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► **To cite this version:**

Valentin Debenay, Grégory Turbelin, Jean-Pierre Issartel, Amine Chellali, Béatrice Alescio-Lautier, et al.. A New Real-Time EEG Source Localization Method. Federation of European Neuroscience Societies (FENS 2022) forum, Jul 2022, Paris, France. 2022. hal-03955214

HAL Id: hal-03955214

<https://hal.science/hal-03955214>

Submitted on 25 Jan 2023

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A New Real-Time EEG Source Localization Method

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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 $\boldsymbol{\mu}$.

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

IV. RESULTS

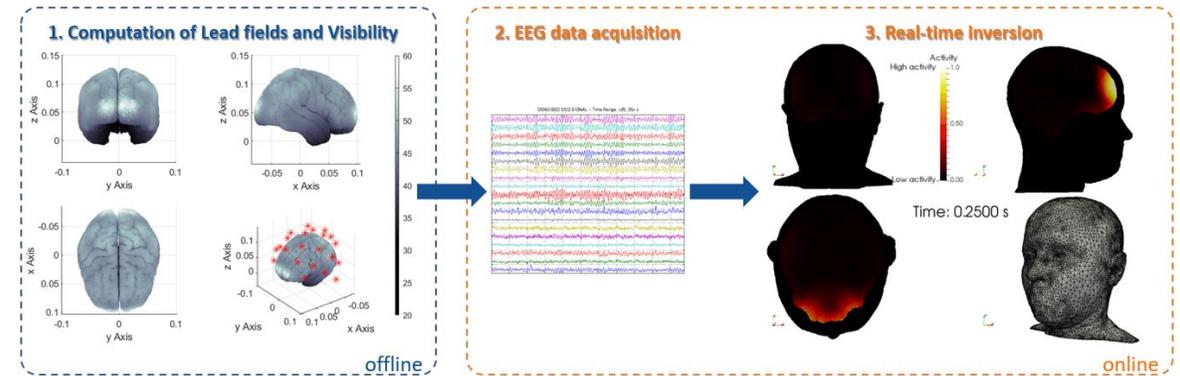


Fig. 2: Image 1 on the left: Visibility field (black = poorly seen areas, white = well seen areas). Image 2: EEG signal samples. Image 3: Source reconstruction (black = inactive areas, yellow = most active areas)

- 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.

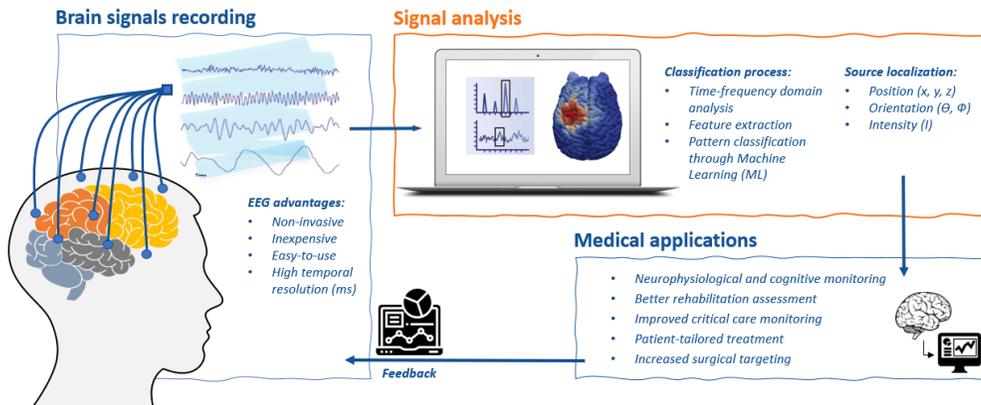


Fig. 1: The Renormalization method possible medical applications

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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