1st International Summerschool in Biomedical Engineering

Decomposition Methods for Multidimensional Data

(held in Erfurt, August 7-11 2006)

Course Material

Program overview

Introduction	Monday (7.8.) a.m.
Independent Components Analysis	Monday (7.8.) p.m. – Tuesday (8.8.) a.m.
Parallel Factor Analysis	Tuesday (8.8.) p.m.
Wavelet Analysis	Wednesday (9.8.) a.m. and p.m.
Matching Pursuit	Thursday (10.8.) a.m. and p.m.
Dipolar Source Separation	Friday (11.8.) a.m.
Conclusion & Demonstration	Friday (11.8.) p.m.

Program (detailed)

Monday (August 7th 2006)

Introduction

09:00-09:15	Welcome speech	Jens Haueisen
09:15-09:45	A case of multifocal epilepsy	Jens Haueisen
09:45-10:30	Physiological signals I	Thomas Knösche
10:30-10:45	*Coffee break*	
10:45-11:30	Physiological signals II	Jens Haueisen
11:30-12:00	The principles of data decomposition	Thomas Knösche
12:00-13:15	*Lunch break*	

Symposium 1 – Independent Components Analysis

13:15-14:45	Concepts of independent component analysis	Guido Nolte
14:45-15:15	*Coffee break*	

15:15-16:45	The Influence of spatial and spatio-temporal preprocessing on the quantification of the synchronization processes	Galina Ivanova
16:45-17:45	Panel discussion	

Tuesday (August 8th 2006)

Symposium 1 – Independent Components Analysis (continued)

09:00-10:30	Interacting Source Analysis (ISA): Studying true brain interactions with an ICA-related method	Guido Nolte
10:30-10:45	*Coffee break*	
10:45-12:00	Using ICA for pre-processing magnetic cardiac data	Dania Di Pietro Paolo
12:00-13:15	*Lunch break*	

Symposium 2 – Parallel Factor Analysis

13:15-14:45	The Parafac method for multi-dimensional data analysis	Alwin Stegeman
14:45-15:15	*Coffee break*	
15:15-16:45	Analyzing the Wavelet Transformed EEG using Non-negative Matrix and Tensor Factorization	Morten Mørup
16:45-17:45	Panel discussion	

Wednesday (August 9th 2006)

Symposium 3 – Wavelet Analysis

09:00-10:30	Wavelet analysis, an introduction with applications from geophysics and neuro sciences	Matthias Holschneider
10:30-10:45	*Coffee break*	
10:45-12:15	Wavelets and medical imaging	Gerd Teschke
12:12-13:15	*Lunch break*	
13:15-14:45	Cross wavelet analysis of biomedical time Series	Uwe Graichen
14:45-15:15	*Coffee break*	
15:15-16:15	Panel discussion	
16:15-17:45	to be anounced	

Thursday (August 10th 2006)

Symposium 4 – Matching Pursuit

09:00-11:00	Matching pursuit: what it is, how it works and what can it do for you	Pjotr Durka
11:00-11:15	*Coffee break*	
11:15-12:15	Robust incertainty relations in Matching Pursuit	Ernest Aleksy Bartnik
12:15-13:15	*Lunch break*	
13:15-14:00	Matching Pursuit in music	Ernest Aleksy Bartnik
14:00-14:45	Spatial-time-frequency filtering of bioelectromagnetic data using Matching Pursuit	Maciej Gratkowski
14:45-15:15	*Coffee break*	
15:15-16:45	Unification in EEG analysis and other applications	Pjotr Durka
16:45-17:45	Panel discussion	

Friday (August 11th 2006)

Symposium 5 – Dipolar Source Separation

09:00-10:30	Techniques for MEG source separation	Jukka Nenonen
10:30-10:45	*Coffee break*	
10:45-12:15	Processing of MEG data by the signal space separation method	Samu Taulu
12:15-13:15	*Lunch break*	
13:15-14:15	Simultaneous suppression of disturbing fields and localization of magnetic markers by means of multipole expansion	Bernd Hilgenfeld

Summary and Concluding Remarks

14:15-15:15	Analysis of case with multifocal epilepsy introduced at first day	Frank Zanow
15:15-15:45	*Coffee break*	
15:45-16:15	General panel discussion	
16:15-16:30	Concluding remarks	Thomas Knösche

Symposium 1 – Independent Components Analysis (ICA)

Organizer: Dania Di Pietro Paolo (University of Jena)

Speakers: Guido Nolte (Fraunhofer FIRST)
Galina Ivanova (Technical Univeristy of Ilmenau)
Dania Di Pietro Paolo (University of Jena)

Introductory material (abstracts, full papers attached):

1) "Survey on Independent Component Analysis"
Aapo Hyvärinen

Neural Computing Surveys 2, 94-128 , 1999

This paper is a good introduction of ICA and can be useful for the Overview-Talk.
A general view of the classical linear transformations (PCA, FA, and others high order statistics algorithms) is presented before going in details on ICA and its relation to the classical methods.
The paper sums up the possible applications of ICA in different fields and surveys contrast functions and adaptive and batch-mode algorithms. A small mention to NoisyICA is done.

2) "Independent Component Analysis for biomedical signals"
Christopher J James and Christian W Hesse

Physiol. Meas. 26 (2005) R15-R39
Topical Review

This paper could be useful for the Practical-Demonstration.
This paper concentrates on reviewing the ICA concepts at a practical level and in particular in EEG. The assumptions done when applying ICA to the data are explained. The different criteria used to drive to the different algorithms are shown and a summary of the most used methods (fICA, Infomax, Jade, BSS methods based on temporal structure) is presented. Advanced methodologies, taking into account the already known algorithms are also investigated.

3) "Identifying interactions in mixed and noisy complex systems"
Guido Nolte, Frank Meinecke, Andreas Ziehe, Klaus-Robert Müller

Physical Review E 73, 051913 (2006)
This paper could be useful for the Hot-Topic "Interacting Source Analysis (ISA): Studying true brain interactions with an ICA related method"

This papers deals with a new method, applied on EEG/MEG, data (ISA) that is used for extracting interacting components in the brain suppressing spurious interaction coming from the volume conduction. Indeed, until now neither BSS method nor typical phase synchronization analysis can handle signals when the sources are interacting (not independent). For the extractions of these interacting sources anti-symmetrized cross-correlation matrices and a subsequent diagonalization are used.

Symposium 2 – Parallel Factor Analysis (PARAFAC)

Organizer: Stefan Illek (University of Halle)

Speakers: Alwin Stegeman (University of Groningen)
Morten Mørup (Technical University of Denmark)

Introductory material (abstracts, full papers attached):

1) "Decomposing EEG data into space-time-frequency components using Parallel Factor Analysis"
Fumikazu Miwakeichi, Eduardo Martinez-Montes, Pedro A. Valdes-Sosa, Nobuaki Nishiyama, Hiroaki Mizuhara, Yoko Yamaguchia

NeuroImage 22 1035-1045 (2004)

This paper introduces Parallel Factor Analysis as a new type of space/frequency/time atomic decomposition of the power of the ongoing EEG. The application of PARAFAC on the multichannel evolutionary spectrum of the EEG arranged as a three-way data array yields unique solutions without imposing additional constraints as necessary in PCA and ICA.

2) "Parallel Factor Analysis as an exploratory tool for wavelet transformed event-related EEG"
Morten Mørup, Lars Kai Hansen, Christoph S. Herrmann, Josef Parnas, Sidse M. Arnfred

NeuroImage 29, 938 – 947(2006)

In this article, PARAFAC is used for the first time to decompose wavelet transformed event-related EEG given by the inter-trial phase coherence (ITPC) encompassing ANOVA analysis of differences between conditions and 5-way analysis of channel x frequency x time x subject x condition. The extracted components show that PARAFAC decomposition is a promising data exploratory tool in the analysis of wavelet transformed event-related EEG.

3) "Decomposing the time-frequency representation of EEG using non-negative matrix and multi-way factorization"
Morten Mørup, Lars Kai Hansen, Josef Parnas, Sidse M. Arnfred

Technical Report

Here it is demonstrated, how the generalization of non-negative matrix factorization (NMF) to the PARAFAC model, the non-negative multi-way factorization (NMWF) can effectively extract the most similar activities across subjects and or conditions in the decomposition of the inter trial phase coherence (ITPC) of multi-channel EEG. The easy interpretability of the obtained results proposes the presented decomposition techniques to be valuable tools in multi-subject, multiple condition data analysis.

Symposium 3 – Wavelet Analysis

Organizer: Uwe Graichen (Technical University of Ilmenau)

Speakers: Matthias Hohlschneider (University of Potsdam)
Gerd Teschke (Konrad Zuse Zentrum Berlin)
Uwe Graichen (Technical University of Ilmenau)

Introductory material (abstracts, full papers attached):

1) "Introduction to continuous Wavelet Analysis"
Matthias Hohlschneider

These lecture notes are a self-contained introduction to the theory of wavelets.

2) "A practical guide to wavelet analysis"
Torrence C, Compo GP

BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY 79 (1): 61-78 JAN 1998

Abstract: This paper is a practical step-by-step guide to wavelet analysis. It includes a comparison to the windowed Fourier transform, the choice of an appropriate wavelet basis function, edge effects due to finite-length time series, and the relationship between wavelet scale and Fourier frequency. Extensions to wavelet analysis such as filtering, the power Hovmoller, cross-wavelet spectra, and coherence are described.

3) "Recent advances in wavelet analyses: Part I. A review of concepts"
Labat D

JOURNAL OF HYDROLOGY 314 (1-4): 275-288 NOV 25 2005

Abstract: In this paper a multiresolution continuous wavelet analysis method is shown to significantly improve the determination of the temporal-scale structure of a given signal. The concept of wavelet entropy in both continuous and multiresolution frameworks is introduced. New insights in the scale-dependence of the relationship are exposed by introducing wavelet cross-correlation and wavelet coherence.

Symposium 4 – Matching Pursuit

Organizer: Maciej Gratkowski (Technical University of Ilmenau)

Speakers: Pjotr Durka (University of Warsaw)
Ernest Aleksy Bartnik (University of Warsaw)
Maciej Gratkowski (Technical University of Ilmenau)

Introductory material (abstracts, full papers attached):

1) "Matching pursuit with time-frequency dictionaries."
S. Mallat and Z. Zhang

IEEE Trans. Signal Proc. 41(12), 3397-3415 (1993)

The paper introduces an algorithm, called matching pursuit, which decomposes any signal into a linear expansion of waveforms (called atoms). The algorithm creates concise approximations of signals using a relatively small number of atoms chosen from a very big and redundant set, called dictionary. The atoms are iteratively and adaptively chosen in order to best match the signal structures. Typical atoms are scaled, translated and modulated Gauss functions and are called Gabor atoms. With a dictionary of Gabor atoms, a matching pursuit defines an adaptive time-frequency plane.

2) "Multichannel matching pursuit and EEG inverse solutions"
P.J. Durka, A. Matysiak, E.M. Montes, P.V. Sosa, K.J. Blinowska,

J Neurosci Methods. 15, 148(1):49-59 (2005)

The paper presents a new approach to the preprocessing of the electroencephalographic time series for EEG inverse solutions. As the first step, EEG

recordings are decomposed by multichannel matching pursuit algorithm. This algorithm is a generalization of matching pursuit algorithm for multidimmensional data. Based upon the parameters of the waveforms fitted by the mutlichannel matching pursuit to the EEG (frequency, amplitude and duration), those corresponding to the phenomena of interest are chosen, like e.g. sleep spindles. For each structure, the corresponding weights of each channel define a topographic signature, which can be subject to an inverse solution procedure, like e.g. Loreta, used in this work. As an example, an automatic detection and parameterization of sleep spindles, appearing in overnight polysomnographic recordings is presented.

Symposium 5 – Dipole source separation

Organizer: Roland Eichardt (Technical University of Ilmenau)

Speakers: Jukka Nenonen (Elekta Neuromag Oy,
Helsinki University of Technology)
Samu Taulu (Elekta Neuromag Oy,
Helsinki University of Technology)
Bernd Hilgenfeld (University of Jena)

Introductory material (abstracts, full papers attached):

1) "Presentation of electromagnetic multichannel data: The signal space separation method"
Taulu, Kajola

JOURNAL OF APPLIED PHYSICS 97, 2005.

The signal space separation (SSS) method creates a fundamental linear basis of a measured multichannel magnetic signal. The magnetic field can be expressed as a combination of two separate and rapidly converging expansions of harmonic functions; one for signals arising from inside of the measurement volume of the sensor array and one for signals arising from outside of this volume. Consequently, the external interference signals can be suppressed by leaving its components out of a reconstruction based on the decomposition. The paper gives a fundamental introduction into the SSS method.

2) "Applications of the Signal Space Separation Method"
Taulu, Simola, Kajola

IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 53, NO. 9,
SEPTEMBER 2005.

The paper gives a closer view to the applications of the signal space separation (SSS) method. SSS is demonstrated to provide suppression of external interference signals, standardization of different positions of the subject and of different sensor configurations, compensation for distortions caused by movement of the subject (even a subject containing magnetic impurities), suppression of sporadic sensor artifacts, a tool for fine calibration of the device, extraction of biomagnetic DC fields, and an aid for realizing an active compensation system.

3) "Simultaneous suppression of disturbing fields and localization of magnetic markers by means of multipole expansion"
Hilgenfeld, Haueisen

BioMagnetic Research and Technology, 2:6, 2004.

In this paper multipole expansions are used for the localization of magnetically marked capules. Thereby, the measurement data are expanded in terms of inner and outer multipoles,which provides a direct separation of marker field and outer disturbing fields. The method enables a fast localization of markers and a high suppression of interferences. The paper gives an introduction to the multipole expansion method and it shows its localization results for magnetic markers with simultaneous elimination of disturbing fields.

4) “Magnetoencephalography – theory, instrumentation, and applications to noninvasive studies of the working human brain”
Hämäläinen, Hari, Ilmoniemi, Knuutila, Lounasmaa

Reviews of Modern Physics, Vol. 65, No. 2, April 1993

The article gives a general introduction into MEG. The mathematical theory of the method is explained in detail, followed by a thorough description of MEG instrumentation, data analysis, and practical construction of multi-SQUID devices. Additionally, several MEG experiments are described.