Noninvasive electromagnetic source imaging of spatiotemporally distributed epileptogenic brain sources

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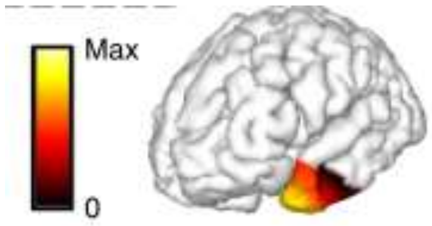
1. Epilepsy

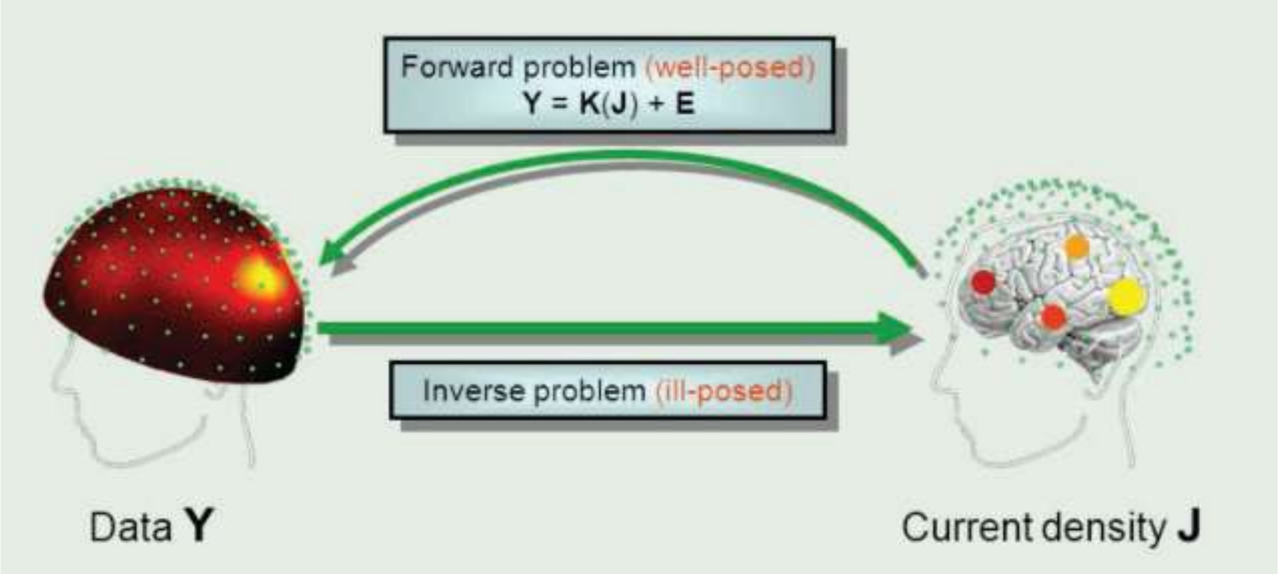
Wiki: Eplilepsy



A Sohrabpour, et al. 2020

2. Inverse Problem

Inverse Problem?



[Felix Bitzer, 2018]

2. Inverse Problem

Distributed model

$$V(\vec{r}) = \frac{1}{4\pi\sigma} \int_V \vec{J}_i(\vec{r}') \cdot \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|^3} dv'$$

discretize r

$$\phi = As + n$$

To many parameters!

He, B., et al. (2018)

3. IRES

L2 Norm + penalty on “the # of parameters” :

$$C(s) = \| \phi - As \|^2 + \lambda f(s)$$

New SSI:

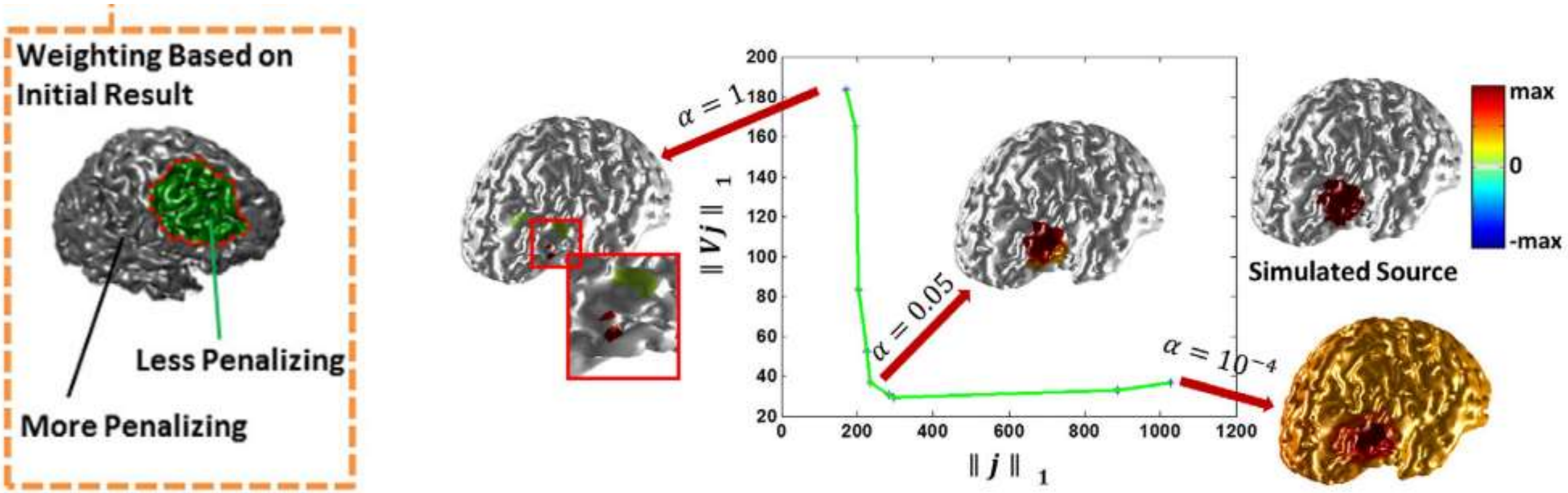
$$\min \| ws \|_1 = \min \sum_{i=1}^{N} \| w_i s_i \|_2$$

$$\text{subject to } \| \phi - As \|_2 < \beta \qquad (3)$$

w: weight. Sources in different depth should have different weight
\beta: tolerance to the noise. Can be determined if known the statistics of the noise

Ding, L., & He, B. (2008).

3. IRES



$$\min \| ws \|_1 \rightarrow j^{est} = \text{argmin}_j \|Vj\|_1 + \alpha \|j\|_1$$

V: gradient operator → the activation of sources should be homogeneous (white background; add penalty on the edges)

\alpha: Can be determined by L-curve

[Sohrabpour, A., Lu, Y., Worrell, G., & He, B. (2016).]

3. IRES

$$\text{subject to} \quad \| \phi - As \|_2 < \beta$$

$$\text{subject to} \quad (\varphi - Kj)^T \Sigma^{-1} (\varphi - Kj) \le \beta$$

Erase the interdependency between noise in different channel

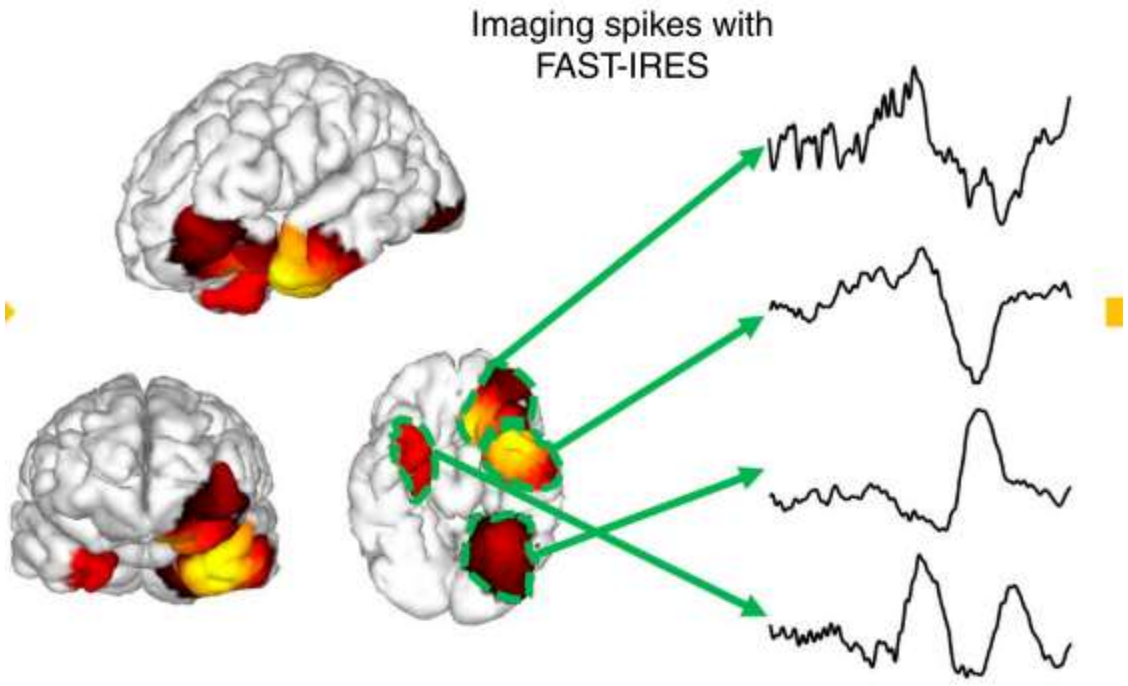
$$j^{est} = \operatorname{argmin}_j \|Vj\|_1 + \alpha \|j\|_1$$
$$\text{subject to} \quad (\varphi - Kj)^T \Sigma^{-1} (\varphi - Kj) \le \beta$$

Sohrabpour, A., Lu, Y., Worrell, G., & He, B. (2016).

4. FAST-IRES

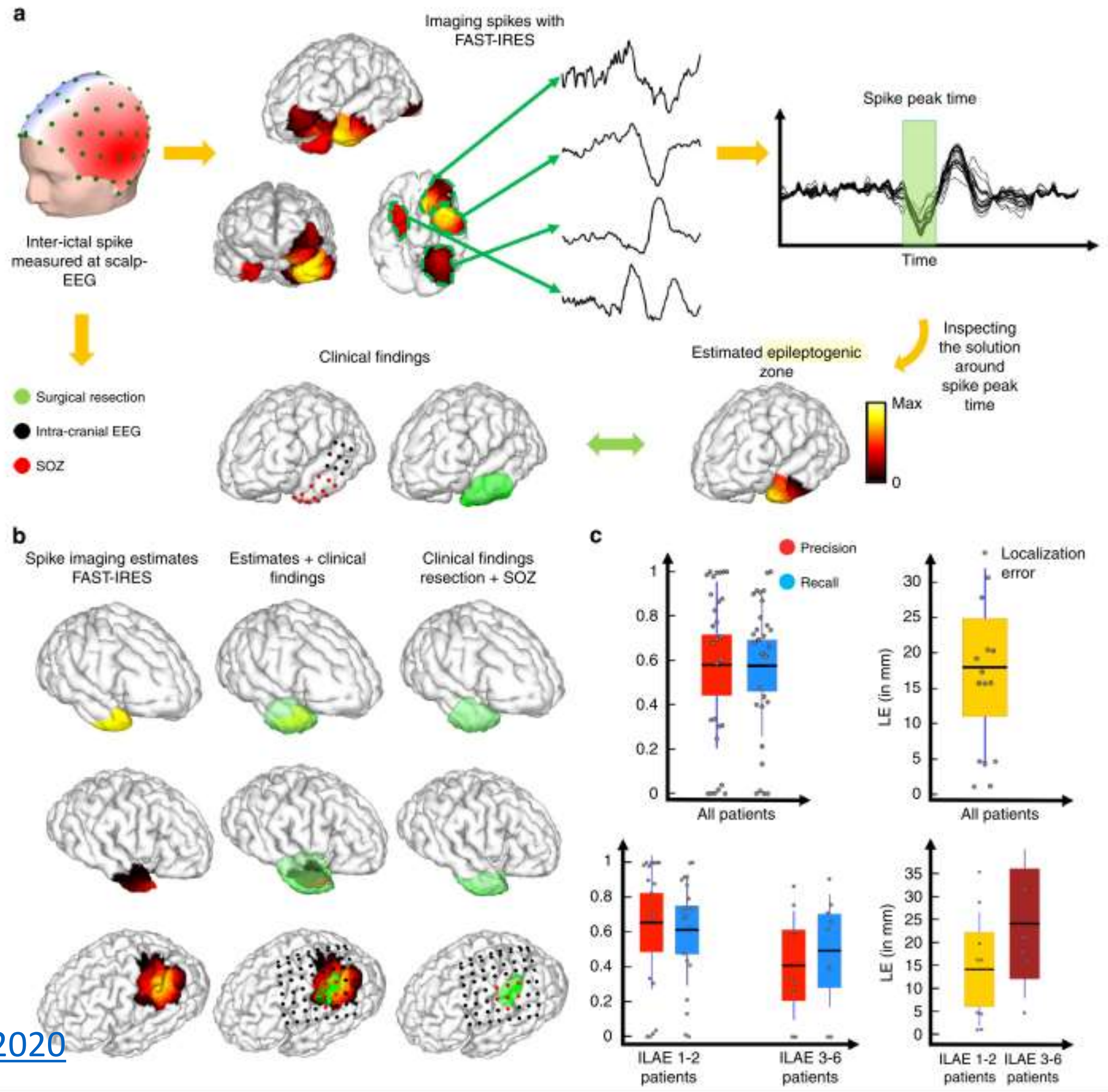
Add time, then do IRES

$$\mathbf{j}(t) = \sum_{i=1}^{N_c} \mathbf{j}_i \otimes \mathbf{a}_i(t)$$



A Sohrabpour, et al. 2020

5. Result



[A Sohrabpour, et al. 2020]

6. Conclusion

FAS-IRES is a method to reveal the spatial and temporal information of the sources of the EEG/MEG signal. It has the following features

1. Only few parameters need to be adjusted manually. This can decrease the bias induced by human.

2. Easy to distinguish the signal region and the background. The gradient operator add strong penalty on the edge of the active region and the background. Thus only limited number of active regions are allowed.

3. Noninvasive. This is quite important in practice. Since invasive methods (e.g. iEEG) is expensive and could possibly cause infection.