MEG Data Analysis

1 What is MEG?

Magnetoencephalography (MEG) is a neuroimaging method used to track and record the magnetic fields produced by the brain during various activities. These magnetic signals are extremely weak, requiring highly sensitive sensors such as **SQUIDs** (Superconducting Quantum Interference Devices) to detect them accurately. These sensors are placed within a helmet-like device that sits over the head and records the brain's magnetic activity.

Due to the weak nature of MEG signals, MEG systems are typically housed in **magnetically shielded rooms** to minimize interference from external magnetic sources such as power lines, electronic devices, and vehicles. This shielding ensures a high signal-to-noise ratio, allowing for more precise data collection and analysis.

MEG is widely used in **neuroscience, clinical diagnostics, and brain-computer interface research** to study brain function, identify epileptic activity, and analyze cognitive processes.

2 Tools Used

To analyze and manipulate the MEG dataset, we used **MNE-Python**, a Python module designed for processing, analyzing, and visualizing functional neuroimaging data. MNE-Python supports multiple neuroimaging data, such as **EEG, MEG, ECoG, fNIRS, and sEEG**.

2.1 Python Packages Used

- `os` → Used to handle file paths
- `mne` → The package used for MEG data processing and visualization
- `matplotlib.pyplot` → For plotting MEG signals

2.2 Functions Used

- `raw.info` → Displays metadata about the dataset (e.g., sampling rate, channel names, bad channels, etc.)
- `raw_meg = raw.pick(['meg'])` → Extracts only the MEG channels from the given dataset
- `raw_meg.drop_channels(raw_meg.info['bads'])` → Removes bad channels from the dataset for cleaner analysis
- `raw_meg.plot(duration=10, n_channels=5)` → Plots 5 MEG channels over a 10-second window

These tools and functions are used to preprocess and visualize the MEG signals effectively.

3 Dataset

The data used in this analysis was acquired with the Neuromag VectorView system, located at the MGH/HMS/MIT Athinoula A. Martinos Center for Biomedical Imaging. The dataset includes both **MEG (Magnetoencephalography)** and **EEG (Electroencephalography)** signals, recorded simultaneously. In this particular experiment, **checkerboard patterns** were presented to the subject in the left and right visual field, interspersed by tones to the left or right ear. The interval between these stimuli was 750 ms. Occasionally, a **smiley face** was displayed at the center of the visual field, prompting the subject to press a key with their right index finger as quickly as possible after seeing the smiley face.

3.1 Signal Description

The dataset contains both **EEG** and **MEG** signals, recorded from a combination of **EEG electrodes** and **MEG sensors**. These signals capture the brain's magnetic activity during the experiment, with MEG data providing information on the **magnetic fields** generated by neuronal currents.

- **EEG Data**: Captures the electrical activity of the brain through surface electrodes placed on the scalp.
- **MEG Data**: Records the magnetic fields generated by neuronal currents, with higher spatial resolution compared to EEG.

3.2 Brain Regions and Sensor Locations

The **MEG signals** are recorded from various parts of the brain, depending on the sensor placements. The sensors in the **Neuromag VectorView system** are distributed across the scalp to measure the magnetic fields generated by brain activity. These sensors are specifically sensitive to the **magnetic fields** produced by neuronal currents within the brain's cortical areas.

3.2.1 How to Identify Brain Regions

The sensor locations and their corresponding brain areas can be identified by the channel names, which reflect the positioning of the sensors on the head. For example, the sensor **MEG 0113** corresponds to a **magnetometer** sensor placed at a specific location on the scalp. Using **MRI scans** and the system's **coordinate frame**, you can map these sensor locations to specific brain regions. For instance:

This method can be applied to all other sensors in the dataset to determine the corresponding brain areas they monitor.

4 Understanding the Graph

When plotting MEG signals, the **X-axis** and **Y-axis** represent key aspects of the brain's magnetic activity.

- **X-axis: Time** → The X-axis represents **time** in seconds, showing how the MEG signals change over time. This helps in tracking neural responses to different stimuli or events.
- **Y-axis: Magnetic Field Strength** → The Y-axis represents **the strength of the recorded magnetic fields**. MEG signals are typically in the femtoTesla (**ft**) range because the brain's magnetic fields are incredibly small.

4.1 Graph Interpretation

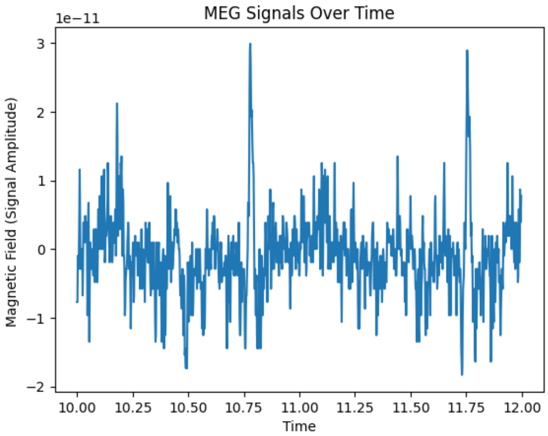

Figure 1: MEG Signal

- Each line in the plot represents the activity recorded by a different MEG sensor over time.
- Peaks and dips in the signals correspond to neural activity fluctuations.