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

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I. CONTEXT

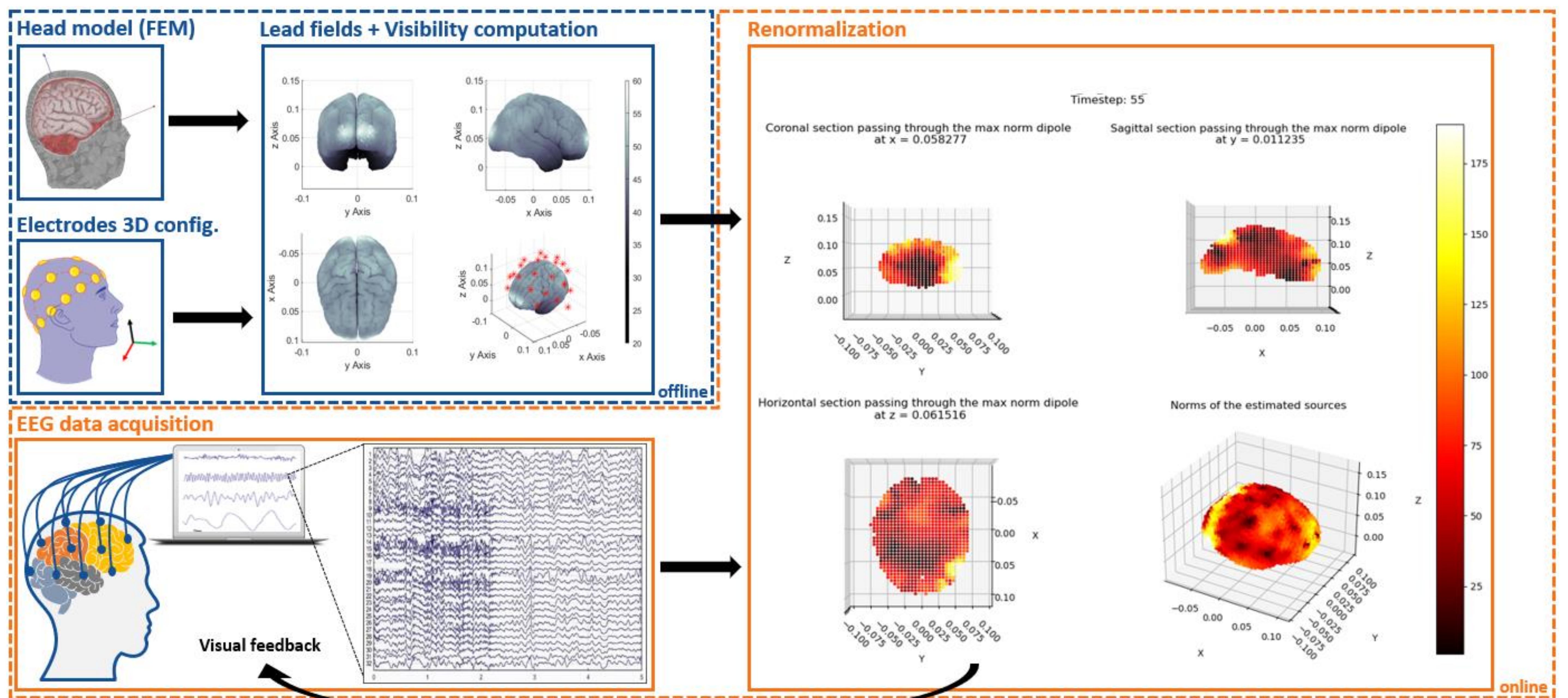
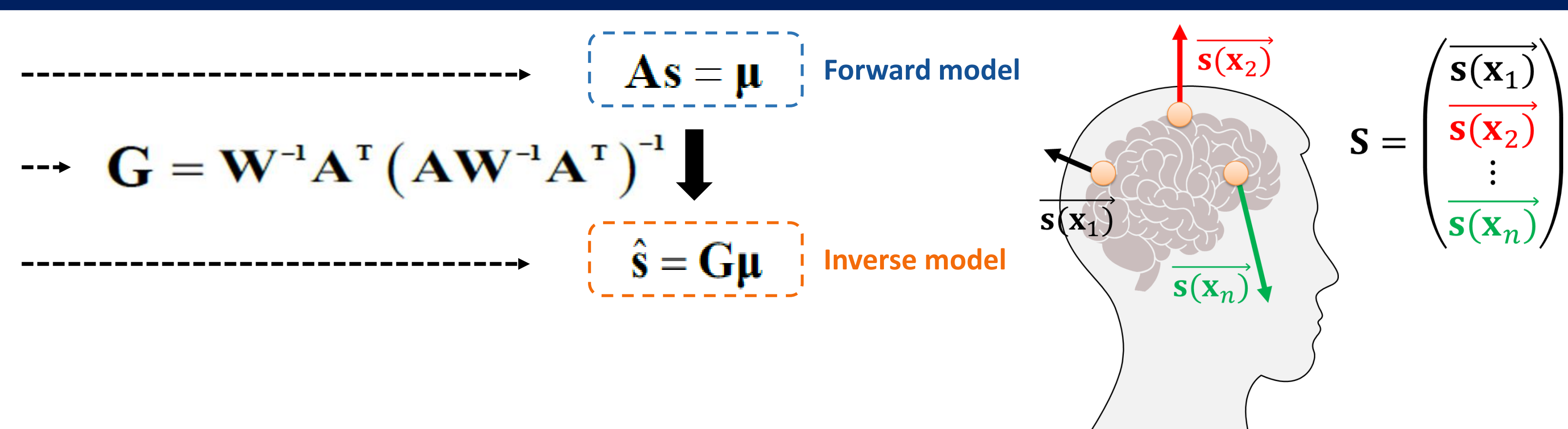
- Electroencephalography (EEG), a widely used **brain imaging technique**:
 - ✓ **Noninvasive, easy to use, inexpensive, very high temporal resolution (ms).**
 - ✗ **Poor spatial resolution (volume conduction, poor SNR).**
- EEG scalp potentials can be input into the **ill-posed brain source imaging 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 μ** .
- 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.