Day-3: Laboratory Exercise on MEG Data.

An MEG dataset for motor and cognitive imagery-based brain-computer interface

Aims

- Study of neuroimaging data obtained from MEG scanner during motor imagery and cognitive imagery tasks.
- Developing a BCI decoder.

Objectives

Attendees will familiarise with an MEG data-set and its usage in a BCI decoder design. The data-set is available on-line as part of the following *Scientific Data-Nature* paper. Attendees are advised to download the data-set in advance of attending the SN^3 Autumn School.

Rathee, D., Raza, H., Roy, S., & Prasad, G. (2021). A magnetoencephalography dataset for motor and cognitive imagery-based brain–computer interface. *Scientific Data-Nature*, (8), [120]. https://doi.org/10.1038/s41597-021-00899-7.

MEG data-set at figshare Collection: A magnetoencephalography dataset for motor and cognitive imagery BCI (figshare.com)

Introduction

Recent advancements in magnetoencephalography (MEG)-based brain-computer interfaces (BCIs) have shown great potential in more accurate detection of mental imagery related brain activities. BCIs can detect and translate brain activities into actions and thus, provide a potential medium for communication and rehabilitation for patients with severe neuromuscular impairments. MEG has the advantage of recording brain activity across the whole scalp while maintaining much higher spatial and temporal resolution. In addition, compared to EEG, MEG allows detection of higher frequencies as magnetic fields are less attenuated by the head bone and tissue as compared to electric fields. However, the performance of current MEG-BCI systems is still inadequate and one of the main reasons for this is the unavailability of open-source MEG-BCI datasets. MEG systems are expensive and hence MEG datasets are not readily available for researchers to develop effective and efficient BCI-related signal processing algorithms. We have released a 306-channel MEG-BCI data recorded at 1kHz sampling frequency during four mental imagery tasks (i.e. hand imagery, feet imagery, subtraction imagery, and word generation imagery). The dataset contains two sessions of MEG recordings performed on separate days from 17 healthy participants using a typical BCI imagery paradigm. The current dataset is the only publicly available MEG imagery BCI dataset as per our knowledge. The dataset can be used by the scientific community towards the development of novel data analytics and machine learning methods to detect brain activities related to motor imagery and cognitive imagery tasks using MEG signals. The data recording paradigm, participants demographics, data acquisition procedure, details of data records and results of preliminary data analysis are available in the article: https://doi.org/10.1038/s41597-021-00899-7.

We have provided the MEG BCI dataset in two different file formats:

1. Brain Imaging Data Structure **(BIDS)**. To read more click and under BIDS format the raw data is available in Functional Image File Format **(.fif)** files. To read more click.
2. MAT-file is the data file format MATLAB **(.mat)**.

As part of a preliminary data analysis, pre-processing and feature extraction of the MEG data, as well as the single-trial classification were performed using custom MATLAB codes based on Fieldtrip toolbox functions. All codes are available at our GitHub repository https://github.com/sagihaider/MEGBCI2020.git.

In this repository, we have provided MATLAB scripts for the following tasks:

1. *Step0_script_fif2bids.m* : Script to convert MEG data from Elekta MEG format (.fif) to .MAT format.

2. *Step1_script_bids2mat.m* : Script to convert MEG data from BIDS format to .MAT format.

3. *Step2_script_mat2features_CN3lab.m*: Script to extract the motor and cognitive imagery features using common spatial patterns (CSP) algorithm.

4. *Step_3_script_ClassifyFeatures_SN3lab.m*: Script for single-trial MEG classification to produce the baseline results.

For running the above scripts, please download the above repository as <MEGBCI2020-master.zip> and extract the files in a folder (eg. \MEGBCI2020-master) and use that folder as your current directory in MATLAB.

We have used fieldtrip toolbox for basic pre-processing of MEG BCI dataset. As a dependency we recommend to download and add fieldtrip to your MATLAB path. The fieldtrip version used in the above scripts can be downloaded from: https://github.com/sagihaider/fieldtrip.git.

Task-1

Load one subject's data-set (eg. *sub-1_ses-1_task-bcimici_meg.mat*) in MATLAB environment. Find out what variable type is used to store the data of a recording session. Find out the types and contents of the fields used to store a data record.

Task-2

The MATLAB script in the file < *Step2_script_mat2features_CN3lab.m*> extracts trial-wise task relevant features in multiple different ways. The extracted features are used in the MATLAB script file <*Step_3_script_ClassifyFeatures_SN3lab.m*> to train binary classifiers and test their task decoding accuracy on an unseen data-set. Run the codes in these files to observe their functioning. Based on these scripts, work out the following questions.

- What pairs of task classes are studied in the scripts?
- What features are extracted?
- Which MEG sensors are used for feature extraction?
- Which recording session is used for classifier training?
- Find out 10-fold cross validation (CV) decoding accuracy for different task class pairs for the subject_1 and the subject_2. Also, find decoding accuracy for different task class pairs, when the trained classifiers are applied to the recording session data that was not used in classifier training.
- Make appropriate modifications in the scripts to find 10-fold CV decoding accuracy on one recording session and test accuracy on a different recording session data for the subject_3.

Task-3

Think of how you can improve the BCI decoding accuracy using an MEG data-set. You may like to take up this task as a project work to be worked out in your own time. There are several ways to undertake this task. Firstly, this data-set can be used to test the effectiveness of already developed BCI data analysis pipelines in other projects. Secondly, we encourage any use that can contribute towards development of novel data analysis and machine learning methods to detect brain activities related to motor imagery (MI) and cognitive imagery (CI) tasks using MEG signals. Thirdly, since we have performed a basic analysis and single-trial classification of tasks using the raw data, future work may involve exploring impact of various MEG pre-processing methods e.g. head movement correction.

Additionally, as the dataset contains two sessions that were recorded on different days for each participant, robustness of data analysis pipelines towards inter-session non-stationarity can be assessed using this dataset.

References for Further Reading

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