Visualising a multi-modal neuroimaging dataset

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DATA FROM THE CENTRAL NERVOUS SYSTEM (CNS)

- Electroencephalography (EEG): measuring neural activity through recording electrical activity originating from the brain
- Magnetoencephalography (MEG): measuring neural activity through recording magnetic fields originating from the brain
- functional Magnetic Resonance Imaging (fMRI): measuring neural activity through changes in blood flow in the brain
- ...

DATASET

- **“A multi-subject, multi-modal human neuroimaging dataset”** (Wakeman & Henson, 2015):
  - Freely available
  - EEG, MEG, and fMRI for 19 subjects
  - Multiple runs of hundreds of trials of a simple perceptual task on pictures of familiar, unfamiliar and scrambled faces
  - Through the combination of multiple modalities aim to increase the spatial and temporal resolution above that of any one modality alone

INTENTION

- Focus on EEG and MEG
- Provide a flexible but simple visualisation for comparisons of the EEG and MEG data
- Allow for simple operations such as windowing, averaging, and fourier transforms
- Target users are neurology researchers who can use it as:
  - For understanding the brain
  - For learning patterns
  - Domain expert in the context of A.I., for finding and correcting artefacts

APPROACH

PREPROCESSING: FREQUENCY FILTERING

- Oscillating signals originating from the CNS are often divided into frequency bands:

Brainwave	Frequency band	Mental condition
Delta	0 – 4 Hz	State of deep sleep, when there is no focus, the person is totally absent, unconscious.
Theta	4 – 8 Hz	Deep relaxation, internal focus, meditation, intuition access to unconscious material such as imaging, fantasy, dreaming.
Low Alpha	8 – 10 Hz	Wakeful relaxation, consciousness, awareness without attention or concentration, good mood, calmness
High Alpha	10 – 12 Hz	Increased self-awareness and focus, learning of new information.
Low Beta	12 – 18 Hz	Active thinking, active attention, focus towards problem solving, judgment and decision making.
High Beta	18 – 30 Hz	Engagement in mental activity, also alertness and agitation.
Low Gamma	30 – 50 Hz	Cognitive processing, senses, intelligence, compassion, self-control.
High Gamma	50 – 70 Hz	Cognitive tasks: memory, hearing, reading and speaking

Table: CNS signal frequency bands. Data from Kawala-Sterniuk et al. (2021).

APPROACH

PREPROCESSING: FREQUENCY FILTERING

- Often recording devices record more frequencies
- Only interested in 0 to 70 Hz, so we filter out all other frequencies

APPROACH

PREPROCESSING: DOWNSAMPLING

- According to Shannon-Nyquist sampling theorem (Shannon, 1949), sampling frequency should be $> 2 \cdot$ upper frequency bound
- Hence, we can downsample to 150Hz ($> 2 \cdot 70$Hz)
- The visualisation now also requires a 45Hz version
- This and dropping other irrelevant data significantly reduces the size of the dataset: 78GB to 7.1GB

APPROACH

PREPROCESSING: ARTEFACT CORRECTION

- Aside from the activity of interest, a lot of other things are happening in the human body
- These will result in noise in the data, i.e., artefacts, e.g., heartbeat and eye-blinks
- To filter out these artefacts, artefact correction techniques are used, in our case: Independent Component Analysis (ICA; Sun et al., 2005) in combination with 2 Electrooculography (EOG) channels and 1 Electrocardiography (ECG) channel

APPROACH

PREPROCESSING: ARTEFACT CORRECTION

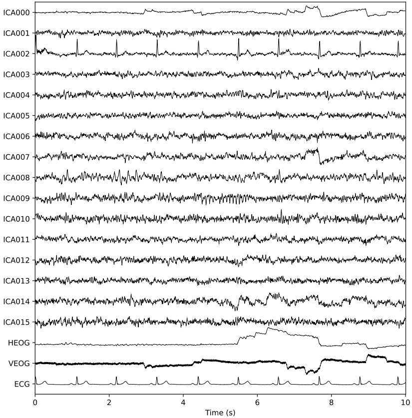


Figure: 10 seconds of 16 ICA components of the data, including EOG and ECG channels.

APPROACH

PREPROCESSING: METADATA EXTRACTION

- Clear separation between core neuroimaging data and metadata:
  - Age
  - Sex
  - EEG electrode locations (subject specific)
  - MEG sensor locations (equivalent for all subjects)

APPROACH

MOCK-UP: MAIN PAGE

Subject A

Subject A

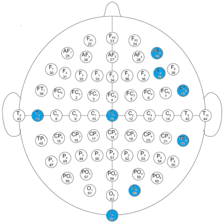
Subject A

Subject A

Subject A

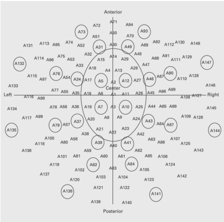
- Sex: Female
- Age: 22
- ...

EEG



- [x] Visual
- [ ] Motor
- [ ] Sensory
- [ ] ...
- [ ] ...
- [ ] ...

MEG

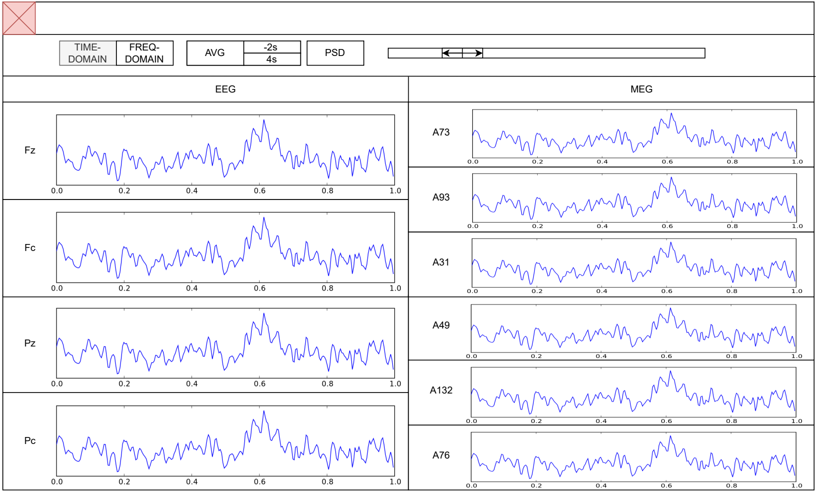


- [x] Visual
- [ ] Motor
- [ ] Sensory
- [ ] ...
- [ ] ...
- [ ] ...

GO

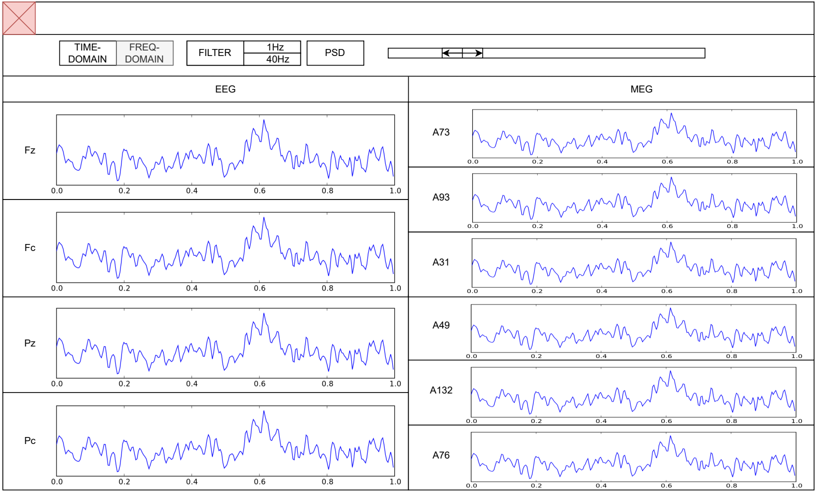
APPROACH

MOCK-UP: TIME DOMAIN PAGE



APPROACH

MOCK-UP: FREQUENCY DOMAIN PAGE



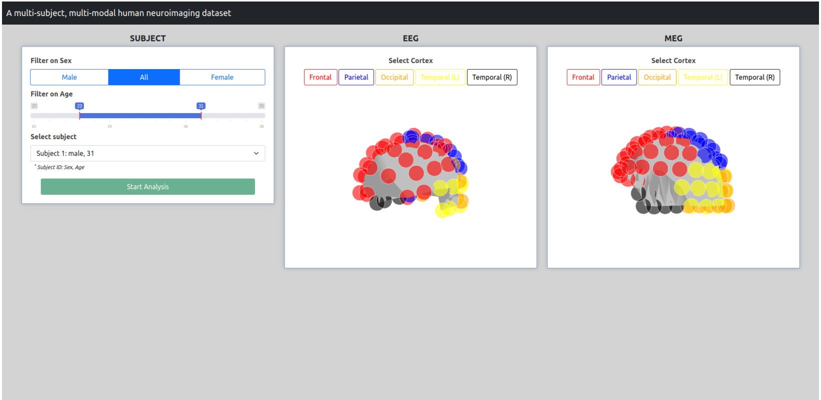
APPROACH

VALIDATION: INITIAL RESEARCH

- Understanding the field:
  - Refreshing signal theory knowledge
  - Superficial study of neurology, EEG, and MEG
- Analysing what exists:
  - Python MNE library (Gramfort et al., 2013)
  - FieldTrip package (Oostenveld et al., 2010)
  - ...
- Informing through family/friends that study medicine/neurology or are doctors/neurologists

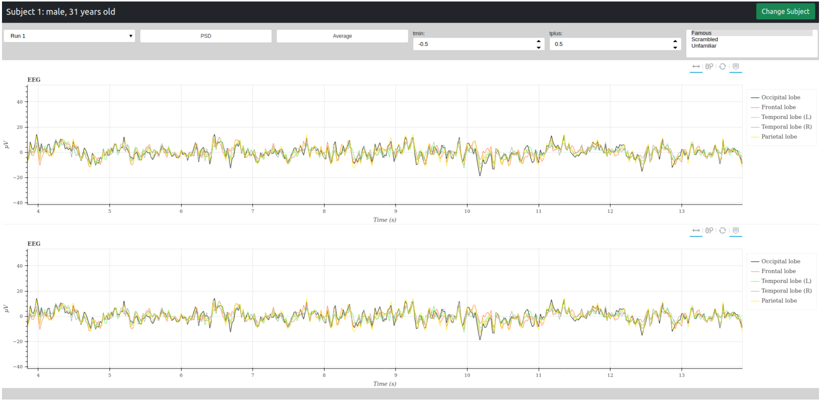
RESULTS

FIRST VERSION: FIRST PHASE



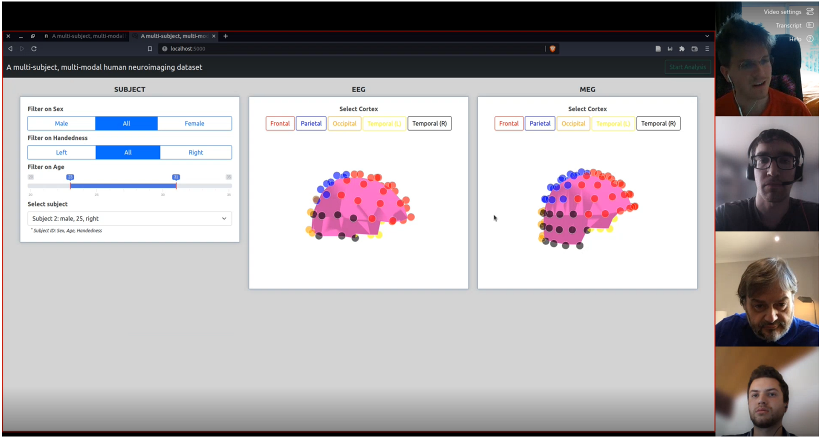
RESULTS

FIRST VERSION: SECOND PHASE



APPROACH

VALIDATION: QUALITATIVE INTERVIEW WITH PROF. DR. IR. GUY NAGELS



APPROACH

VALIDATION: QUALITATIVE INTERVIEW WITH PROF. DR. IR. GUY NAGELS

- “From what you have I can see that you have a good understanding of the data.“
- Clinical neurologists have lots of specific needs:
  - Viewing individual electrodes/sensors
  - Setting up montages
  - Inter-subject comparisons
  - ...

  handling all of these would be hard for a small group
- However, neurology researchers can benefit a lot from such a visualisation, both in the context of neurology and in the context of A.I.

APPROACH

VALIDATION: QUALITATIVE INTERVIEW WITH PROF. DR. IR. GUY NAGELS

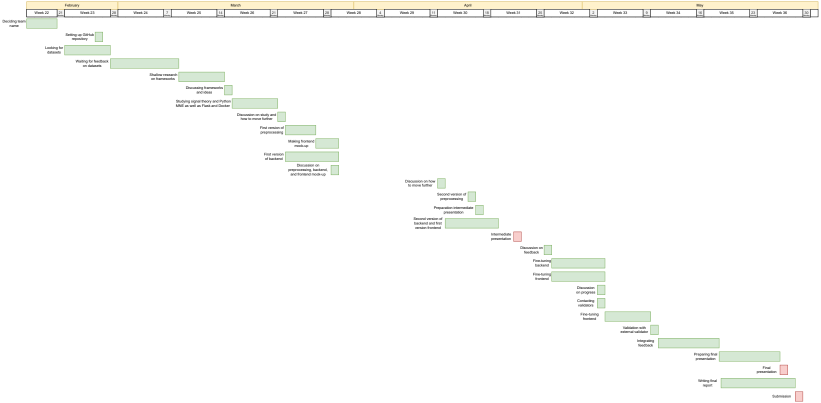
- Specific comments:
  - It would be nice to have the 3D channel placements next to the signal plots, making it clear at any point what you are actually looking at
  - The power-spectral density feature is useful, it clearly shows which frequencies show the most activity, allowing researchers to relate this to the frequency bands
  - The average overview is a common way to show a complete run, the eye can not differentiate between sampling frequency differences, it is the calculation of the windows and power-spectral densities that must have the higher sampling frequencies

RESULTS

DEMO

```
panel serve visualisation/run.py
```

QUESTIONS


February
March
April
May
Week 22
21
Week 23
28
Week 24
7
Week 25
14
Week 26
21
Week 27
28
Week 28
4
Week 29
11
Week 30
18
Week 31
25
Week 32
2
Week 33
9
Week 34
16
Week 35
23
Week 36
30
Deciding team name
Setting up GitHub repository
Looking for datasets
Waiting for feedback on datasets
Shallow research on frameworks
Discussing frameworks and ideas
Studying signal theory and Python MNE as well as Flask and Docker
Discussion on study and how to move further
First version of preprocessing
Making frontend mock-up
First version of backend
Discussion on preprocessing, backend, and frontend mock-up
Discussion on how to move further
Second version of preprocessing
Preparation intermediate presentation
Second version of backend and first version frontend
Intermediate presentation
Discussion on feedback
Fine-tuning backend
Fine-tuning frontend
Discussion on progress
Contacting validators
Fine-tuning frontend
Validation with external validator
Integrating feedback
Preparing final presentation
Final presentation
Writing final report
Submission

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