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► **To cite this version:**

Valentin Debenay, Grégory Turbelin, Jean-Pierre Issartel, Amine Chellali, Béatrice Alescio-Lautier, et al.. The Renormalization Method: A Real-time EEG Source Localization Technique. 30e Colloque Alain BOUYSSY, Dec 2022, Orsay, France. 2022. hal-03955262

**HAL Id: hal-03955262**

**<https://hal.science/hal-03955262v1>**

Submitted on 25 Jan 2023

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# The Renormalization Method: A Real-time EEG Source Localization Technique

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## I. CONTEXT

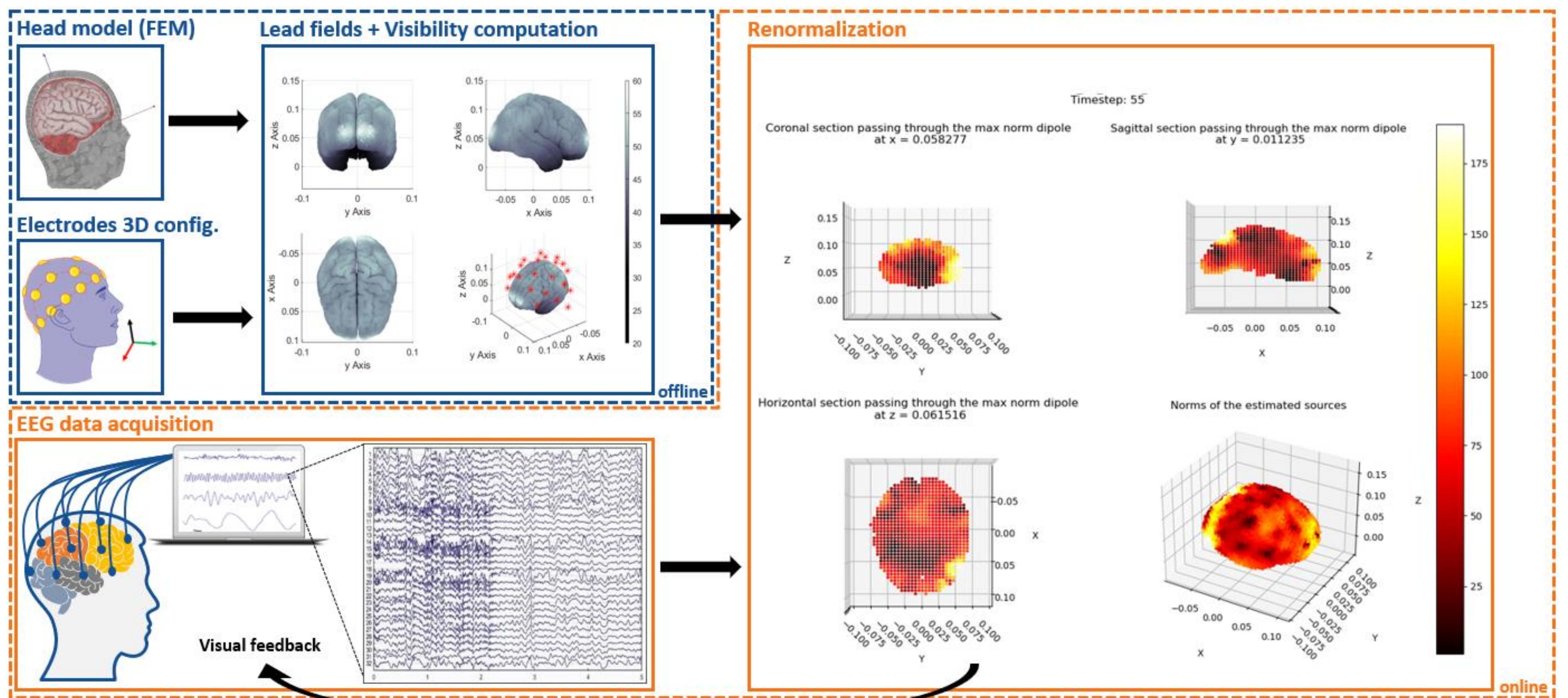
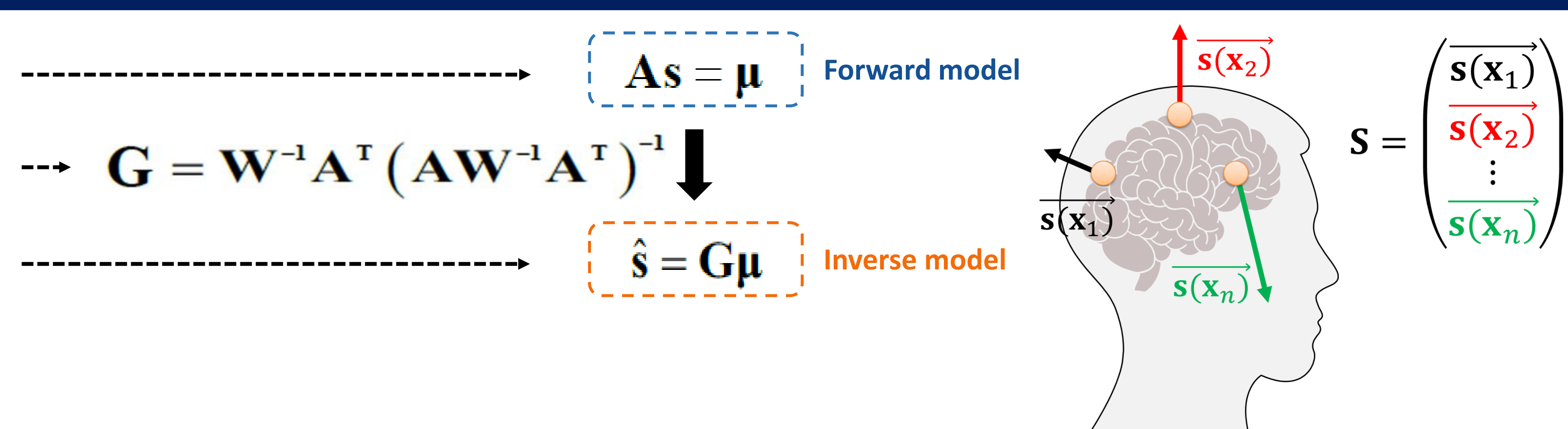
- Electroencephalography (EEG), a widely used **brain imaging technique**:
  - ✓ **Noninvasive, easy to use, inexpensive, very high temporal resolution (ms).**
  - ✗ **Poor spatial resolution (volume conduction, poor SNR).**
- EEG scalp potentials can be input into the **ill-posed brain source imaging inverse problem**: Localizing the electrical current sources in the brain that generate these potentials.
- Our idea: Adapt an approach initially developed to solve a **source term estimation problem for atmospheric dispersion** of NRBC substances, called “**Renormalization**” (TRL 5-6), in real time.
- Using anatomically faithful high-resolution 3D head models (FEM), our approach can provide valuable insights for **neurophysiological & cognitive monitoring**.

## II. OBJECTIVES

- Can the Renormalization method bring **valuable additional information** as compared to other existing source imaging techniques (Minimum Norm, LORETA, MUSIC, Beamformers, ...)?
- Evaluate the **complementarity** between our source localization technique and classical signal processing pipelines (CSD, time-frequency analysis, Machine Learning, ...) to improve **real-time interpretation of EEG signals**.
  - => To open new perspectives in the field of **Brain-Computer Interfaces (BCIs)** and to contribute to a better **understanding of cognitive functions to improve the care of brain-injured patients** (post-TBI rehabilitation assessment, ...).
- Implement and evaluate both a **BCI prototype** and a **new post-TBI rehabilitation assessment pipeline** that integrate our method.

## III. METHOD

- The workflow:
  - 1) Compute the **lead field matrix  $A$**  from a sensor point of view.
  - 2) Generate the **visibility matrix  $W$** , corresponding to a tensor field, via a “3D renormalization” process.
  - 3) Compute the **estimated source  $\hat{s}$**  at each time step by applying the **inverse operator  $G$**  to the **measurement vector  $\mu$** .
- The source estimation enables:
  1. Accurate real-time mapping of electrical brain activity.
  2. Characterization (position, orientation & intensity) of single punctual or distributed sources.



## IV. CONCLUSION & OUTLOOK

- Possible applications:

- Work remaining:

### Improved neurophysiological & cognitive monitoring

- Neurophysiological monitoring in real time
- Accurate localization of epileptogenic foci
- Cognitive states monitoring
- Surgical efficacy improvement
- Patient-tailored treatment



### More reliable Brain-Computer Interfaces (BCIs)

- Exoskeletons, prostheses, ...
- Drones (UAVs, ...)
- VR, software ...



- Compare our Renormalization method's outputs with other existing source imaging techniques results, based on the EEG recordings of a 20-subject dataset.
- Implement the real-time part and display the 3D source vectors at each time step.
- Explore the potential links between our source localization method and Connectivity.
- Implement and evaluate a BCI prototype as well as a post-TBI rehabilitation assessment pipeline.