Application of Independent Component Analysis (ICA) on Magnetoencephalography (MEG)

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Introduction

Magnetoencephalography (MEG) is a noninvasive technique by which the brain activity can be measured with very good temporal resolution (1ms) and moderate spatial resolution (1cm).

MEG signals are recorded in a magnetically shielded room with a 160 channel whole-scalp Neuromag-160 neuromagnetometer, which is sensitive to small magnetic field as 10fT.

KIT-UMD whole head MEG system & shielded room. 160 axial gradiometers,

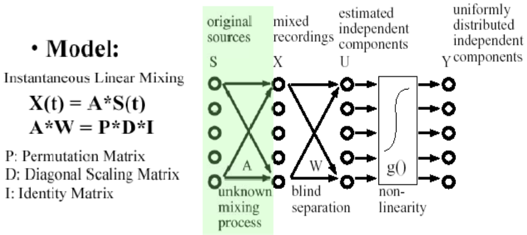
To analyze MEG recordings, we need to extract the essential features of the neuro-magnetic signals in the presence of artifacts. A new method to separate brain activity from artifacts is Independent Component Analysis (ICA), which is based on the assumption that the brain activity and the artifacts, e.g. heart beat or eye movements are anatomically and physiologically separate processes, and this separation is reflected in the statistical independence between the magnetic signals generated by those processes[1][2][3].

Experiment

Acoustic stimuli are sinusoidal amplitude-modulated tones at 16, 32 and 48 Hz, with carrier frequency at 400 Hz. Each 20 second stimuli is presented 10 times in pseudorandom order. 157 sensors are placed on that subject's scalp to record the magnetic field. 3 additional magnetometer are placed away from the brain to record the reference noise.

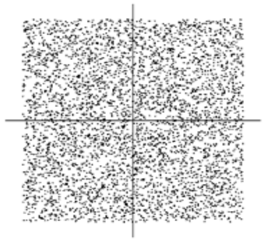
ICA model

We use ICA to unmix the separate sources' activity.



- Assumption
  Sources are independent
- Method
  Estimate Weights so to maximize output entropy H(Y) ⇔ Minimize mutual information I(Y)
- Goal
  Learn the transform which unmix the recorded signal so that the output is as independent as possible
- Example

Joint distribution of mixed signals x1, x2



Joint distribution of unmixed sources s1,s2

Results

After applying ICA on the MEG recording, we display the unmixed components according to their spatial distribution on the scalp. Figure 1 is the ordered spatial contribution for every component. Figure 2 presents the first component's waveform, power spectral density and spatial contribution on the sensors. It shows this component is heart beat artifact. Figure 3 presents the 29th component, it is related to the auditory response.

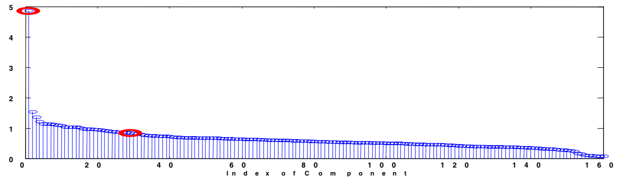


Figure 1 Spatial Contribution

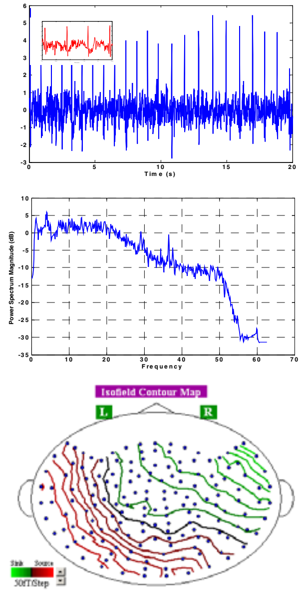


Figure 2 Heart Beat

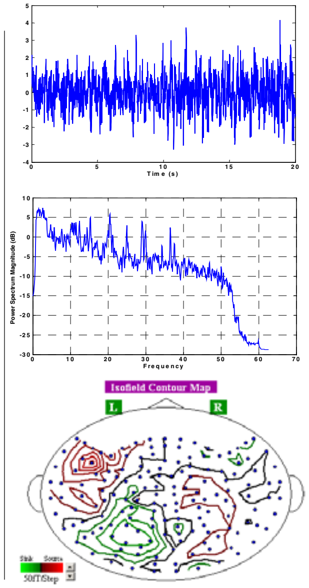


Figure 3 Component 29

Conclusion

ICA is a powerful way to enhance the MEG signal. In addition to reducing artifacts, ICA can be used to decompose auditory related responses, which enables direct access to the underlying brain function.

Reference

[1] Aapo Hyvärinen and Erkki Oja, Independent Component Analysis: Algorithms and Applications, *Neural Networks*, 13(4-5): 411-430, 2000

[2] What is MEG, http://www.geocities.com/Tokyo/1158/meg.html

[3] Anthony J. Bell and Terrence J. Seinowski, An Information-Maximization Approach to Blind Separation and Blind Deconvolution, Volume 7, Issue 6 (November 1995) Pages: 1129–1159