

Independent Component Analysis (ICA)

Ganesh Naik
RMIT University,
Melbourne

ganesh.naik@rmit.edu.au

Introduction

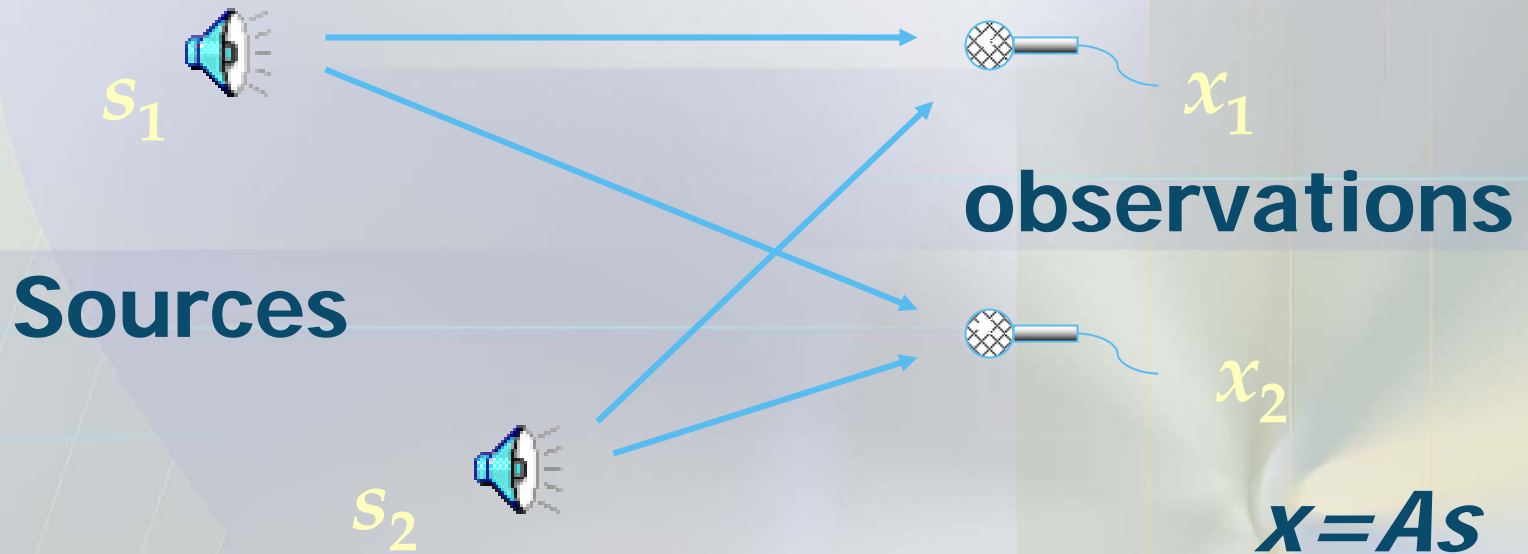
- **Surface electromyogram (SEMG) is an indicator of the underlying muscle activity**
- **Difficulty in the use of SEMG for identifying complex movements is the mixing of muscle activity from other muscles, referred to cross-talk.**
- **Remedy for this is Independent Component Analysis (ICA) which is a useful technique for blind source separation.**

What is Independent Components Analysis

- **Blind Signal Separation (BSS) or Independent Component Analysis (ICA) is the identification & separation of mixtures of sources with little prior information.**
 - Major technique for Blind Signal Separation
 - Has advantages from other multivariate techniques like PCA
 - Applications in EEG, ECG, fMRI

The simple "Cocktail Party" Problem

Mixing matrix A



n source $m=n$ observations

Cocktail Party Problem

- **Problems Specification**

- 2 people talking simultaneously($s_1(t)$ $s_2(t)$)
- 2 microphones in different locations gives us two time signals $x_1(t)$ $x_2(t)$

$$x_1 = a_{11} * s_1 + a_{12} * s_2$$

$$x_2 = a_{21} * s_1 + a_{22} * s_2$$

- a_{ij} are values depending on distance of mic from speakers.
- Want to estimate s_1 and s_2 using only x_1 and x_2
- ICA solves this problem without knowing a_{ij} , the major assumption is that $s_1(t)$ and $s_2(t)$ are independent.

More Details on ICA

- **Interested in solving $x=As$**
 - A is mixing matrix, s is source vector, x is mixtures
 - Generative model: describes how observed data are generated by a process of mixing components of s .
- **Two major assumptions**
 - Components s_i are statistically independent
 - Independent component must have nongaussian distributions
- **Part of Larger Problem Blind Source Separation (BSS)**
 - Little known about mixing matrix
 - Little assumed about source signals

Ambiguities of ICA

Because $y=Bx$ is just a copy of S :

- we can not determine the variance (energies) of the independent components.
- we can not determine the order of the independent components.
 - applying a permutation matrix P to $x=As$, i.e., $x=AP^{-1}Ps$, then Ps is still like the original signals, and
 - AP^{-1} is just a new unknown mixing matrix, to be solved by the ICA algorithms,
 - the order of s will be changed.

ICA – Fast Fixed Point Algorithm

- FFPA converges rapidly to the most accurate solution allowed by the data structure

Fast fixed-point algorithm for ICA (one component)

Step 1. Prewhiten the observed data \mathbf{x} to obtain vector \mathbf{v} .

Step 2. Randomly set the values of the initial weight vector $\mathbf{w}(0)$ (note the subscript is dropped here because we are only initially concerned with finding one independent (component), and normalize to unit length, that is,

$$\mathbf{w}(0) \leftarrow \frac{\mathbf{w}(0)}{\|\mathbf{w}(0)\|_2}$$

and set $j = 1$.

Step 3. Let

$$\mathbf{w}(j) = E[\mathbf{v}(\mathbf{w}^T(j-1)\mathbf{v})^3] - 3\mathbf{w}(j-1)$$

The expectation operator can be estimated using a relatively large number of \mathbf{v} vectors.

Step 4. Normalize $\mathbf{w}(j)$ to unit length:

$$\mathbf{w}(j) \leftarrow \frac{\mathbf{w}(j)}{\|\mathbf{w}(j)\|_2}$$

Step 5.[†] If $|\mathbf{w}^T(j)\mathbf{w}(j-1)|$ is not close to 1, then let $j \leftarrow j + 1$ and go back to step 3. Otherwise, output vector $\mathbf{w}(j)$.

Step 6. Using $\mathbf{w}(j)$, one of the separated source signals is given by

$$s(k) = \mathbf{w}^T(j)\mathbf{v}(k) \quad k = 1, 2, \dots$$

Conventional Approaches

❖ Time-Domain ICA (TDICA)

- ◆ To estimate the separation FIR filter in the time domain

❖ Frequency-Domain ICA (FDICA)

- ◆ To estimate the separation coefficients every frequency bin in the frequency domain

Choice of Algorithm

- One choice is between estimating all the independent components in parallel or just estimating a few of them
- Choose the nonlinearity used in ICA best choice is *tanh* function
- Choice between Online and Batch Algorithm
 - Use batch if whole set of data is available before the estimation. e.g., Fast ICA
 - Use online algorithm If mixing matrix change every time, e.g., Adaptive signal processing applications

EMG and ICA

- One property of the SEMG is that the signal originating from one muscle can generally be considered to be independent of other bioelectric signals such as ECG, EOG, EMG etc from neighboring muscles
- This is the motivation for using ICA for EMG signals

Difficulties

- ICA separates the signals without any prior information
- Difficult to find the spatial location of the active muscle activities

Possible Solution

- **Use Prior knowledge of the muscle anatomy**

Advantage

- **Model Based approach that provides that provides well defined muscle activity pattern**

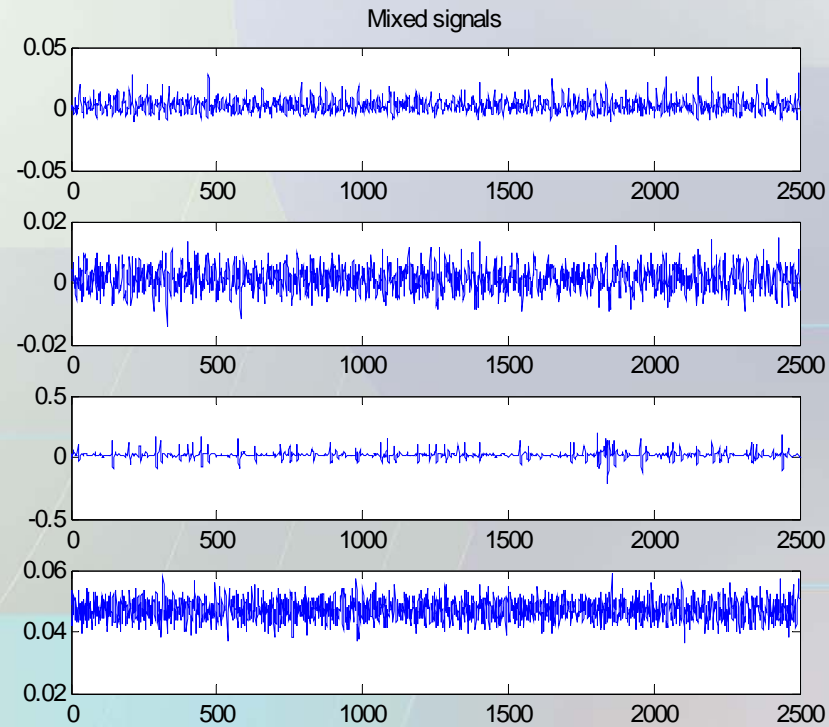
Disadvantage

- **Need for well location of the electrodes**

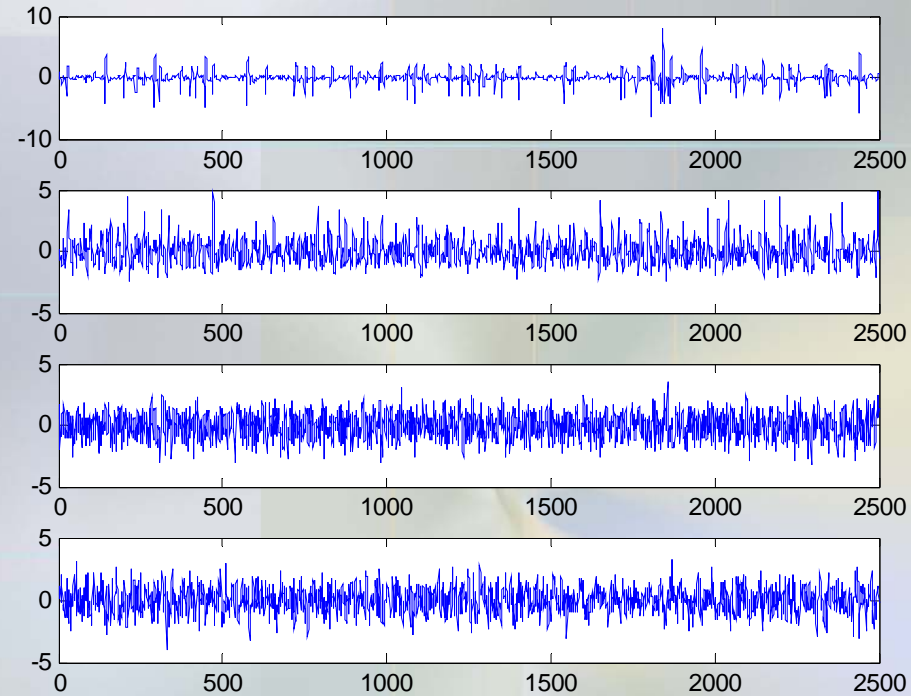
EMG Analysis using ICA

Four Chanel EMG Recordings

Estimated Sources using ICA



ICA



EMG Analysis using ICA

- **Get the EMG data (Recordings)**

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

- **Estimate the sources using**

$$\mathbf{s} = \mathbf{B}\mathbf{x} = \mathbf{A}^{-1}\mathbf{x} \quad \text{where } \mathbf{B} \text{ is } \mathbf{A}^{-1}$$

- **Compute the RMS values using**

$$\sqrt{\frac{1}{N} \sum_{i=1}^N s_i^2}$$

EMG analysis using ICA

- **ICA results are combined with Neural network to get the classification results.**

Action performed	Action identified for each sub experiments				
Wrist flexion	100%	100%	100%	100%	100%
Finger Flexion	100%	100%	100%	100%	100%
Finger flexion and wrist flexion	100%	100%	100%	100%	100%

Why ICA with Other classifiers ?

Reasons.

- **ICA is a form of Blind Source Separation**
- **Time Delay and Ambiguity problems.**
- **ICA assumes the sources as linear mixtures**

Future Work

- ❖ **Further evaluation with different types of hand body gestures**
 - ◆ **Test large set of data for Inter and intra experimental variations**
 - ◆ **Usage of ICA with classifiers like Support vector machine, Bayesian classifier etc**
- ❖ **To apply Frequency domain ICA (Convolutive -ICA) on EMG data**
- ❖ **On-line and real-time algorithm**

ICA -Links

- http://www.cis.hut.fi/aapo/papers/NC_S99web/node11.html
- http://www.cis.hut.fi/projects/ica/ica_demo/
- <http://sig.enst.fr/~cardoso/>
- http://www.cnl.salk.edu/~tewon/ica_cnl.html
- <http://www.salk.edu/faculty/sejnowski.html>

Thank You