Fusion of EEG and fMRI

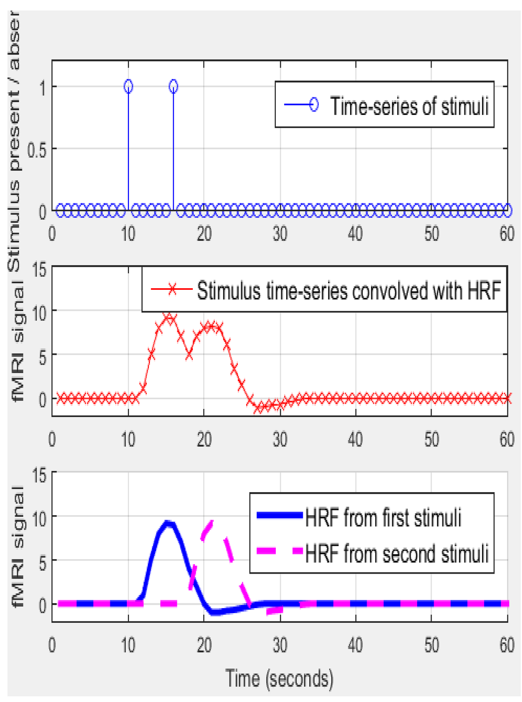
Author: Wong Leong Tim, 黃量添

Supervisor: Prof. Shi Lin

Biomedical Engineering Programme, The Chinese University of Hong Kong

INTRODUCTION

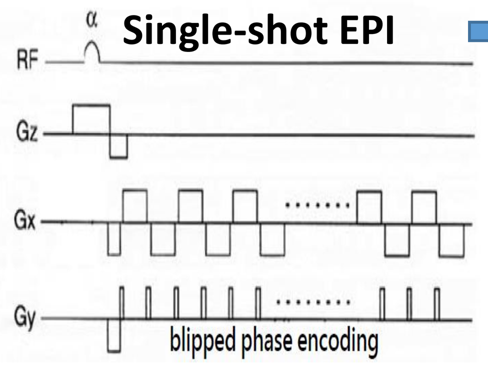
The motivation of EEG-fMRI fusion is to overcome the drawbacks of these two modalities. An EEG-informed fMRI analysis is one of the asymmetrical data integration approaches using the high temporal resolution EEG signal to guide and optimize the high spatial resolution fMRI data analysis.



Data collected from simultaneous EEG-fMRI acquisition contains a substantial amount of noise like gradient-induced EEG artifact, and it has to be removed during pre-processing. Different methods of artifact removal were evaluated.

Data from both motor movement (ME) and motor imagery with visual aid (AO) was analyzed. The choice of EEG channels, EEG rhythms and ways of forming regressors in the GLM were investigated, in the hope of conducting a more comprehensive EEG-informed fMRI analysis.

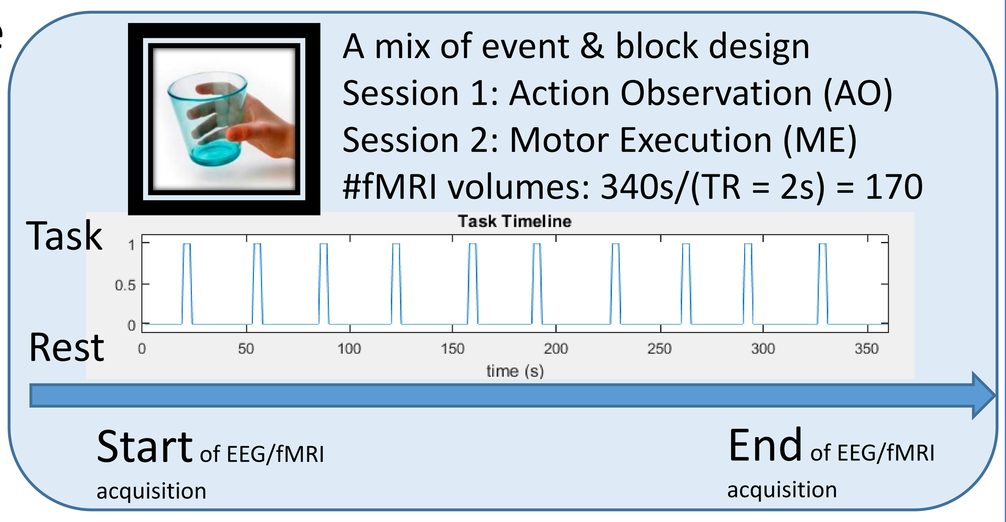
MRI Pulse Sequence: Single-shot EPI



PROPOSED APPROACH

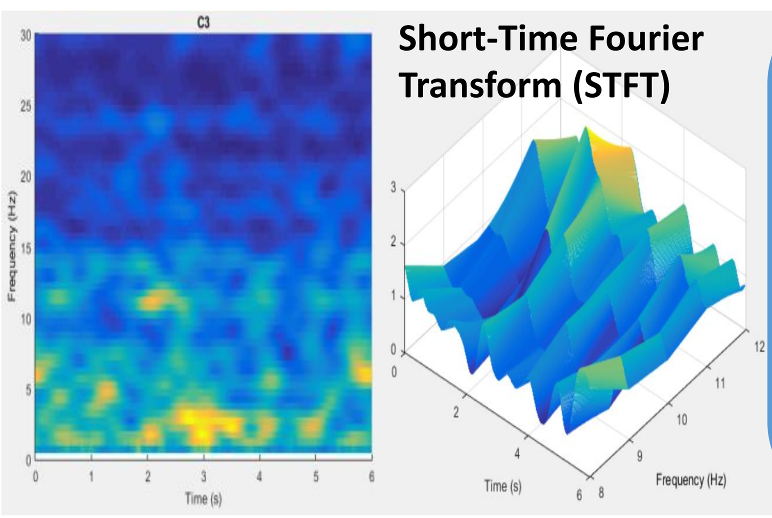
The data from 1 healthy + 6 stroke adults performing left/right hand gripping task was being investigated in the study.

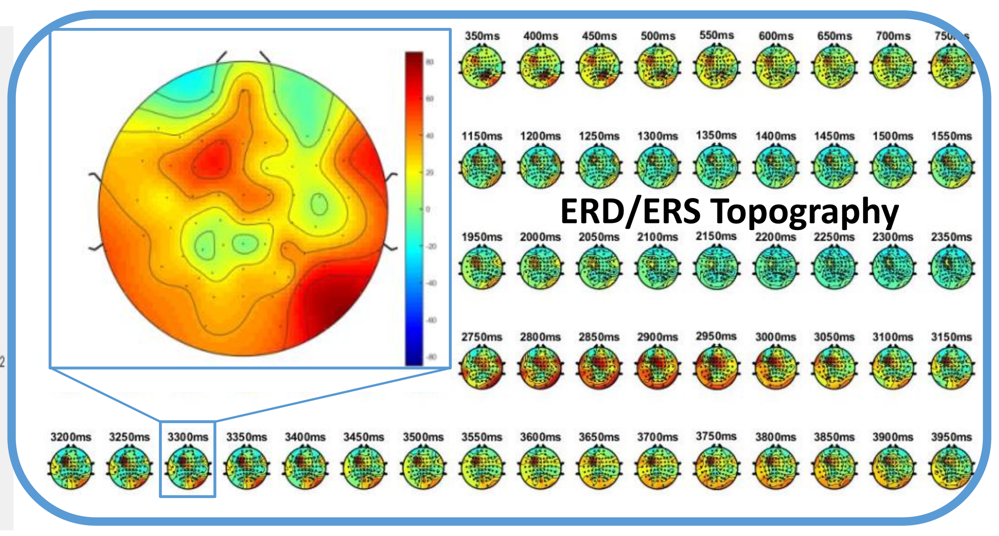
EEG features extraction for GLM in fMRI analysis is very demanding for EEG signal quality, and requires careful consideration on the choice of EEG channels.



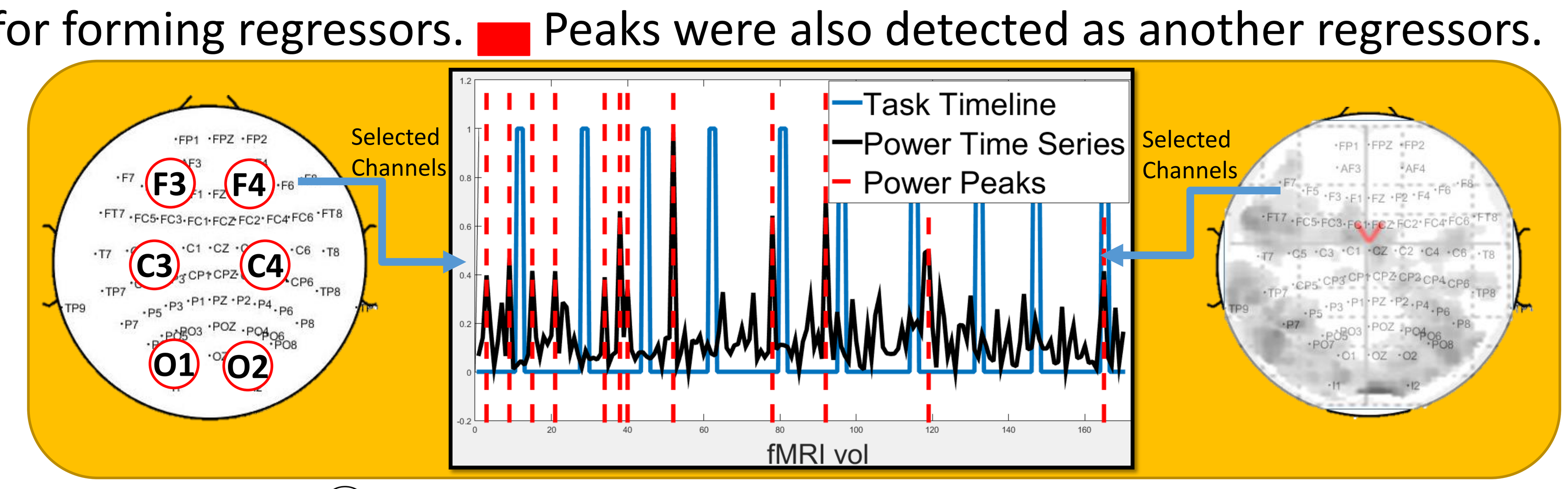
Experimental Paradigm

Gradient artifact (GA) is an electromagnetic interference induced by turning on and off the gradient coil of MR scanner. It was removed offline using three methods implemented in different libraries or plugins for EEGLAB.

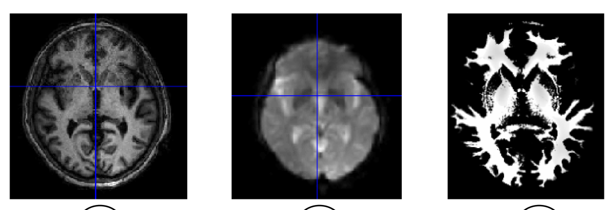




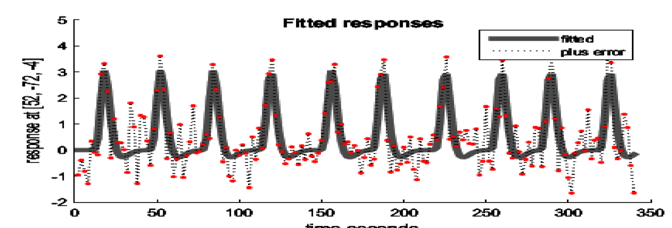
1) Six channels spanning frontal, central, occipital cortex and 2) channels with significant activation from EEG and fMRI-alone analysis were selected for further analysis. EEG time-frequency analysis was performed using STFT/FIR filtering to 1) compute the ERD/ERS showing activated areas during tasks and 2) extract ■ Power Time Series from specific bandwidth (8-12Hz for α wave) for forming regressors. ■ Peaks were also detected as another regressors.



①Structural and ②functional MRI images were pre-processed before statistical analysis. ③Tissue probability maps from white matter and cerebrospinal fluid were used to exclude physiological noise from these areas. Regressor of ■ Task Timeline convoluted with HRF is shown below. Data from each voxel was checked to see how closely it matches the regressors of the GLM model.



① ② ③



fMRI data = Design matrix * Model parameters + Residual

$\underline{Y} = \tilde{X}\,\underline{\beta} + \underline{\varepsilon}$, $\underline{\varepsilon} \sim N(0,\tilde{V})$ → General Linear Model (GLM)

Nx1 NxP Px1 Nx1 NxN, N time points, P regressors

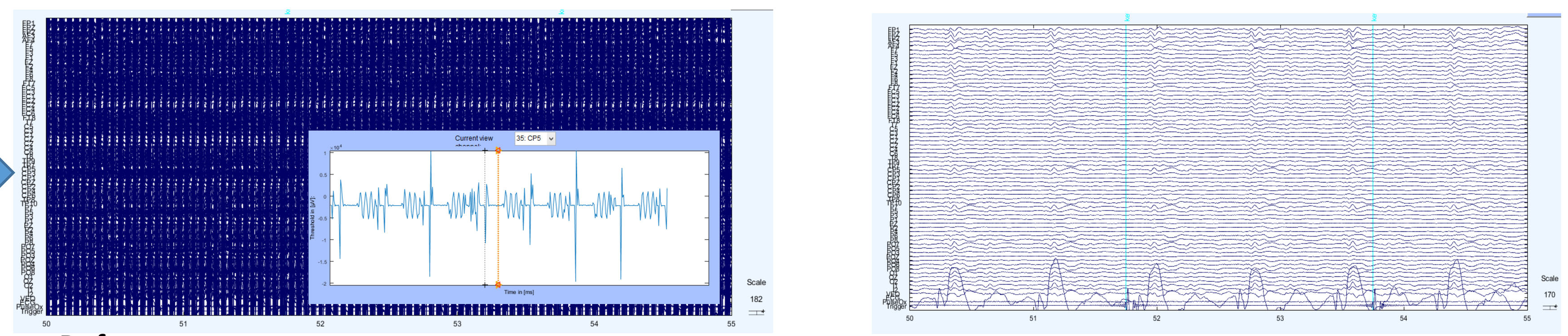
Measured: $\underline{Y}$, User defined: $\tilde{X}$, Unknown: $\underline{\varepsilon}$, $\tilde{V}$, Want to find: $\underline{\beta}$

Goal of linear regression is to minimize sum of square of residuals (SSE)

$= \varepsilon_1^2 + \varepsilon_2^2 + \ldots + \varepsilon_n^2 = \underline{\varepsilon}'\,\underline{\varepsilon}$

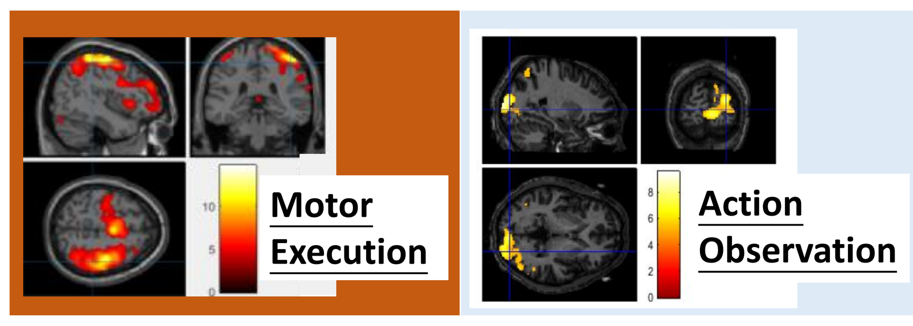
RESULTS

Overall, the Moving Average Algorithm implemented in the Bergen plugin was more successful in the reduction of gradient artifact in comparison to AMRI and FMRIB, retaining the original shape and amplitude of the signal.



Before After

fMRI analysis
- **ME**
- **AO**



For a single subject performing left hand task, most activated areas are located at **right inferior temporal gyrus, supplementary motor area** (AO) **and right precentral gyrus** (ME).

AO
- **fMRI analysis**
- **EEG-informed fMRI analysis**

Most activated area from alpha power informed fMRI analysis is **left parietal superior gyrus**, which processes visual input and was NOT identified in fMRI-alone analysis. Results from different regressors built from channel pair C3/C4 (the best) are shown on the right.

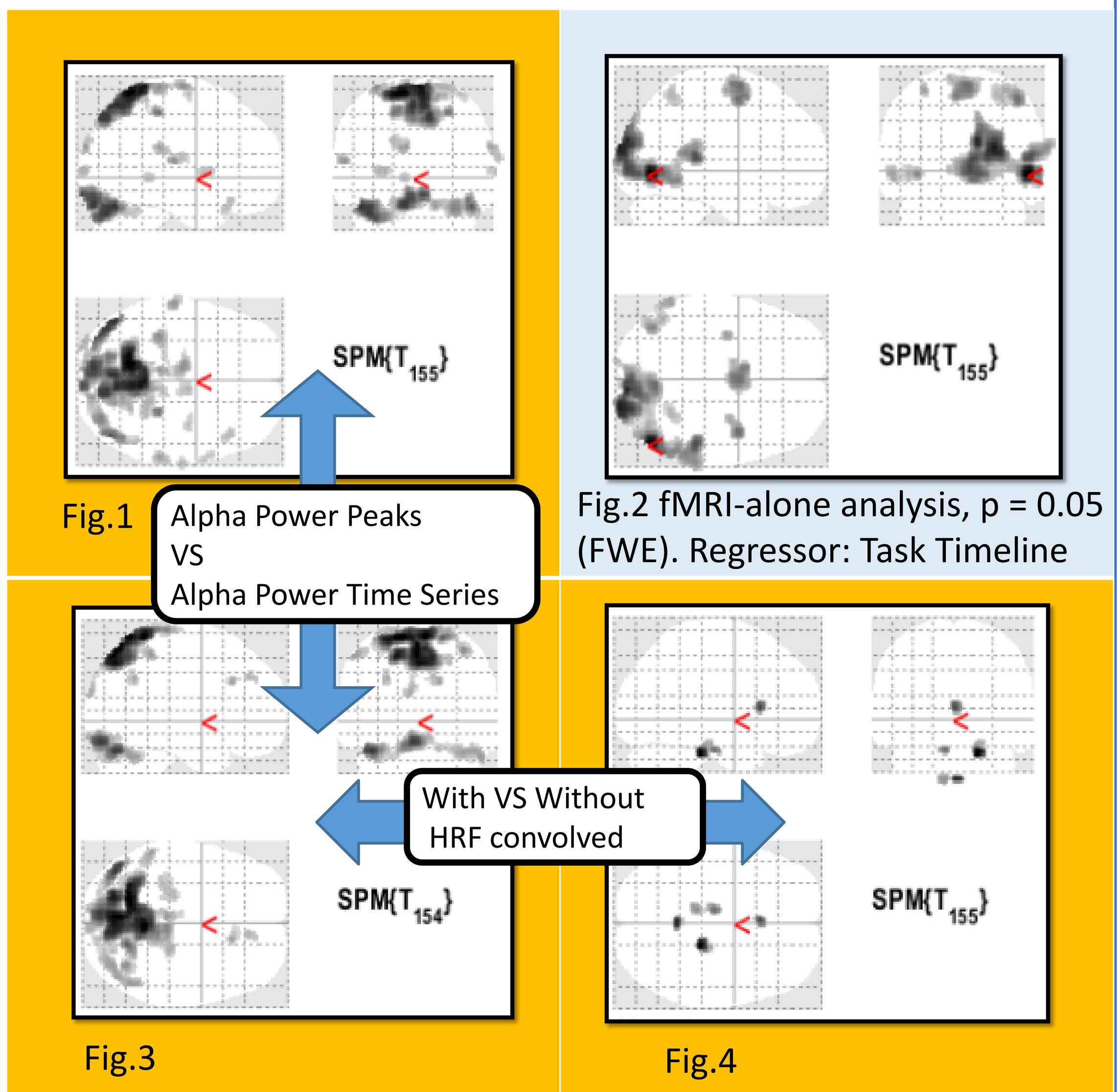


Fig.2 fMRI-alone analysis, p = 0.05 (FWE). Regressor: Task Timeline

Fig.1,3,4: examples of EEG-informed fMRI, p = 0.001 (uncorrected)

CONCLUSION

With the proposed data preprocessing and regressors design, fMRI analysis guided by the denoised EEG signal was able to identify brain areas with significant activation. Some EEG channels not documented to be related to the experimental task can also localize activated areas. This study shows a discrepancy between fMRI and EEG-informed fMRI result, which is open for interpretation and future studies. Fusion of EEG and fMRI can offer a new alternative because the EEG-informed regressors can tackle fMRI mismodelling and incorporate pre/post stimuli response and parametric modulation.

REFERENCES

1. *Neuroimage*, vol. 102, no. 1, pp. 24–34, 15 Nov. 2014. [Online]. Available: ScienceDirect, http://www.sciencedirect.com.
2. M. Lindquist, "Introduction to fMRI", "Pre-processing II", "Model Building I", "Noise Model" in *Statistical Methods in functional MRI*, Department of Biostatistics, Johns Hopkins University, 2015, ch. 1,9, 2,13. [Online]. Available: Coursera, https://www.coursera.org
3. P.J. Allen, O. Josephs, R. Turne, "A Method for Removing Imaging Artifact from Continuous EEG Recording during Functional MRI" *NeuroImage* , Vol. 12, no. 2, pp. 230-239, Aug. 2000. [Online]. Available: ScienceDirect, http://www.sciencedirect.com.

ACKNOWLEDGEMENT

I would like to thank Prof. Shi Lin, Mr. Lou Wu Tao (Imaging and Interventional Radiology) and Prof. Tong Kai Yuen (Electronic Engineering) for offering the data from their collaborative project for this study and for their valuable discussions and comments.