Lead-field Matrix for neurolib

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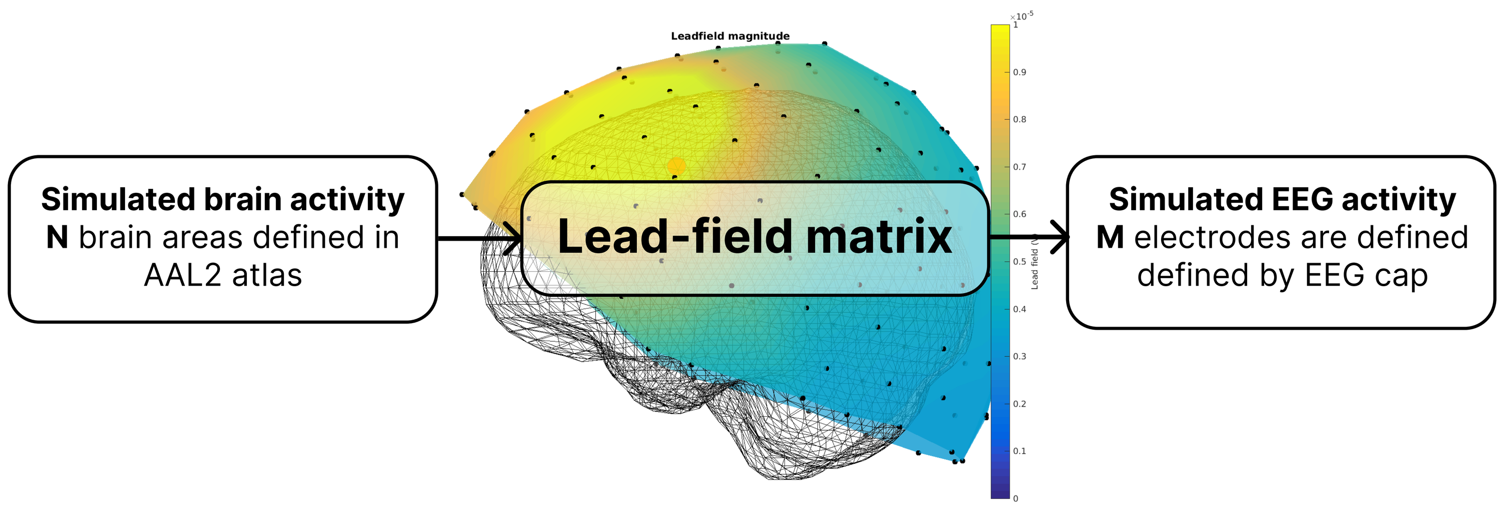
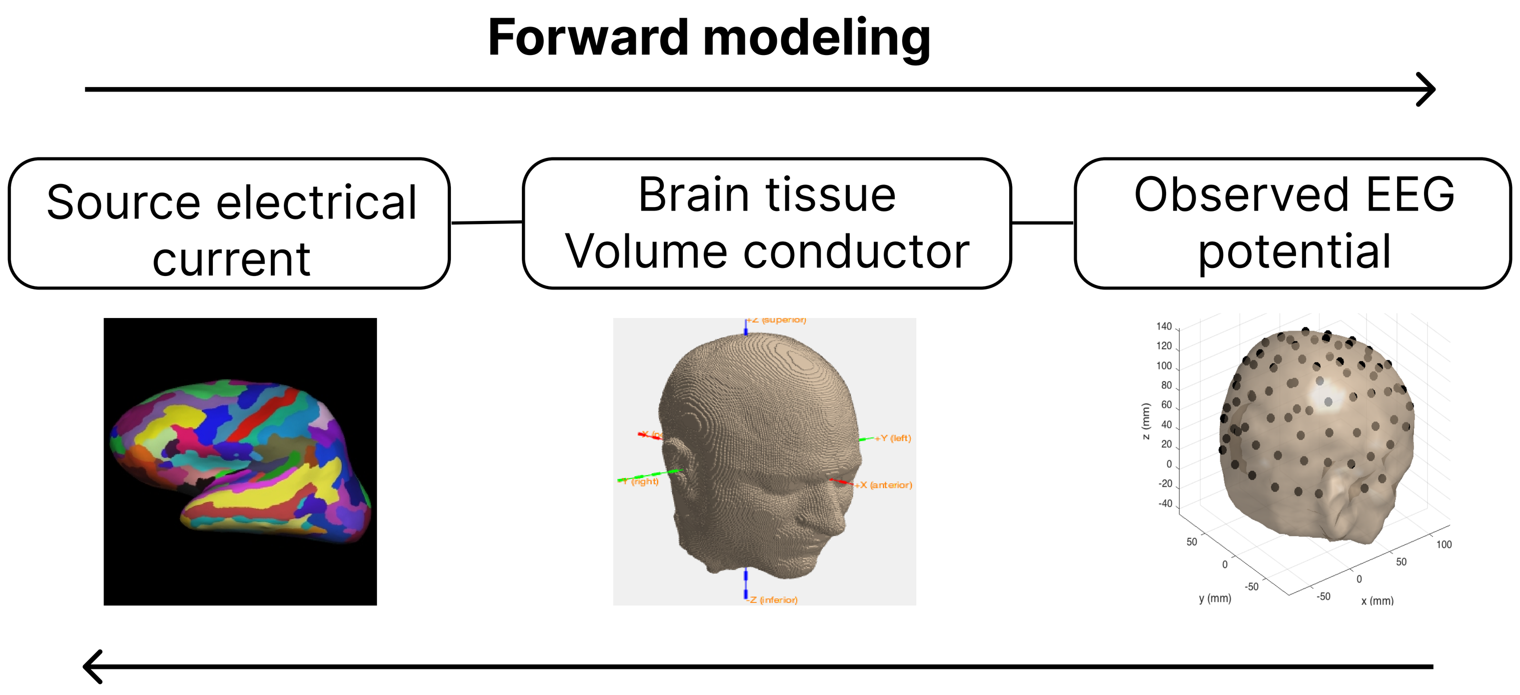
Abstract

The objective of our project is to construct a **lead-field matrix** corresponding to the Automated Anatomical Labeling 2 (**AAL2**) atlas, employing a standard electroencephalographic (EEG) electrode configuration, utilizing computational resources such as the MNE Python or the Matlab FieldTrip toolbox.



Background

The process of predicting the distribution of EEG potentials or magnetoencephalographic (MEG) fields given a known neural source is termed as **forward modeling**. Conversely, the process of deducing the unidentified neural sources from the observed EEG or MEG data is termed as **inverse modeling**.

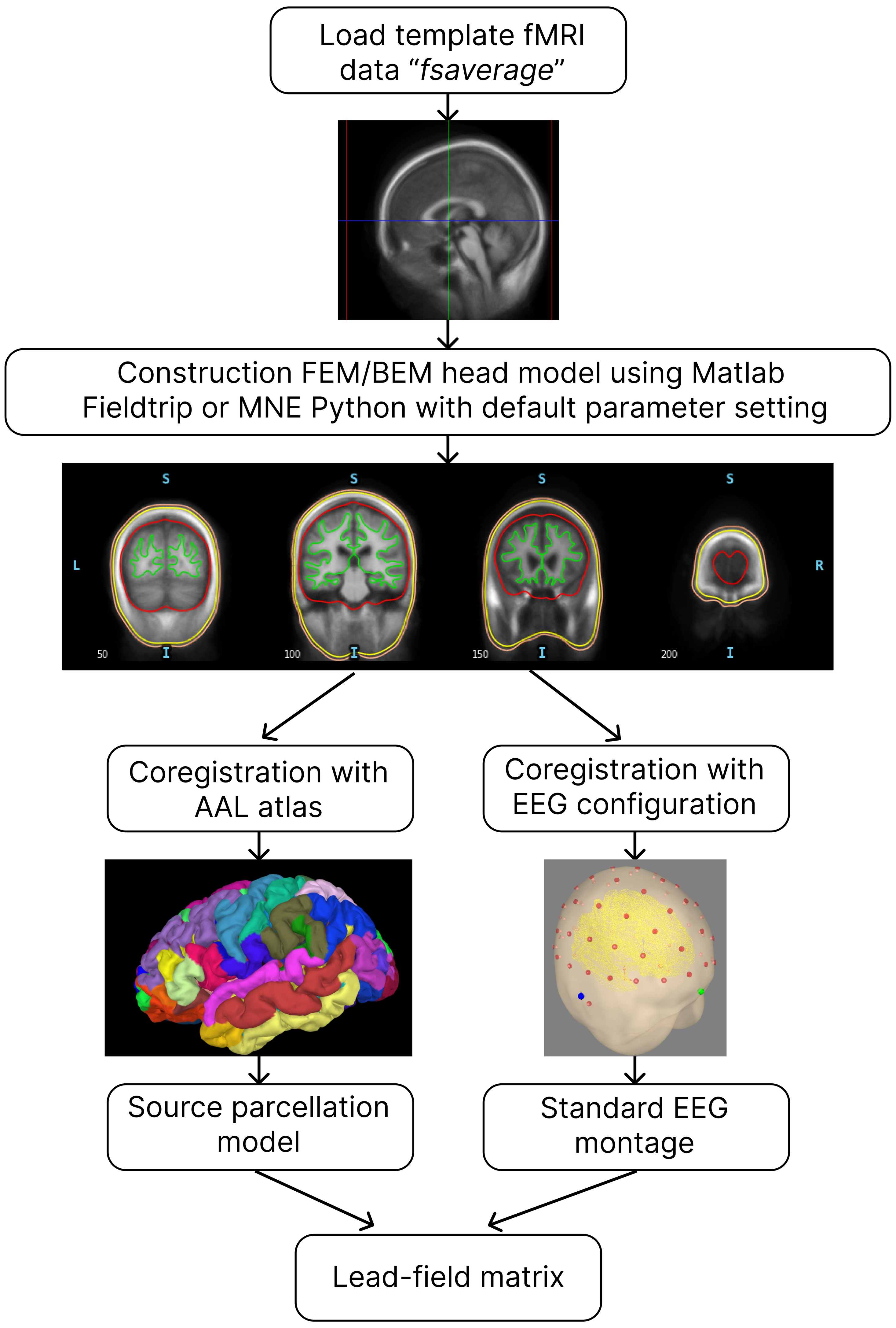


The lead-field matrix fundamentally characterizes the responsiveness of each sensor, for instance, an EEG electrode, to every potential neural source location within the brain. Utilization of the lead-field matrix serves to expedite the computation of the forward solution.

The **volume conductor** characterizes the electrical properties of tissue, provides a geometrical model of the head, and outlines the path of electric current flow.

For computational modeling of volume conductors in head geometries, methods such as the Boundary Element Method (**BEM**) and the Finite Element Method (**FEM**) can be employed.

Methods



Lead-field matrix calculation

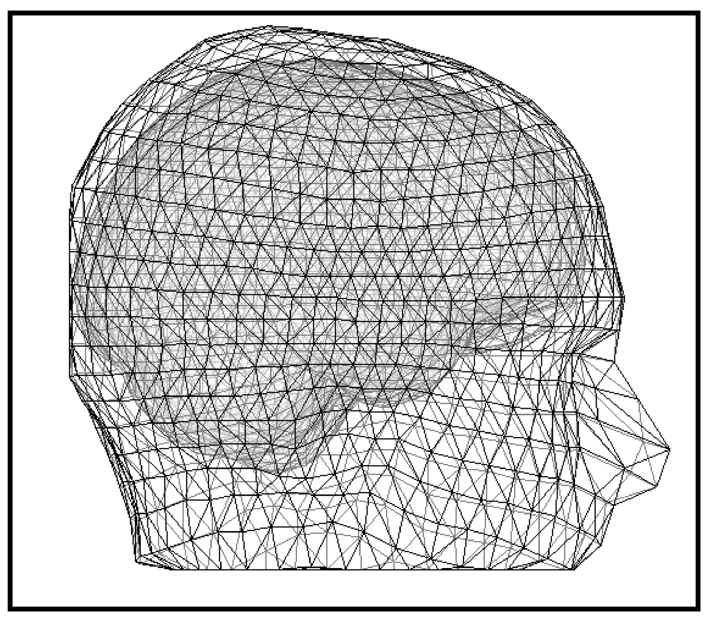
$$\vec{y}_{m\times 1} = L_{m\times n}\,\vec{x}_{n\times 1}$$

EEG electrodes $(m \times 1)$ = Lead Field Matrix $(m \times n)$ × brain activity $(n \times 1)$

$$\begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{pmatrix} = \begin{pmatrix} L_{11} & L_{12} & \dots & L_{1n} \\ L_{21} & L_{22} & \dots & L_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ L_{m1} & L_{m2} & \dots & L_{mn} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix}$$

The electromagnetic field of each voxel is linear and independent. So the calculation method will be sequential activating the voxels, each activated voxel with a simulated strength, and through forward modeling, generating simulated EEG data, this process facilitates the computation of each column of the lead-field matrix. Aggregating these computed values results in the complete lead-field matrix.

Discussion



Within the MNE Python framework, there currently exists no provision for FEM construction for head models, necessitating the use of the BEM as provided by MNE. It is hypothesized that the application of FEM could yield a more precise lead-field matrix. However, the process that the application of FEM could yield a more precise lead-field matrix. Nevertheless, the process to construct the FEM head model is anticipated to require a substantial increase in computational resources and computational time.

Exemplary Results

Within the framework of the source model, utilizing the Desikan-Killiany Atlas and a standard 10-20 EEG configuration for the template data designated as "fsaverage", and employing the BEM for the head model, a lead-field matrix is consequently derived. This matrix is characterized by a dimensional configuration of 64 sensors cross 1548 dipoles.

References

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