Jacobi iterations for spatially constrained Independent Component Analysis

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Electroencephalography (EEG) is a non-invasive tool that offers millisecond temporal resolution for the study of neural mechanisms underlying mental activity. Eye movement and blink artifacts often contaminate EEG recordings, which complicate the interpretation. Several techniques have already been proposed to remove eye artifacts from the EEG. However, most of them require the availability of peri-ocular electrooculographic (EOG) electrodes, which is not always recorded simultaneously with the EEG in an Epilepsy Monitoring Unit.
Recently, Independent Component Analysis (ICA) is introduced in order to blindly separate interesting brain signals from artifacts in EEG recordings. Especially SOBI (Second Order Blind Identification), which exploits the temporal correlation of the source signals, has been shown to accurately separate eye artifacts from the EEG. A disadvantage of blind techniques is that the extracted sources have to be inspected afterwards, which is time-consuming and rater-dependent. In the case of ocular artifacts, there is a strong *a priori* knowledge about the spatial distribution of eye movement and blinking artifacts. An objective way to automate eye artifact rejection is to incorporate the knowledge of a mixing vector in a constrained ICA algorithm. This algorithm will extract independent components, but the last source will have a spatial distribution similar to the known one.

In this study, we developed two new, spatially constrained ICA algorithms. A first algorithm can be used when one or more mixing vectors are exactly known. In this case, solving the ICA problem can be reduced to solving an ICA problem of a lower dimension. When a mixing vector is only approximately known, another algorithm is required. In this case, the cost function of ICA has to be modified. SOBI is computed by means of joint approximate diagonalization of correlation matrices. This joint diagonalization criterion is iteratively optimized under plane rotations. In the unconstrained ICA problem, the optimal Jacobi angles are given as the solution of an eigenvalue problem [1]. In order to solve the (weighted) constrained ICA problem, an extra term is added to the cost function of unconstrained ICA. This extra term is the projection of the computed mixing vector on the known spatial distribution, multiplied with a weighting factor. The new cost function is maximised by means of the technique of Lagrange multipliers. We also explain how prior knowledge about the mixing vector can be incorporated in the prewhitening step for the case that there are more sensors than sources.
A new method for eye artifact removal from EEG recordings is developed based on constrained ICA. We demonstrate this method on simulations, and show also that it accurately removes ocular artifacts in *in vivo* recordings.

[1] J-F Cardoso, A. Souloumiac. *Blind beamforming for non gaussian signals*. IEE- Proceedings-F, 140 (6): 362-370 (1993)