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

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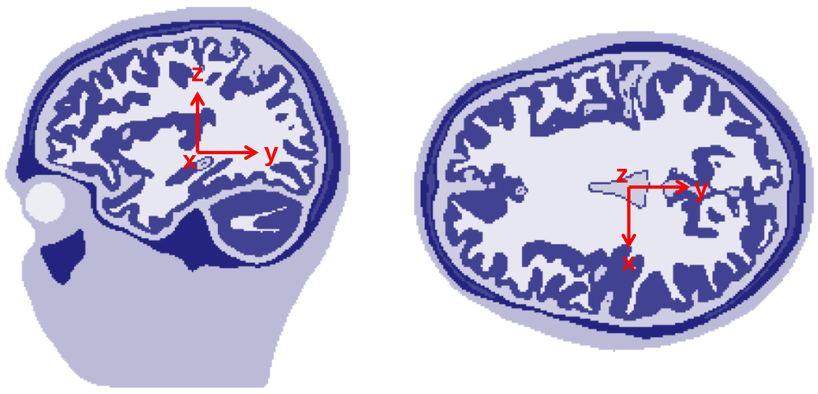
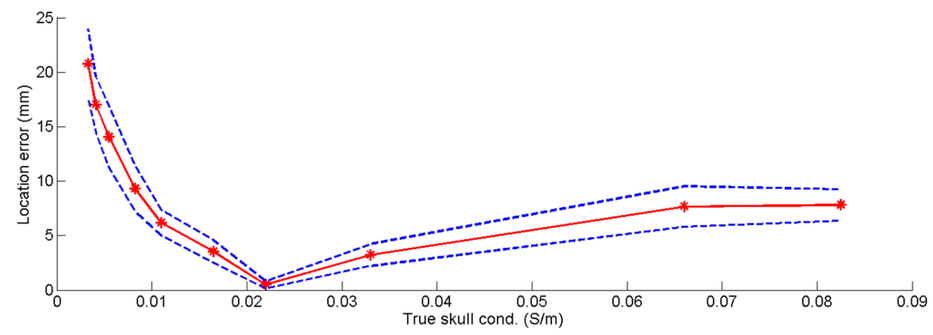
EEG Source Imaging

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: $\sigma_S = 0.022\ S/m$

Problem: Individual skull conductivity is reported to vary within a wide range of values, $\sigma_S \in [0.0041 \rightarrow 0.070]\ S/m$. 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:
$\sigma_S = 0.022\ {}^{S}/_{m}$

E-step
- Create head model with current σ_S
- Calculate the source distribution over volume of the head $p(\overline{J})$

(Until convergence)

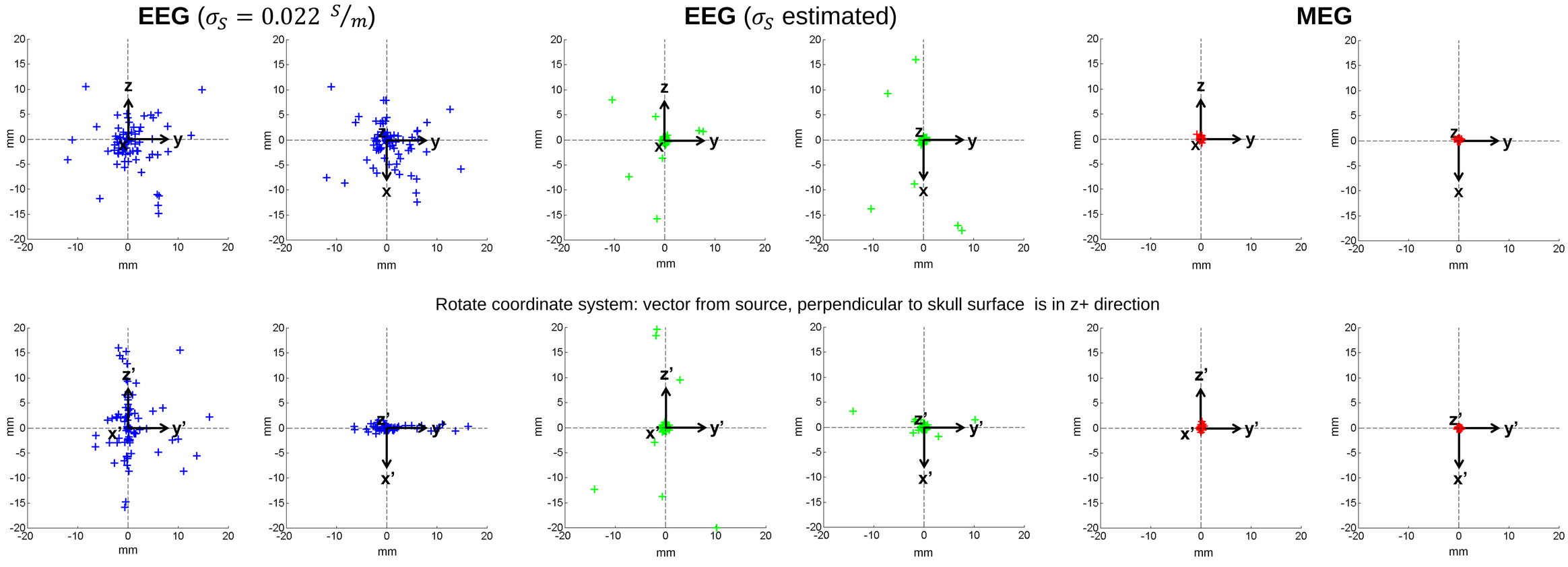
M-step
Find the σ_S that maximizes the likelihood of the measured EEG $\overline{V_m}$ under the given source distribution

Simulation

- 100 Simulations
- 3 layered spherical head model
- Unit dipole source with random position & orientation
- Generate electric and magnetic activity
- 36 electrode positions capture EEG, 162 sensors capture MEG
- Add 20% uncorrelated noise

- Perform single dipole estimation on EEG (with $\sigma_S = 0.022\ {}^{S}/_{m}$ and σ_S estimated from EEG) as well as on MEG
- Compare the error on the estimated source location

EEG ($\sigma_S = 0.022\ {}^{S}/_{m}$) | **EEG** ($\sigma_S$ estimated) | **MEG**



Rotate coordinate system: vector from source, perpendicular to skull surface is in z+ direction

Simulation	Δx mean ± std	Δy mean ± std	Δz mean ± std
EEG ($\sigma_S = 0.022\ {}^{S}/_{m}$)	2.6 ± 3.0	2.5 ± 3.0	2.6 ± 2.8
EEG (σ_S estimated)	1.0 ± 3.4	0.6 ± 1.6	0.7 ± 1.9
MEG	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.2
After Rotation	**Δx' mean ± std**	**Δy' mean ± std**	**Δz' mean ± std**
EEG ($\sigma_S = 0.022\ {}^{S}/_{m}$)	0.3 ± 0.3	2.1 ± 3.3	3.7 ± 4.1
EEG (σ_S estimated)	0.3 ± 0.4	0.6 ± 1.7	1.2 ± 3.8
MEG	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2

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.

[1] Strobbe G., Carrette E., Lopez J.D., Van Roost D., Meurs E., Vonck K., Boon P., Vandenberghe S., van Mierlo P. (2015) EEG source imaging of interictal spikes using multiple sparse volumetric priors for presurgical focus localization, *NeuroImage*, in preparation for submission.
[2] Kassem A., Jackson D., Baumann S., Williams J., Wilton D., Fink P. and Prasky B. (1998) Effect of Conductivity Uncertainties and Modeling Errors on EEG Source Localization Using a 2-D Model, *IEEE Transaction on Biomedical Engineering*, vol. 45, no. 9, pp. 1135-1145
[3] Huiskamp G. (2008) Interindividual variability of skull conductivity: an EEG-MEG analysis, *International Journal of Bioelectromagnetism*, vol. 10, no. 1, pp. 25-30

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