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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 $\mathbf{A}$ from a sensor point of view.
2) Generate the visibility matrix $\mathbf{W}$, corresponding to a tensor field, via a “3D renormalization” process.
3) Compute the estimated source $\mathbf{s}$ at each time step by applying the inverse operator $\mathbf{G}$ to the measurement vector $\mathbf{\mu}$.

The source estimation enables:
1. Accurate real-time mapping of electrical brain activity.
2. Characterization (position, orientation & intensity) of single or distributed sources.

Possible applications:
- 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, ...)