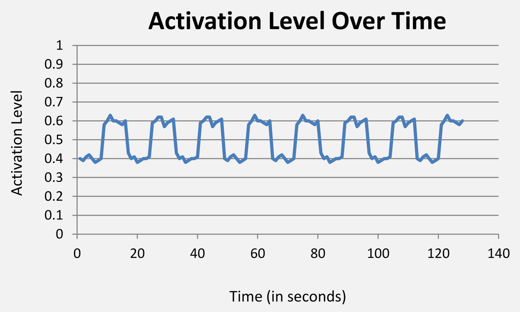


Real Life Data

Sample Graphs of Activation Levels in Voxels Involved in Given Motor Function



Ideal Data



Real Life Data

Linear Regression

-used to determine whether or not a voxel is involved in a given motor function

-creates a “line of best fit” through the data points with a slope of β, β = 0 implies no involvement, β ≠ 0 implies involvement

-for each voxel, create two column vectors with as many rows as samples taken

-the first matrix, X, represents time and the second matrix, Y, represents activation levels

-estimate β using the following formula:

$$\beta=(X'X)^{-1}X'Y$$

Likelihood Ratio Test

-method used to generate test statistics—in this case, a t-statistic

-tests H_0: $\beta = 0, \sigma^2 > 0$ vs. H_1: $\beta \neq 0, \sigma^2 > 0$

-find the log likelihood function by taking the log of $L(\beta , \sigma^2)$

-take the partial derivatives of this function with respect to both β and σ^2 under the conditions in both the null and the alternative hypotheses

-take the ratio of the likelihood functions assuming the null and the alternative hypotheses

-using algebra, transform this variable into one which follows the t-distribution

-reject H_0 if $|t| > t_{\alpha/2}(n-q-1)$

Future Work

-consolidate MATLAB functions and revise coding to make these functions more versatile

-look into the conditions surrounding linear regression and determine whether or not this is the best way to look for changes in activation levels

-explore different methods of testing the data to deal with correlations between voxels

References

Rencher, Alvin C. *Linear Models in Statistics. New York: Wiley, 2000. Print*
Rowe, Daniel B., and Brent R. Logan. "A Complex Way to Compute FMRI Activation." *NeuroImage 23 (2004): 1078-092. Print.*