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Complex Independent Component Analysis with Real Mixing

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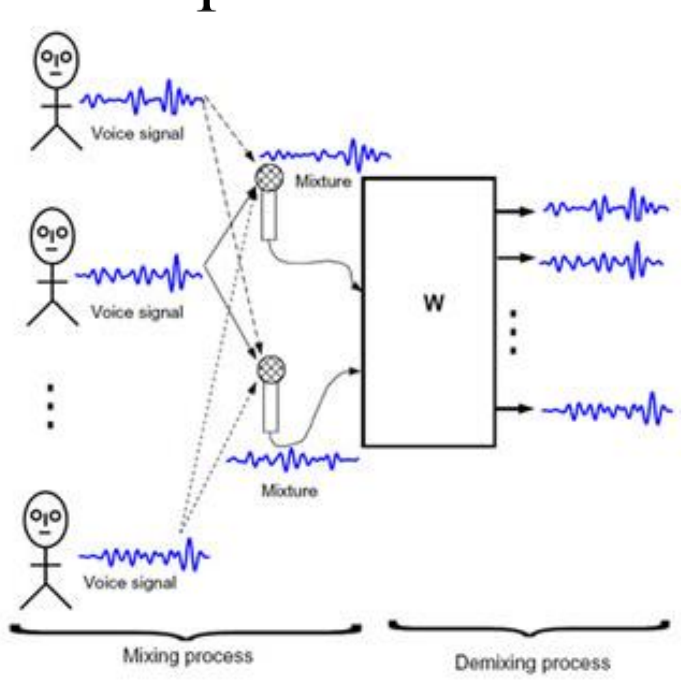
Introduction

- Extended from cocktail party / ICA problem
- Complex observations $\boldsymbol{x}$ are real mixtures $\boldsymbol{A}$ of independent circular complex sources $\boldsymbol{s}$



Mixing process:

$$\boldsymbol{x} = \boldsymbol{A}\boldsymbol{s}$$

$$\boldsymbol{A} \in \mathbb{R}; \boldsymbol{x}, \boldsymbol{s} \in \mathbb{C}$$

Demixing process:

$$\hat{\boldsymbol{s}} = \boldsymbol{W}\boldsymbol{x}$$

$$\boldsymbol{W} \in \mathbb{R}$$

Motivation

- Based on Central Limit Theorem, sum of independent random variables is more Gaussian than the original variables.

$$y = \boldsymbol{w}^T\boldsymbol{x} = \boldsymbol{w}^T\boldsymbol{A}\boldsymbol{s} = \boldsymbol{z}^T\boldsymbol{s}$$

- $\boldsymbol{z}^T\boldsymbol{s}$ is more Gaussian than any of the s_i and will become least Gaussian when it equals one of s_i (only one element of $\boldsymbol{z}$ is non-zero).
- Cost function should be a measure of Non-Gaussianity.

Method

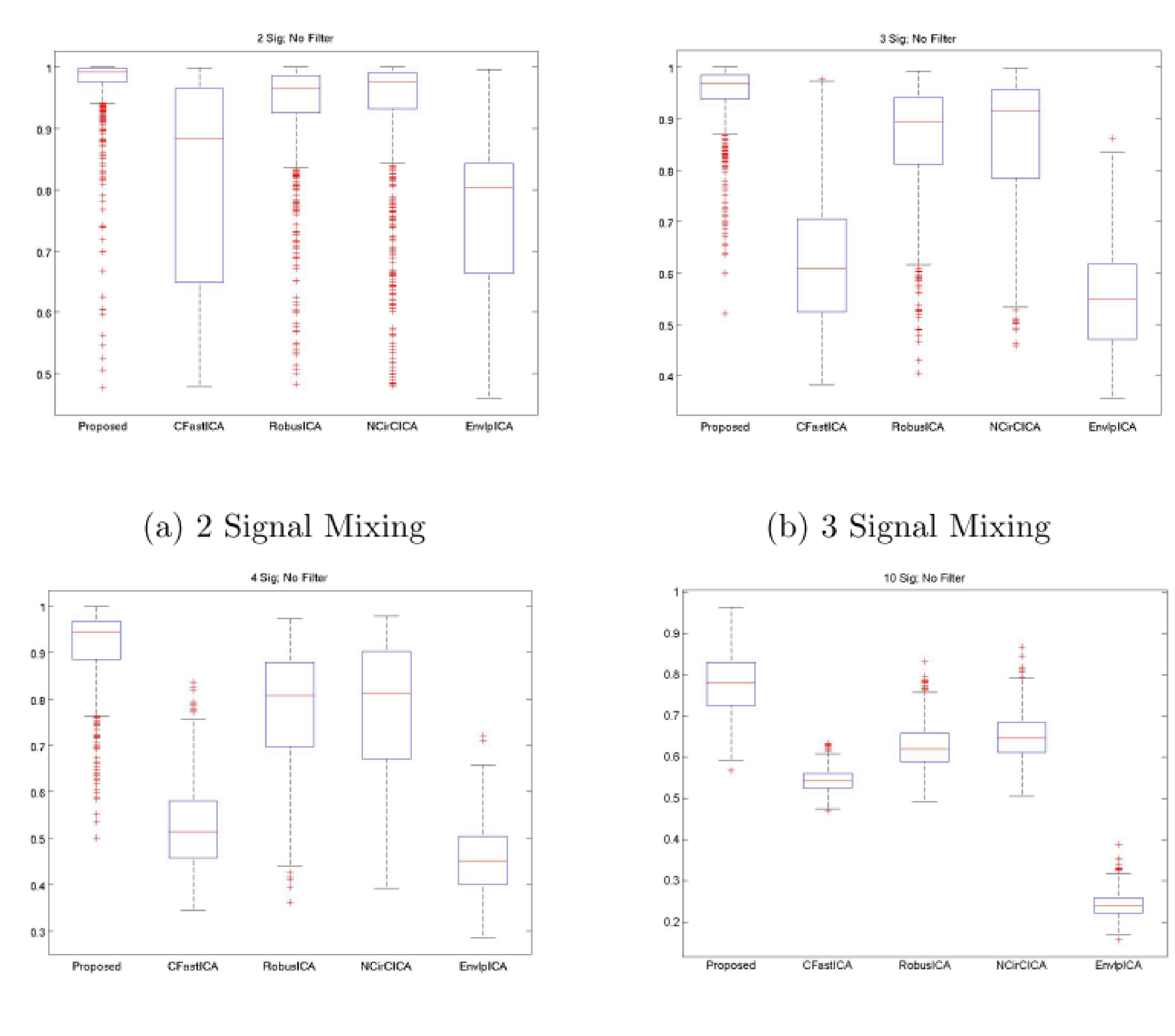
- Cost Function – Normalized Kurtosis Function

$$K(y) = \frac{E\{|y|^4\}}{E^2\{|y|^2\}} - 2$$

Where $y = \boldsymbol{w}^T\boldsymbol{x}$ and $|\boldsymbol{w}| = 1$

- Cost function is optimized based on Quasi-Newton Optimization
- The independent sources are the local maximums of the cost function if super-Gaussian sources are assumed.
- Single/Multiple unit Gram-Schmidt decorrelation is used to prevent different weight vectors $\boldsymbol{w_j}$ from converging to the same maximum.

Result



(a) 2 Signal Mixing (b) 3 Signal Mixing

(c) 4 Signal Mixing (d) 10 Signal Mixing

Simulation

- The complex sources are simulated by
  - Generating independent real Rayleigh signals.
  - Apply Hilbert transform to get imaginary part.
- Separation performance of the proposed method are compared with other methods including complex-fastICA method[1], robust ICA[2], and non-circular fastICA method[3].

1. A. Hyvarinen, etc. Neural Networks, 2000 2. V. Zarzoso, etc. IEEE T. Neural Networks, 2010
3. M. Novey, etc. IEEE T. Neural Networks, 2008

Discussion and Future Works

- The proposed method outperforms other existing complex ICA methods.
- When the number of sources increases, the performance of source separation drops, but our method still provides a reasonable separation compared with others.
- The proposed method can be applied to the EEG/MEG sensor data to get underlying brain network at the sensory level.

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