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# A New Real-Time EEG Source Localization Method

Valentin Debenay<sup>1,2</sup>, Grégory Turbelin<sup>1</sup>, Jean-Pierre Issartel<sup>1</sup>, Amine Chellali<sup>2</sup>, Béatrice Alescio-Lautier<sup>3</sup>, Marie-Hélène Ferrer<sup>4</sup>

<sup>1</sup>Laboratoire de Mécanique et d'Énergétique d'Évry (LMEE, EA 3332), Évry, France. <sup>2</sup>Laboratoire d'Informatique, Bio-Informatique et Systèmes Complexes (IBISC, EA 4526), Évry, France. <sup>3</sup>Laboratoire de Neurosciences Cognitives (LNC, UMR 7291), Marseille, France. <sup>4</sup>Institut de Recherche Biomédicale des Armées (IRBA), Brétigny-sur-Orge, France.

## I. CONTEXT

- Electroencephalography (EEG) is a widely used functional neuroimaging technique generally considered as having an excellent temporal resolution, but a poor spatial resolution.
- Scalp EEG can be input to the ill-posed source localization inverse problem for characterizing the electric currents in the brain generating them.
- Our idea was to adapt an approach initially developed to solve a source term estimation problem for atmospheric dispersion of nuclear, radiological, biological or chemical (NRBC) substances, called "Renormalization".
- Using anatomically faithful high-resolution 3D head models, our approach can provide valuable insights for neurophysiological & cognitive monitoring:

## III. METHOD

- The "Renormalization" method uses the lead field theory to define the concept of "EEG visibility tensor".
- Workflow:
  - We compute the lead field matrix  $\mathbf{A}$  from a sensor point of view.
  - We generate the so-called "Visibility matrix"  $\mathbf{W}$ , corresponding to a tensor field, by a "3D renormalization" process.
  - To estimate the source  $\mathbf{s}$  at each time step, we simply apply the inverse operator  $\mathbf{G}$  to the measurement vector  $\boldsymbol{\mu}$ .

$$\begin{array}{c} \text{Forward model} \\ \boxed{\mathbf{A}\mathbf{s} = \boldsymbol{\mu}} \\ \downarrow \\ \mathbf{G} = \mathbf{W}^{-1}\mathbf{A}^T(\mathbf{A}\mathbf{W}^{-1}\mathbf{A}^T)^{-1} \\ \downarrow \\ \boxed{\hat{\mathbf{s}} = \mathbf{G}\boldsymbol{\mu}} \\ \text{Inverse model} \end{array}$$

## IV. RESULTS

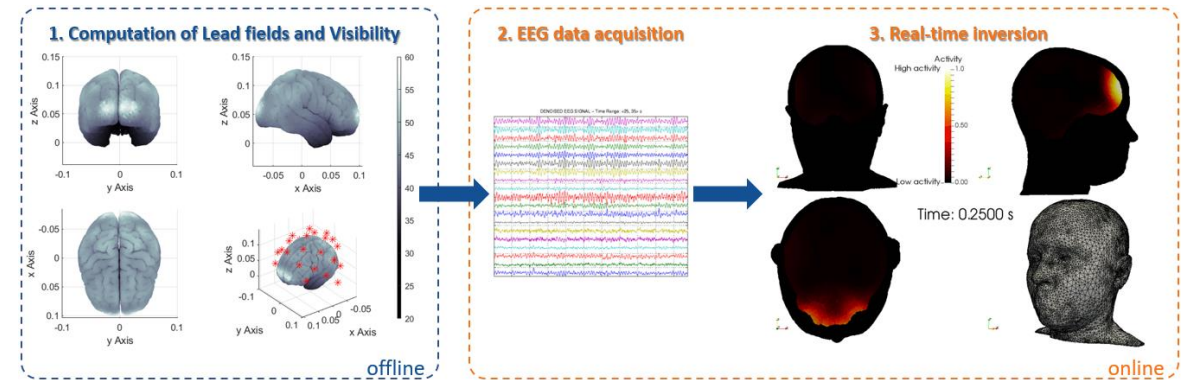


Fig. 2: Image 1 on the left: Visibility field (black = poorly seen areas, white = well seen areas). Image 2: EEG signal samples. Image 3: Source reconstruction (black = inactive areas, yellow = most active areas)

- The source estimation  $\hat{\mathbf{s}}$  enables:
  - Accurate real-time mapping of electrical brain activity.
  - Characterization (location, orientation, intensity) of single punctual or distributed sources.

## V. CONCLUSION

- We expect the "Renormalization" method not only to open new perspectives in the field of BMIs but also to contribute to a better understanding of the brain functions and improve the care of brain-injured patients:
  - Refined rehabilitation assessments by detecting brain activity changes correlated with cognitive disorders.
  - Better evaluation of post-TBI rehabilitation benefits.

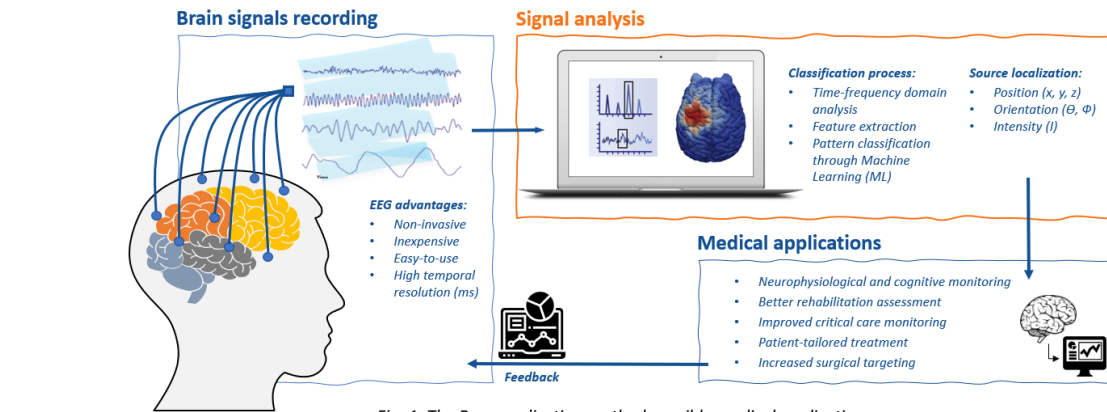


Fig. 1: The Renormalization method possible medical applications

## II. AIMS

- Improve the real-time interpretation of EEG signals for:
  - Neurophysiological & cognitive monitoring.
  - Development of brain-machine interfaces (BMI).
- Assess the complementarity between our source identification method and classical approaches (signal processing, AI, ...).
- Determine whether our approach brings valuable additional information for real-time feedback.

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