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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 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:
  - 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 ...
- Work remaining:
  - 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.