



HAL
open science

Improving non-invasive Brain-Computer Interfaces using an innovative real-time inversion method for EEG source reconstruction

Valentin Debenay, Grégory Turbelin, Jean-Pierre Issartel, Amine Chellali,
Marie-Hélène Ferrer

► To cite this version:

Valentin Debenay, Grégory Turbelin, Jean-Pierre Issartel, Amine Chellali, Marie-Hélène Ferrer. Improving non-invasive Brain-Computer Interfaces using an innovative real-time inversion method for EEG source reconstruction. Annual CORTICO Days Meeting 2022, Mar 2022, Autrans, France. 2022. hal-03955180

HAL Id: hal-03955180

<https://hal.science/hal-03955180>

Submitted on 25 Jan 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Improving non-invasive Brain-Computer Interfaces using an innovative real-time inversion method for EEG source reconstruction

Debenay V.^{1,2}, Turbelin G.¹, Issartel J.-P.¹, Chellali A.², Ferrer M.-H.³

Contact: VALENTIN DEBENAY valentin.debenay@univ-evry.fr

1-Laboratoire de Mécanique et d'Énergétique d'Évry (LMEE, EA3332), Évry, France 2-Informatique, BioInformatique, Systèmes Complexes (IBISC, EA 4526), Évry, France 3-Institut de Recherche Biomédicale des Armées (IRBA), Brétigny-sur-Orge, France

Context

- Non-invasive EEG-based BCIs seek to translate the brain's electrical activity into computer commands:
 1. Feature extraction
 - Application of a variety of commonly used time-frequency domain analysis methods, followed by dimensionality reduction algorithms.
 2. Pattern classification
 - Generally carried out by applying a Machine Learning (ML) classifier.
- EEG-based BCIs have excellent temporal resolution and usability, yet they suffer from poor spatial resolution and are more subject to noise from eye or muscle movements.
- Source reconstruction methods improve the spatial resolution of scalp EEG, and could be a way to improve classification accuracy.

Aims

- The EEG Inverse Problem's objective is to reconstruct the current distribution of electric sources within the brain, involving:
 - Potentials measured on the scalp
 - A source-receptor model to describe the electric propagation through the head tissues.
- We offer to use our "Renormalization" method to obtain a unique and stable solution to this ill-posed Source Term Estimation (STE) problem.
- We aim to determine whether our "Renormalization" method can complement existing non-invasive EEG-based BCI methodologies.

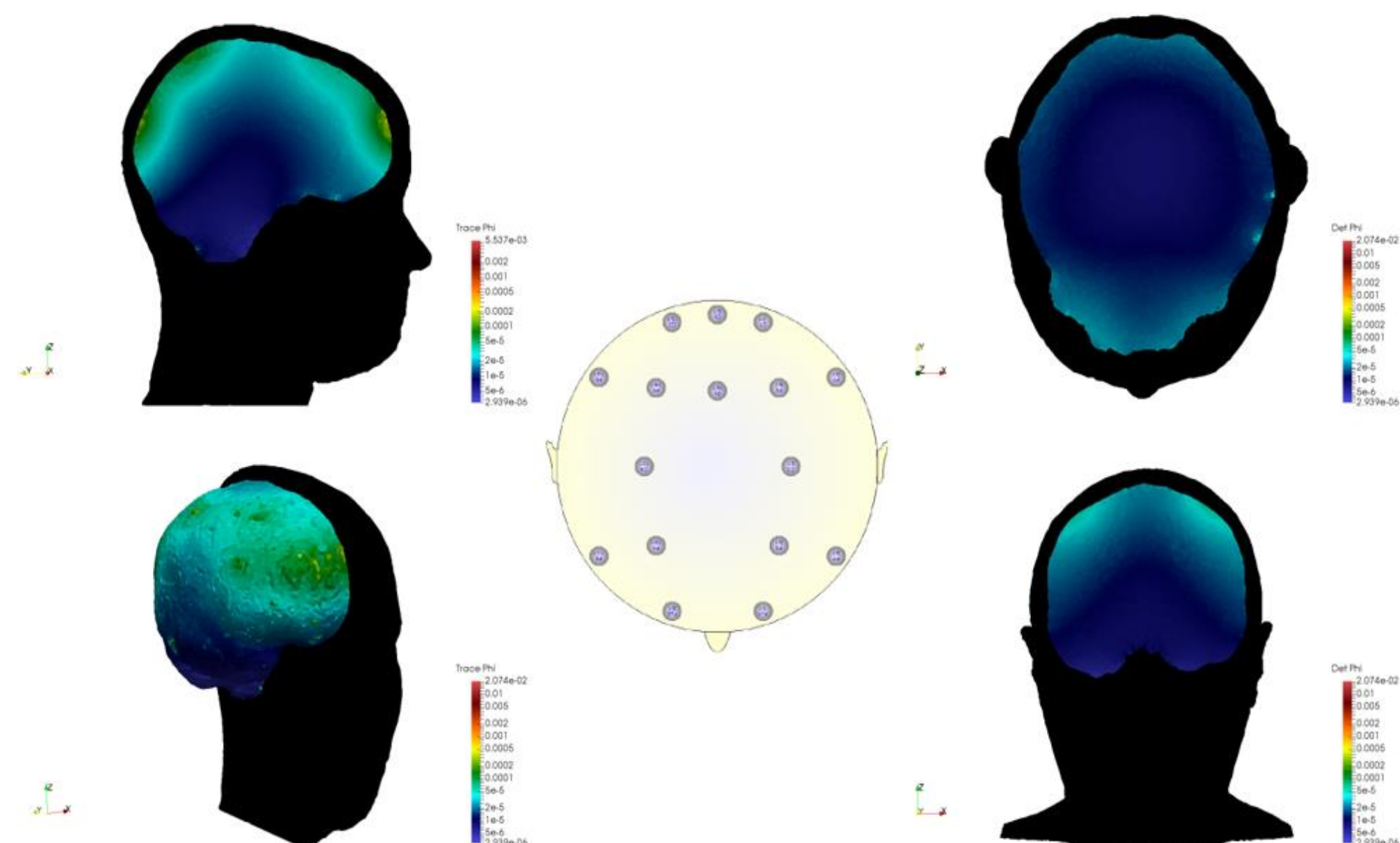
Method description

- The "Renormalization" method is based on the Lead Field and "visibility" concepts.
- It uses the "visibility field" to compute the 3D position, orientation and strength of the sources.
- It can locate distributed sources as well as single sources.
- It generates a unique and stable solution to the inverse problem, in real-time.

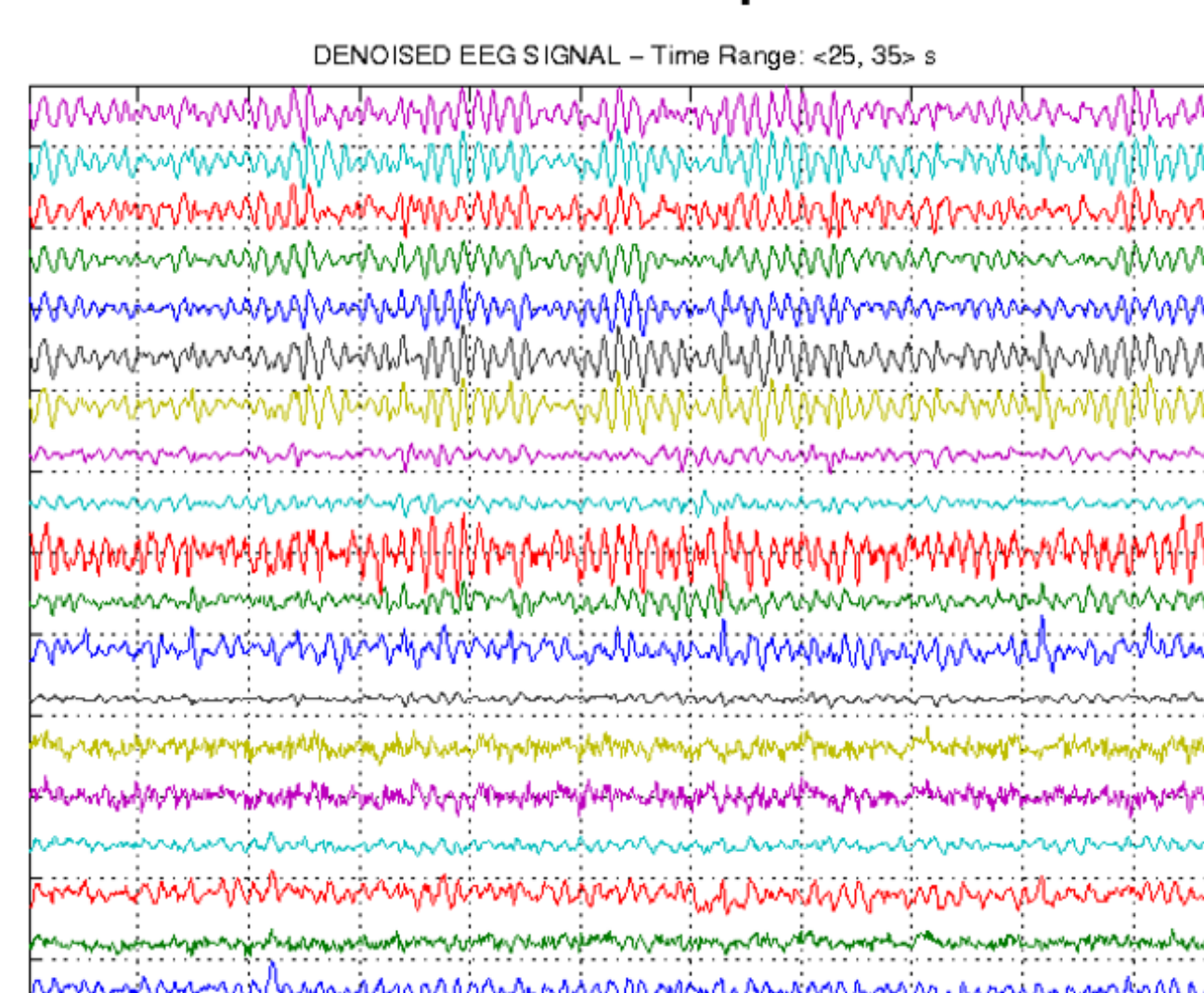
Theoretical properties

- Developed from a deterministic approach
- Low computational costs
- Introduces the concepts of "visibility" and well/badly seen brain areas
- Symmetric resolution matrix with maximums as diagonal elements
- Perfect reconstruction of position and amplitudes of all single sources

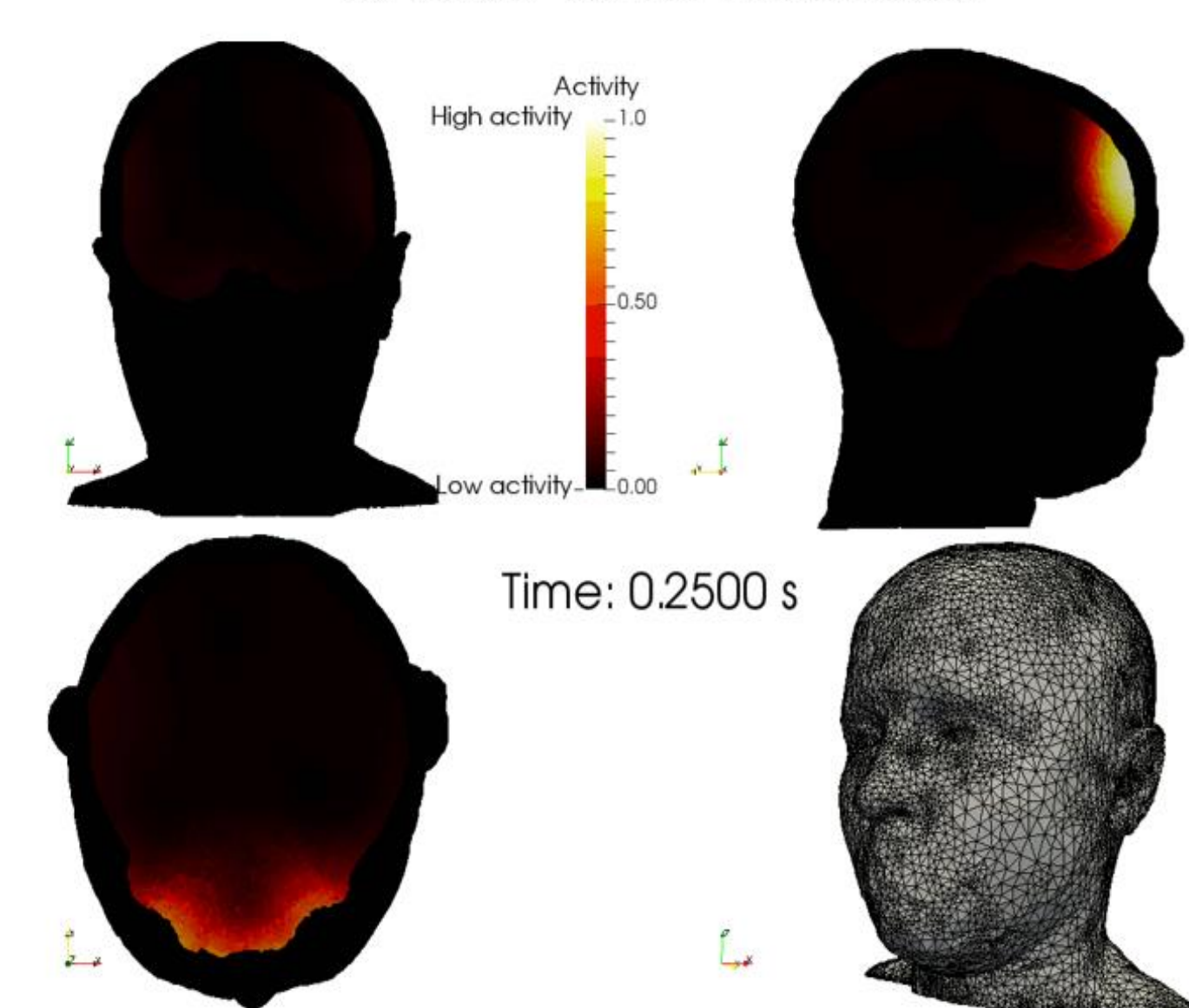
1. Computation of Lead fields and visibility (offline)



2. EEG data acquisition

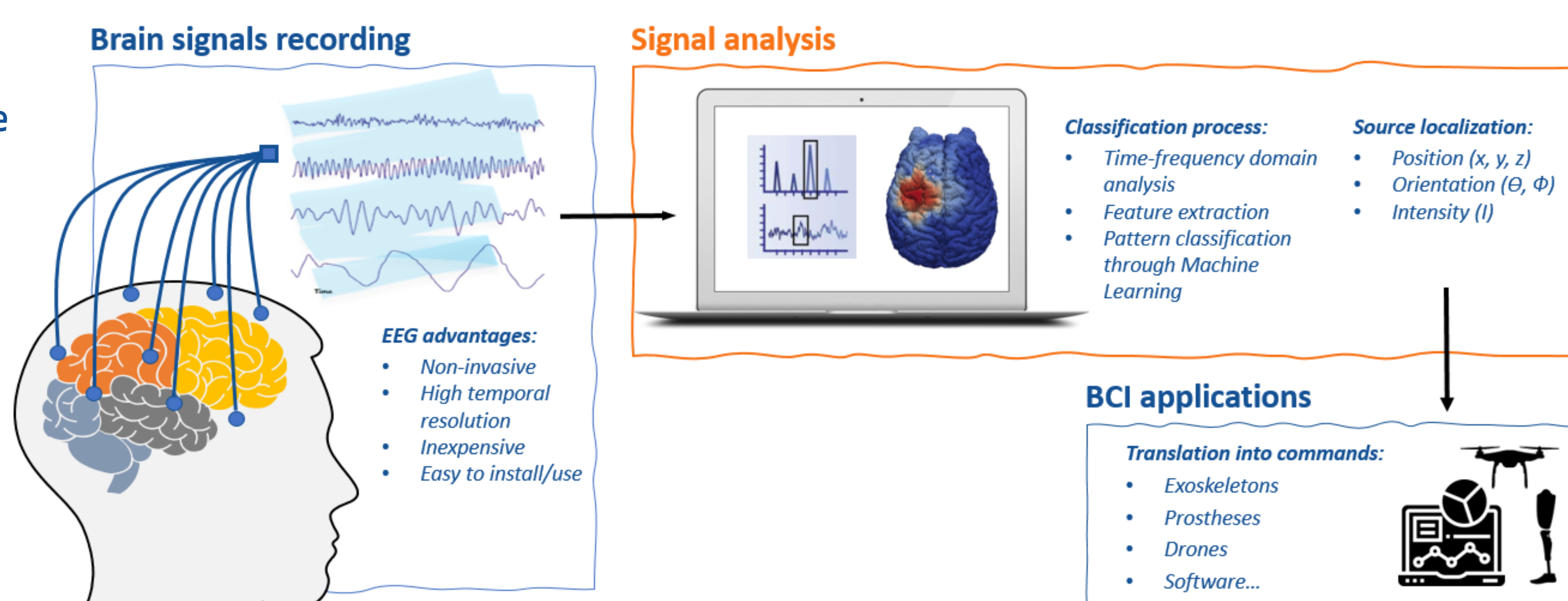


3. Real-time inversion



Conclusions and Prospects

- Source reconstruction methods improve the spatial resolution of scalp EEG, and could be a way to improve classification accuracy.
- The "Renormalization" method generates in real-time a unique and stable solution to the ill-posed Source Term Estimation (STE) problem, based on the Lead Field and "visibility" concepts.
- We aim to determine whether our "Renormalization" method can complement existing non-invasive EEG-based BCI methodologies.
- Alternatively, feature extraction and classification steps can be regarded as a whole within the Riemannian framework:
 - Based on the Riemannian geometry
 - Allows easy manipulation of covariance matrices
 - Characterized by its simplicity, accuracy, robustness, and transfer learning capabilities.



References

Singh, S. K., Turbelin, G., & Issartel, J. P. (2019). Characterizing Variations in Concentration Data Measured from Unknown Releases. Earth and Space Science. Doi.org/10.1029/2019EA000669

Turbelin, G., Singh, S., Issartel, J. P., Busch, X., & Kumar, P. (2019). Computation of Optimal Weights for Solving the Atmospheric Source Term Estimation Problem. Journal of Atmospheric and Oceanic Technology, 36(6), 1053-1061, doi.org/10.1175/JTECH-D-18-0145.1

Singh, S. K., Turbelin, G., Issartel, J.-P., Kumar, P., and Feiz, A. A. (2015). Reconstruction of an atmospheric tracer source in fusion field trials: Analysing resolution features, J. Geophys. Res. Atmos., 120. Doi:10.1002/2015JD023099

Turbelin, G., Singh, S. K., & Issartel, J. P. (2014). Reconstructing source terms from atmospheric concentration measurements: Optimality analysis of an inversion technique. Journal of Advances in Modeling Earth Systems, 6, 1244-1255. Doi:10.1002/2014MS000385.