A Bayesian model to estimate individual skull conductivity for EEG source imaging

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EEG Source Imaging

Estimating 3D brain activity based on measured scalp EEG and a parametric model of the head:

- Geometry of the head can be modelled precisely with anatomical MR image.
- Electrical conductivity of a tissue is usually set to a conventional value, found in previous studies: \( \sigma = 0.022 \text{ S/m} \)

Problem: Individual skull conductivity is reported to vary within a wide range of values, \( \sigma \in [0.0041 \rightarrow 0.070] \text{ S/m} \). Using the conventional value results in substantial errors on estimated source location, especially in the direction from source to skull. A very expensive MEG scan, unaffected by electrical conductivities, is the current solution to this problem.

Goal: Design a probabilistic framework for estimating the individual skull conductivity value based on scalp EEG. As such approach the source localization performance of an MEG scan.

**Expectation Maximization**

- Initialize skull conductivity on conventional value: \( \sigma_0 = 0.022 \text{ S/m} \)
- E-step
  - Create head model with current \( \sigma \)
  - Calculate the source distribution over volume of the head \( p(T) \)
- M-step
  - Find the \( \sigma \) that maximizes the likelihood of the measured EEG \( Y \) under the given source distribution

<table>
<thead>
<tr>
<th>Simulation</th>
<th>( \Delta x ) mean ± std</th>
<th>( \Delta y ) mean ± std</th>
<th>( \Delta z ) mean ± std</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG (( \sigma = 0.022 \text{ S/m} ))</td>
<td>2.6 ± 3.0</td>
<td>2.5 ± 3.0</td>
<td>2.6 ± 2.8</td>
</tr>
<tr>
<td>EEG (( \sigma ) estimated)</td>
<td>1.0 ± 3.4</td>
<td>0.6 ± 1.6</td>
<td>0.7 ± 1.9</td>
</tr>
<tr>
<td>MEG</td>
<td>0.1 ± 0.1</td>
<td>0.1 ± 0.1</td>
<td>0.1 ± 0.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>After Rotation</th>
<th>( \Delta x' ) mean ± std</th>
<th>( \Delta y' ) mean ± std</th>
<th>( \Delta z' ) mean ± std</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEG (( \sigma = 0.022 \text{ S/m} ))</td>
<td>0.3 ± 0.3</td>
<td>2.1 ± 3.3</td>
<td>3.7 ± 4.1</td>
</tr>
<tr>
<td>EEG (( \sigma ) estimated)</td>
<td>0.3 ± 0.4</td>
<td>0.6 ± 1.7</td>
<td>1.2 ± 3.8</td>
</tr>
<tr>
<td>MEG</td>
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Conclusion

Estimation of individual skull conductivity with the expectation maximization algorithm improves EEG source localization. Further research is needed to confirm this improvement on realistic head models and real data.


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**Table 1:** EEG and MEG source localization performance before and after rotation for different conductivity values.

**Graphs:**
- EEG and MEG source localization before and after rotation.
- Graphs showing the estimated skull conductivity values.

**Diagrams:**
- Diagrams illustrating the estimation process and results for EEG and MEG source imaging.

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**References:**
- [Strobbe et al., 2015](#)
- [Koseem et al., 1998](#)
- [Hukkamp, 2008](#)