**Chapter\_3\_Scripts\Step3\_frequency\_analysis folder README**

This document describes the contents of the folder named Step3\_frequency\_analysis. The folder contains scripts with which to conduct the time-frequency analysis described in Chapter 3: Frequency analysis of TMS/TMES response reveals task- dependent shift in central drive to Biceps Brachii. The scripts extract time points from a time-frequency analysis using Matlab’s wavelet sychrosqueezed transform (wsst) and wavelet coherence (wcoher) functions These scripts are automated for this analysis to run on a high performance computer (HPC). This was performed on ARC 4 at the University of Leeds, which uses the Son of Grid Engine scheduler. Scheduling scripts are also provided.

**Dependencies**

* Matlab 2020b
* Matlab Parallel Computing Toolbox

**Contents**

* **Inputfiles**
  + aa.csv … etc (one per subject). Files that Matlab uses as an input for the frequency analysis. These are the files from \Step2\_SortForMatlab\Inputfiles.
* **Results**
  + **WCoh\_2022-03-18\_Amor\_BandsEEG\_FAST\_Unrect\_UID-3641… etc (one per analysis run).** File names detail the analysis type, the date the analysis was run, the parameters, and are assigned a unique ID (UID).
    - aa.csv … etc (one per subject). Data files containing the results for each subject analysed.
    - Anova\_Group\_Pvals\_Two-way.xlsx. Results of ANOVA analysis.
    - N\_trials\_per\_sub.csv. Number of files per condition per subject.
  + WCoh\_2022-03-18\_Amor\_BandsEEG\_FAST\_Unrect\_UID-3641.csv … etc. File containing details of the parameters used for the corresponding analysis.
* \_README.docx. This document.
* cell2csv.m. Matlab script for converting a cell data type to .csv. Credit to: Jerry (2022).
* Coh\_bandpower.m. Matlab script for calculating wavelet coherence within specified bandwidths between two waveforms containing an equal number of samples using the Matlab wcoher() function. There is an option to filter before calculating each band using the filter and aggregate sychrosqueezed transform (FAST) methodology (credit to Desai, 2021), and an option generate plot on completion using plot\_spectrogram.m.
* Coh\_findlat.m. Matlab script with which to extract power spectral density at specified time points using the Matlab wcoher() function.
* Coh\_Processall.m. Matlab script for batch processing of extraction of wavelet coherence in defined bands at time points stored in the input files using wcoher() function. Parallel processing is used to speed up the operation.
* plot\_spectrogram.m. Matlab script for plotting spectrograms of the output of Coh\_bandpower() or WSST\_bandpower().
* run.m. Matlab script for batch processing of analysis performed by WSST\_Processall and Coh\_Processall. Organizes data and performs the analysis based on the specific input parameters.
* sh1\_createUIDs.sh. BASH script for generating UIDs. To be run on HPC prior to running sh\_\*\_run\*.sh scripts.
* sh2\_run\_WSST\_1Hz.sh. BASH script to submit jobs to HPC scheduler to perform WSST analysis with 1 Hz band width.
* sh3\_run\_Coh\_EEG.sh. BASH script to submit jobs to HPC scheduler to perform wavelet coherence analysis with EEG-type band width.
* Workspace.mat (available on request). Matlab workspace containing variables for each subject/condition combination. This is generated by S3\_SpikeToMatlab.m in the Step2\_SortForMatlab folder.
* WSST\_bandpower.m. Matlab script for calculating wavelet synchro-squeezed transform within specified bandwidths using the Matlab wsst() function. There is an option to filter before calculating each band using the filter and aggregate sychrosqueezed transform methodology2, and an option generate plot on completion using plot\_spectrogram.m.
* WSST\_findlat.m. Matlab script with which to extract power spectral density at specified time points using the Matlab wsst() function.
* WSST\_Processall.m. Matlab script for batch processing of extraction of power spectral density in defined bands at time points stored in the input files using wsst() function. Parallel processing is used to speed up the operation.

***Batch performing WSST and wavelet coherence analysis on high performance computer (HPC)***

Step3\_frequency\_analysis is a self-contained folder that can be uploaded to run on an high performance computer (HPC) system. It contains all the scripts necessary to batch automate WSST and wavelet coherence analysis on an HPC. This was performed on ARC 4 at the University of Leeds, which uses the Son of Grid Engine scheduler. The BASH submission scripts etc. may have to be configured to run on different HPCs.

1. Upload the entire folder onto your HPC.
2. Run sh1\_createUIDs.sh. This will automatically generate some UIDs which are used in the file names.
3. Run sh\_\*\_run\*.sh to submit the jobs to the scheduler. You may wish to change the parameters in sh\_\*\_run\*.sh, or in the Matlab script run.m. From here, you can choose the subject, the frequency band configuration, determine whether to perform wavelet coherence or WSST, input the sampling frequency, choose the wavelet type (Amor or Bump), determine whether to perform FAST methodology2, and whether or not to rectify the waveforms. For more information, see the docstrings in the .m files.
4. The results are output into the folder named Results with a name generated using the date, the input parameters, and the unique ID (UID).

The folder named Inputfiles contains input data from the time-frequency analysis in a suitable input for the analysis pipeline, generated in Step2\_SortForMatlab. This will include control data (e.g., mid-biceps contraction, mid-isometric contraction, etc with no stimulation).

***Investigating traces from individual subjects.***

If you want to, you can investigate WSST transforms of individual traces and biceps-triceps wavelet coherence using the scripts WSST\_bandpower.m and Coh\_bandpower.m, respectively.

1. Load Workspace.mat into Matlab.
2. Run WSST\_bandpower.m/Coh\_bandpower.m on your specified input file. The minimum that is required is the input segment and the band boundaries you want to explore. In the workspace variables, the traces for each subject/condition are saved in a cell. You therefore need to specify the number of the trace you want to look at. For example, to plot the data, input:

WSST\_bandpower(biceps\_aa\_cmep\_cycle\_12\_seg{1}, [1 50 100 150 200],[],[],[],[],1)

Or:

Coh\_bandpower(biceps\_aa\_cmep\_cycle\_12\_seg{1}, triceps\_aa\_cmep\_cycle\_12\_seg{1}, [1 50 100 150 200],[],[],0,[],1)

See the docstrings of the functions in the .m scripts for more details.

**References**

Desai A, Richards T, Chakrabarty S (2021). FAST: An extension of the Wavelet Synchrosqueezed Transform. Published online 2021. doi:10.36227/techrxiv.15177819.v2

Jerry (2022). Cell Array to CSV-file [improved cell2csv.m] (https://www.mathworks.com/matlabcentral/fileexchange/47055-cell-array-to-csv-file-improved-cell2csv-m), MATLAB Central File Exchange. Retrieved June 16, 2022.