Independent Component Extraction Framework for Localization of a Moving Visual Evoked EEG Source

TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Mechatronics, Informatics and Interdisciplinary Studies

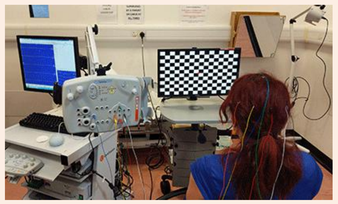
Nesrine Amor and Zbyněk Koldovský

Faculty of Mechatronics, Informatics, and Interdisciplinary Studies, Technical University of Liberec, Studentská 2, 46117, Liberec, Czech Republic

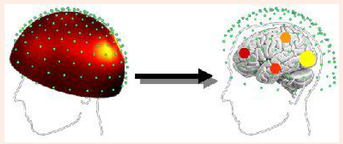
nesrine.amor@tul.cz, zbynek.koldovsky@tul.cz

Background

❖ ***Visual Evoked Potentials (VEPs):*** are useful indicators to explore the hidden neural circuitry in the human brain. VEPs are electrical signals measured from electroencephalograms (EEG) generated by the visual cortex in response to visual stimulation.



❖ ***Dynamic Brain Sources Localization:***



❑ The main sources of EEG potentials, which are measured at the scalp, emanate from the simultaneous current flows of many neighboring neurons in the same direction.

❑ It is postulated that the EEG signal is generated by a few brain sources. Extraction of these brain sources helps us to understand and analyze brain diseases.

❖ ***State-of-the-art:***

❑ The relationship between the EEG channels and the multiple active sources is described by linear combinations.

❑ The widely used approach to separate the mixed EEG signals into components (active sources and artifacts) is Independent Component Analysis (ICA), which does not have any prior information about the signals.

❖ ***Independent Component Analysis (ICA)***

Main idea: ICA mainly relies on a linear transformation model that links the EEG recordings and the active sources in the brain. The instantaneous linear mixing model is given by

$$X = AS$$

Drawbacks: ICA is limited in modeling nonstationary changes in EEG source locations and activities because of its spatial-stationarity assumption produced by its use of a fixed spatial mixing matrix.

❖ ***Contributions and Proposed Work:***

❑ We introduce a novel formulation that uses a blind source extraction method for analyzing the brain responses using continuous stimulus:

(1) Formulation of the moving EEG sources using Independent Component Extraction.

(2) Extraction of a new component that represents most of the activities in the brain using EEG data recorded during checkerboard stimulation.

Independent Component Extraction

Independent Component Extraction (ICE) extracts only one source referred to as the source of interest (SOI), based on the assumption that it is independent from the other signals. The mixing matrix and its de-mixing matrices are parameterized, respectively, as

$$A_{ICE} = (a \quad Q) = \begin{pmatrix} \gamma & h^H \\ g & \frac{1}{\gamma}\left(gh^H - I_{d-1}\right) \end{pmatrix}$$

$$W_{ICE} = A_{ICE}^{-1} = \begin{pmatrix} w^H \\ B \end{pmatrix} = \begin{pmatrix} \beta^* & h^H \\ g & -\gamma I_{d-1} \end{pmatrix}$$

Drawbacks: Both of the above equations only are valid for extracting one static source.

Proposed method: A recent dynamic version of ICE was introduced where it is possible to extract a desired moving source.

Constant Separating Vector (CSV)

Consider that the measured signals can be divided into B blocks (b=1,...,B), as

$$X^b = A^b S^b$$

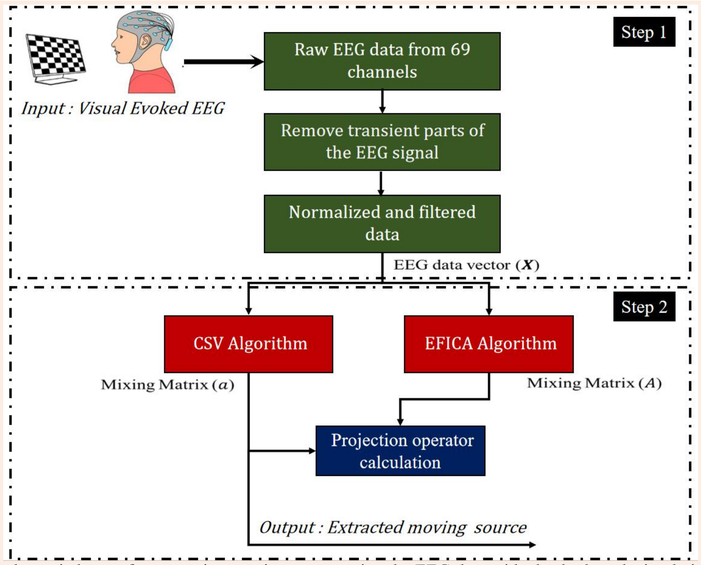
CSV assumes that w is constant over time and that the mixing and de-mixing matrices are parameterized, respectively, as follow

$$A_{CSV}^b = \begin{pmatrix} \gamma^b & h^H \\ g^b & \frac{1}{\gamma}\left(g^b h^H - I_{d-1}\right) \end{pmatrix}$$

$$W_{ICE} = \begin{pmatrix} \beta^* & h^H \\ g^b & -\gamma^b I_{d-1} \end{pmatrix}$$

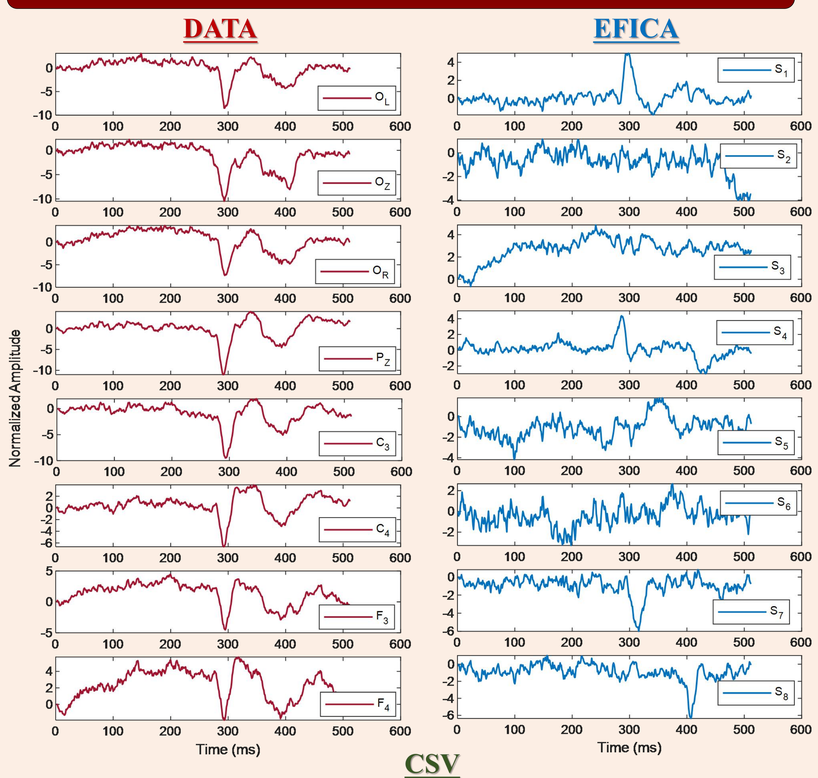
CSV involves a moving SOI under the assumption that a constant separating vector such that extracts the signal from all blocks exists.

Proposed Approach

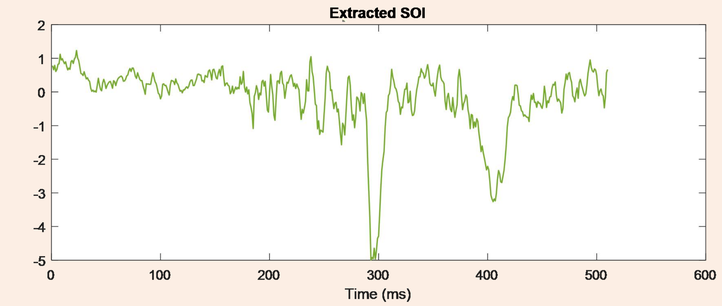


A schematic layout for extraction moving source using the EEG data with checkerboard stimulation.

Simulation Results



CSV



Conclusion

➢ This study introduced a shift in the current paradigm of brain extraction sources by considering one moving EEG source representing most activities in the brain.

➢ Application of CSV mixing model on real multi-channel EEG data provided us the extraction of a new moving source that represents most activities in the brain.

➢ The proposed CSV offers a robust and alternative solution regarding modeling and identifying changes in EEG dynamics.