Department of Electrical and Computer Engineering

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Biological Signal Processing

PROJECT REPORT

GLM Analysis and Contrasts

Using SPM Tool

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I. INTRODUCTION

This report explains the analysis and results obtained by performing a full subject level analysis on the SSA data set in order to analysis the brain region with different actions like “audio – video”, “video – audio”, “computation – sentences”, “vertical checkerboard – horizontal checkerboard” and so on. For the project, the software tool called Statistical Parametric Mapping (SPM12) software, which is specially designed for the statistical analysis of neuro-imaging data is installed in MATLAB in order to implement the GLM design matrix [1].

For neuro-imaging, the image data acquired can be a sequence of images obtained from different subjects or a time series of the same object. In neuro-imaging, fMRI is one of the most popular technique, based on BOLD phenomena, used among the neuroscientists in order to understand the deep working of the brain activities towards various inputs and its functionality. Here, fMRI data set is a time series of single object and the active patterns of the brains for different actions are obtained by statistical analysis method, which is General Linear Model (GLM). In addition to that this technique is very effective in producing spatial and temporal related information of the brain function. This method can generate the BOLD signal, where BOLD stands for Blood Oxygenation Level Dependent, by the linear combination of the design matrix and error term.

The project mainly consists of three stages in which the first stage is the pre-processing of the MRI data set followed by designing and implementing the General Linear Model (GLM). Finally, the experiment obtains the active region of the brain for different actions by using different contrast vectors, which is a 11-bit vector, on GLM model. In this project, single regressors are used in the second stage in every case.

II. METHODOLOGY

This section describes about the various stages involved in analyzing the brain region for different actions. Here, a pre-processed data of single subject is used, and the various stages are:

A. Pre-Processing fMRI Data Set

The pre-processing stage comprises of five steps which are slice-timing correction, realignment, co-registration, normalization and smoothing. In the case of fMRI data set it's a time series of single object because of the fact that there will be a small delay between successive slices , therefore it is important to perform slice-timing correction in order to solve this error, whereas a reference point will choose and all other slices will get realigned based on this reference point [2]. In addition to that there will be motion related errors such as rotational and translational errors because of the movement of the head during the MRI scan and this problem can be solved by co-registration process. In this process, a reference volume will choose in the beginning of process and all other images will get spatially transformed to align with the reference image. One of the main steps involves in image co-registration is the spatial normalization in which all the images will compare with special template image in order to ensure the proper alignment of all the images.

Smoothing is one of the important stages in image processing and it comes under preprocessing stage after normalization. The kernel used inside the smoothing is a gaussian filter and the image get smoothened according to the size of kernel window. If the size of the gaussian filter is too wide, then it makes the image more blurry and eventually it leads to poor quality image after performing convolution with gaussian kernel. At the same time if the window size is too low then the presence of noise level may high, so it's very important to keep the gaussian filter window size at optimum level.

Gaussian function, $g\,(i, j) = \frac{e^{-(i^2+j^2)/2\sigma^2}}{\sqrt{2\pi}\sigma}$

Smoothing is the convolution between the image and the gaussian filter,

Smoothened image = conv (image, Gaussian fn)

B. General Linear Model

The model that considered here is a General Linear Model Y = Xβ + E in which X is a matrix having the values of voxels at different time frame of the acquired signal and β is the regression parameter corresponding for each elements in the matrix X, which is the design matrix.

If the matrix X may not include all the effects during a time frame or the regression values not estimated properly then the expectation of Y would not be equal to Xβ and in this case the model is not appropriate. Thereby the statistical results might be invalid.

The parameters of β can be estimated from the following equation,

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

In GLM design matrix, if fMRI study is conducted under five experimental conditions, then the first five columns will record the effects on the response variable as a function of the presence of these conditions, whereas other columns carries the drift values due to motion related errors. And finally, the last columns consist of the whole brain activity in the design matrix.

In SPM tool, Entering the proper regression values in associated with elements in matrix X can help to yield sensible comparisons. In addition to that SPM can ensure that whether the contrast is estimable or not. Furthermore, the tool can also provide necessary protection measures against certain contrast which can might degrade the design, So, in such circumstances it’s very important to improve contrast.

C. Contrast

The model used over here is a General Linear Model Y = Xβ + E, whereas X is the design matrix, E is the error matrix and finally β is the parameter vector. Contrast is the most important part of the statistical analysis of GLM which determines which parameter weights contribute to the test statistics. In here the parameters for the contrast vector is assessed via SPM {F} or SPM {T} and this vector can be obtained by the linear combination of parameter vector (β) and transpose of column vector (C^T).

In this project, T-contrast is used which is given by, $t = {C^T\beta}\Big/{\sqrt{VAR(C^T\beta}}$. The contrast vector for identifying brain reaction for different activities are given below:

ACTIVITY	**CONTRAST VECTOR**
Audio – Video	[0 0 1 -1 1 -1 1 -1 1 -1 0]
Video – Audio	[0 0 -1 1 -1 1 -1 1 -1 1 0]
Computation – Sentences	[0 0 0 0 0 0 1 1 -1 -1 0]
Vertical – Horizontal Checkerboard	[-1 1 0 0 0 0 0 0 0 0 0]
Left click – Right Click	[0 0 1 1 -1 -1 0 0 0 0 0]
Right Click – Left Click	[0 0 -1 -1 1 1 0 0 0 0 0]
Horizontal – Vertical Checkerboard	[1 -1 0 0 0 0 0 0 0 0 0]

Table 1: Activity vs Contrast Vector

During this experiment contrast vector is used to find the regions of the brain which is more active to specific condition or activity. For instance, in this project there are ten experimental conditions having order chkbd_h, chkbd_v, click_L_audio, click_L_video, click_R_audio, click_R_video, computation_audio and computation_video in order to identify the region of brain which is more active. For example, the area of interest in the case of "Audio – Video" activity to find the part of the brain which is more sensitive than video based on the experimental conditions. In order to find the results it is important to assign the right weights to the experimental conditions with the help of contrast vector because of fact that in the contrast vector a negative weightage gives to video component and positive weightage gives to audio component and likewise in all other activities. The results obtained with single regressor are compared and illustrated in the following section.

III. RESULT ANALYSIS

GLM design matrix with single regressor and with different contrasts of interest are represented below. In these design matrix, white, grey and black shades represent regressors. Smallest value of regressors are represented by black color, largest values with white color and intermediate values with grey color. GLM design matrix with single regressor is used to analyze the variability of signal change over the voxels. Each vertical column of the matrix corresponding to the experimental conditions.

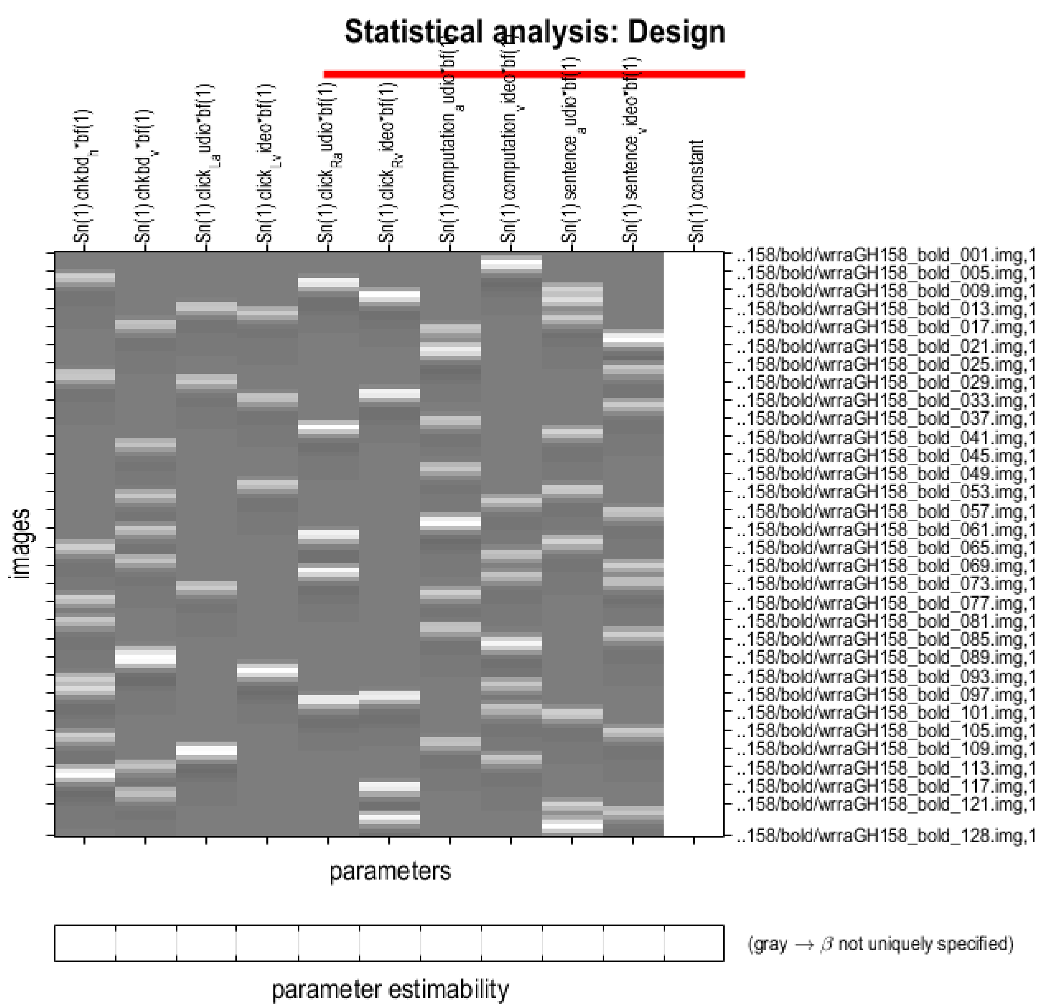
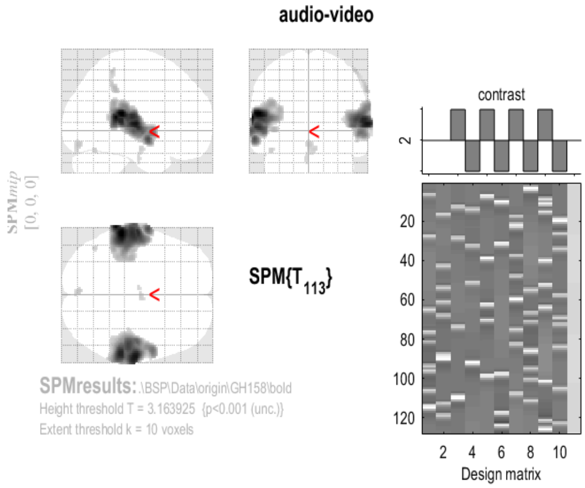
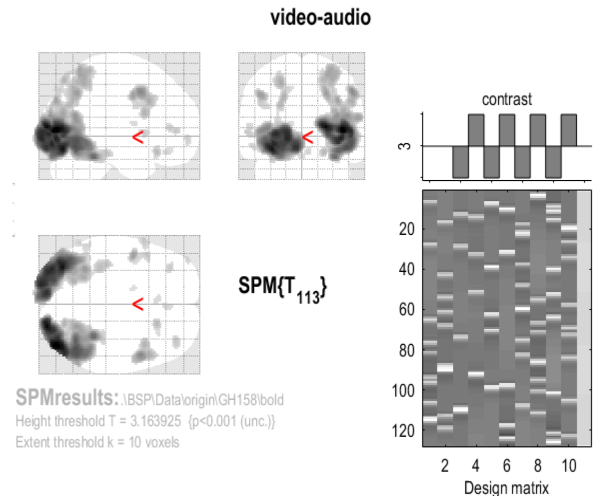


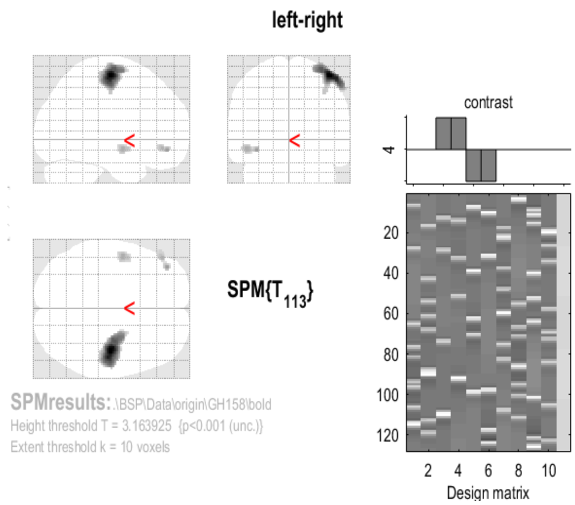
Figure 1 GLM Design Matrix with Single Regressor



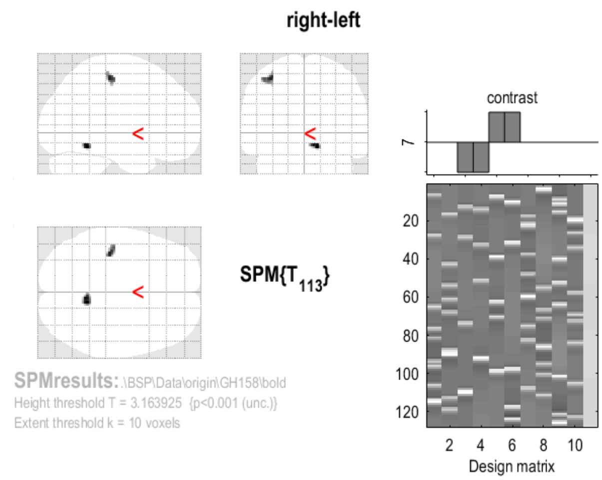
(a) Audio-Video



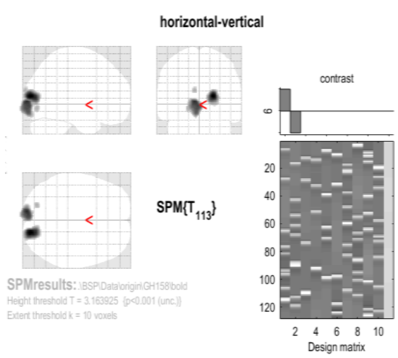
(b) Video-Audio



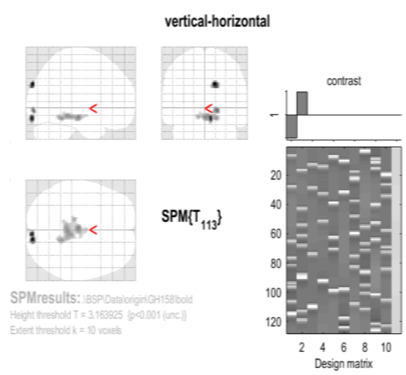
(c) Left-Right



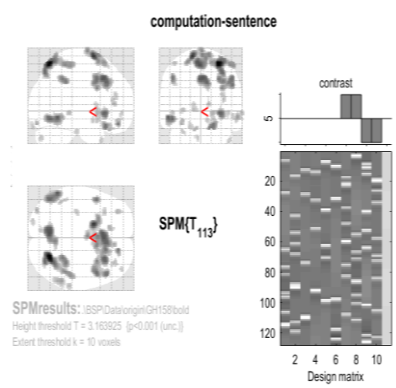
(d) Right-Left



(e) Horizontal-Vertical



(f) Vertical-Horizontal



(g) Computation-Sentence

Figure 2. GLM Design Matrix with different contrasts of interest

Statistical maps obtained using the GLM design matrix with different contrast vector are represented above. Statistical maps of “Audio-Video” represent the part of the brain which is more sensitive to audio with respect to video. Whereas, statistical maps of “Computation-Sentences” represent the part of the brain which is more sensitive to computation with respect to sentences and likewise. Here, black color represents the more sensitive region. SPM also represented the statistical information in form of table including cluster-level, peak-level, etc.

IV. CONCLUSION

Full subject analysis is generally and GLM design matrix with single regressor is analyzed. Concept of Contrast is performed using SPM tool in MATLAB and results obtained using different contrasts of interest are presented in this report. These techniques are used to test different effects and they give statistically significant differences which helps us to know about different activities in brain like which parts are more active. By changing contrast according to our requirement, we can design different effects without having to re-fit the entire model. Future work will be performed using group level analysis.

V. REFERENCES

[1] da Silva AR. A Bayesian multilevel model for fMRI data analysis. Computer methods and programs in biomedicine. 2011 Jun 1;102(3):238-52.

[2] Penny WD, Friston KJ, Ashburner JT, Kiebel SJ, Nichols TE, editors. Statistical parametric mapping: the analysis of functional brain images. Elsevier; 2011 Apr 28.