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

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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.

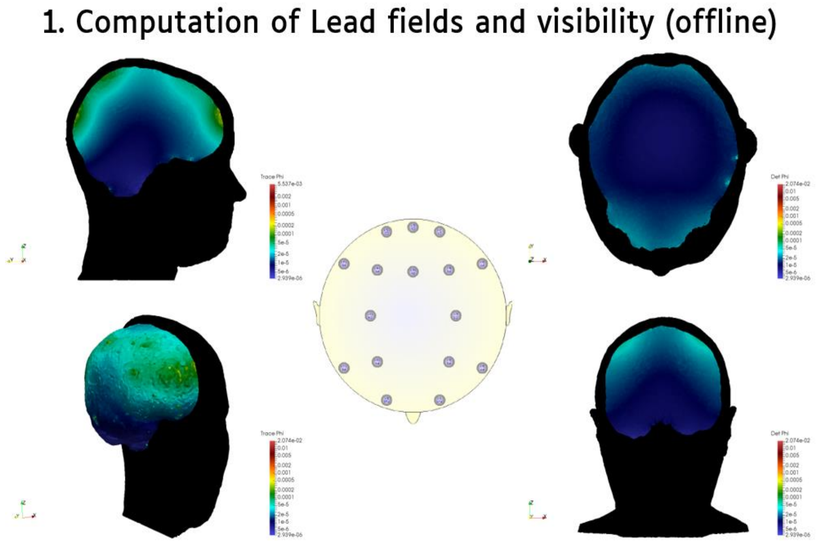
Method description

- 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.

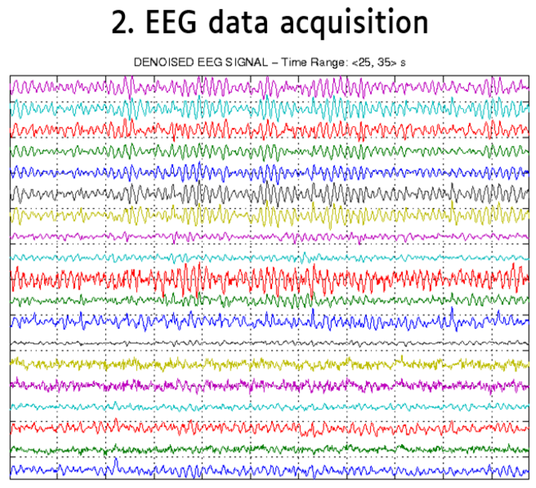
Theoretical properties

- 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

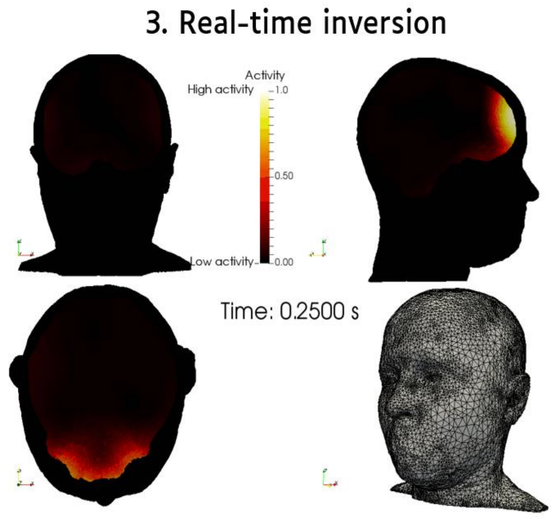
1. Computation of Lead fields and visibility (offline)



2. EEG data acquisition

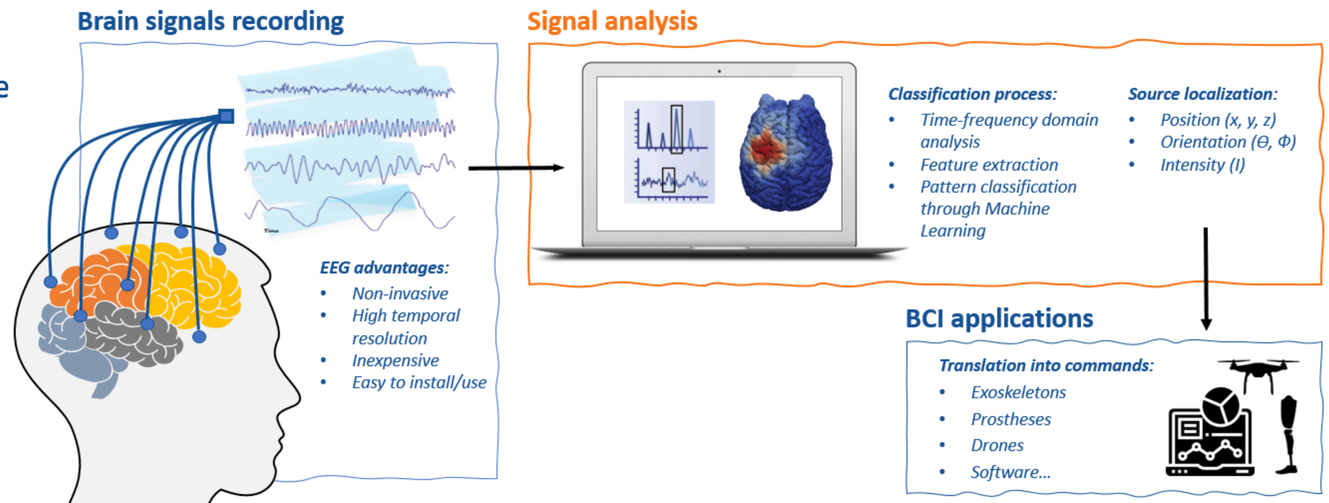


3. Real-time inversion



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

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