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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

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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