Dynamic identification of brain networks by Bayesian tracking of electrophysiological data

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Introduction

1. **Decoding functional brain networks** is key to understanding not only **higher order cognitive functions**, but also in pathologies like **epilepsy**.
2. **Electroencephalography** (EEG) and **magnetoencephalography** (MEG) measure electric and magnetic fields due to the electrical activity of neurons in the brain.
3. Both EEG and MEG are **non-invasive methods** and have **sub-millisecond temporal resolution**.
4. However, **neither of the recording modalities** give any **information** about the underlying **network structure**.
5. In our project **BrainTrack**, we propose a novel method to estimate functional brain connectivity using **Bayesian tracking**.

Significance of research

1. Pathologies like epilepsy can be considered as **network disorders**.
2. Tools for the characterization of epileptic activity as a **dynamic functional network** can greatly aid the accurate **localization** of **epileptic foci**.
3. Many higher order cognitive functions rely of **dynamic reconfiguration** of **functional brain networks**.
4. Thus, dynamic functional connectivity estimation can be of great importance to **cognitive and systems-level neuroscience**.
5. Also, our method allows for real-time connectivity estimation, which can greatly benefit **neurofeedback** experiments.

Research objectives

1. To develop a common **statistical framework** for the source and connectivity estimation.
2. To incorporate of **soft priors** such as connectivity information from diffusion tensor imaging data.
3. To offer **real-time** estimation of brain connectivity for neurofeedback experiments.

Research methodology

Forward modeling

1. Individual magnetic resonance images (MRI) will be segmented using **FreeSurfer** software.
2. Realistic head model including white matter, grey matter, cerebrospinal fluid, skull and scalp will be constructed using boundary element method (BEM).
3. Lead field matrix mapping the sources to EEG/MEG sensors will be derived using the MEG/EEG analysis software **MNE**.

Preprocessing of EEG/MEG data

1. EEG/MEG will be preprocessed using the **FieldTrip** toolbox.
2. Independent component analysis will be used to remove ocular artifacts.
3. Signal space separation will be used to enhance the quality of MEG data.

Inversion and connectivity estimation

1. Spatio-temporal particle filter algorithm will be developed and implemented to estimate network structure along with neural source parameters.
2. Rao-Blackwellization will be used to ensure efficiency with high state dimensions.
3. The estimation of source signals X_t and connectivity parameters θ_t from the observations $Y_{1:t}$ will be given by the posterior probability distribution $p(X_t, \theta_t | Y_{1:t})$.

Research framework

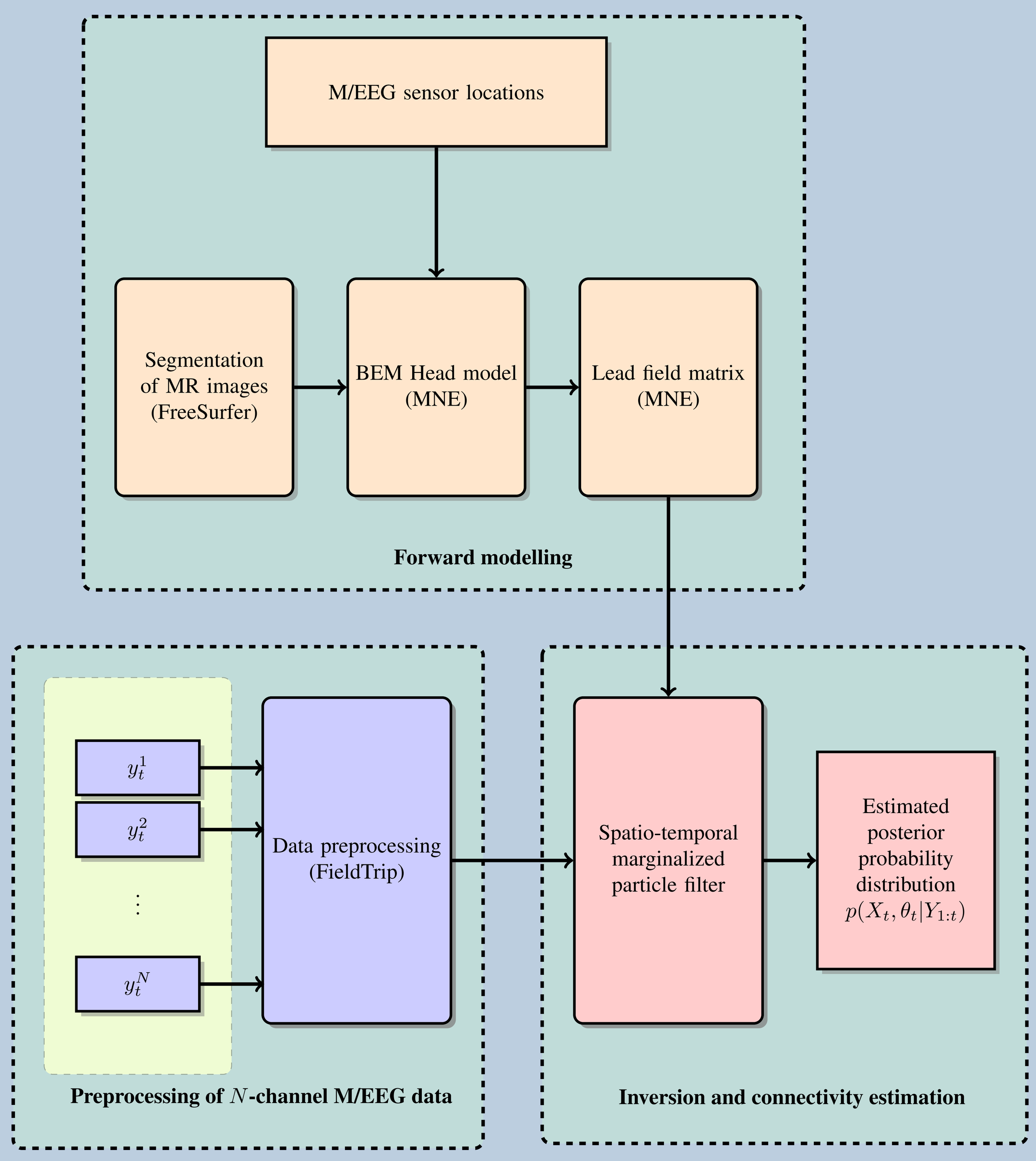

Figure 1: Research framework representing the workflow of different modules

Expected results and impact

1. An on-line platform for **accurate and real-time** estimation of functional brain connectivity from electrophysiological data.
2. **Better characterization** of spreading of pathological activity in **network disorders** like epilepsy.
3. **Neurofeedback** based on functional brain networks.
4. The results of BrainTrack project will find quick acceptance within the EEG/MEG community, among **cognitive neuroscientists** and as well as **clinical researchers**.