# Bibliography on Independent Component Analysis in Functional Neuroimaging

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**Abstract**

References for *independent component analysis* (ICA) applied in functional neuroimaging are collected. Functional neuroimaging here includes functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electroencephalography (EEG) and magnetoencephalography (MEG).

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Note that there is a index at the very end of this document.

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## 1 General references

A general introduction is (Hyvärinen and Oja, 2000). A list of papers from the Third International Conference on Independent Component Analysis and Signal Separation (ICA2001) is available from http://ica2001.org.

### 1.1 Neuroimaging

Overviews of ICA for neuroimaging are available in (McKeown et al., 2003; Calhoun et al., 2003) for functional magnetic resonance imaging (fMRI), and Stone (2002) discuss ICA for EEG, fMRI and optical imaging.

## 2 Methods

- Independent component analysis

- "Bell and Sejnowski ICA" (BS-ICA) — "Infomax" (Bell and Sejnowski, 1995).
    - "Maximum likelihood ICA" (MacKay, 1999; Lee et al., 1999). (Usually) the same as infomax but developed from maximum likelihood rather than information theory with the sources as, e.g., hyperbolic secant distributions.
- "Extended infomax" (Lee et al., 1999) is able to model heavy- and light-tailed distributions.
- 'Probabilistic ICA' (PICA) or 'Noisy ICA' (Beckmann et al., 2001a), (Kolenda, 2002, section 3.3 and 3.6)

$$\mathbf{X} = \mathbf{S}\mathbf{A} + \mathbf{U}. \tag{1}$$

  The noise is usually assumed to be isotropic Gaussian distributed $\mathbf{u} \sim \mathcal{N}(\mathbf{0}, \sigma^2\mathbf{I})$. A silimiar noise assumption is made in 'probabilistic principal component analysis' (PICA) — a special factor analysis model — where model selection can be based on AIC and test set (Hansen et al., 1997, 1999a), Minka, Bishop, Zoubin G.
- FastICA (Hyvärinen, 1999; Hyvärinen and Oja, 2000)
- Mean field ICA (MF-ICA) (Højen-Sørensen et al., 2002, 2001).

• Decorrelation methods — Dynamic component analysis (DCA)

- Molgedey-Schuster (MS-ICA) (Molgedey and Schuster, 1994). Probabilistic Molgedey-Schuster ICA: ICA with preliminary PCA and model selection with BIC (Hansen et al., 2001). Min/max autocorrelation factorization (MAF) is related to Molgedey-Schuster ICA (Molgedey and Schuster, 1994). MAF was originally described in (Switzer and Green, 1984; Green et al., 1988) and other descriptions are by Conradsen et al. (1986) and Nielsen (1994).
- Georgiev and Cichocki (2001)
- Dynamic component analysis (Attias and Schreiner, 1998, 1997)
- 'Hansen convolutive ICA' — 'Convolutive independent component analysis by prediction' (CICAP) (Hansen, 2003; Hansen and Dyrholm, 2003).

## 2.1 Methods in functional neuroimaging

Table 1 displays some of the 'methods' papers in ICA for functional neuroimaging.

Hansen (1998) develops noisy ICA with a mean field approximation and applies it together with PCA on an fMRI data set.

### 2.1.1 fMRI ICA for multiple subjects

Multisubject data may be analyzed in a variety of ways (Calhoun et al., 2008; Schmitthort and Holland, 2004):

- Pre-average data and then perform a single ICA (Schmitthort and Holland, 2004).
- Perform single subject ICAs and then combine or correlate the subject specific independent component with each other (Calhoun et al., 2001b).
- ICA with temporal concatenation. Here the subjects need to be in the same space, i.e., spatially normalized.
- ICA with spatial concatenation. Here the design in the temporal dimension need to be the same, e.g., the stimulus need to occure at the same time point across subjects
- Tensor-methods, e.g., PARAFAC.

A comparison on simulated data is reported in (Schmitthort and Holland, 2004).

| Modality | ICA Type | Purpose | Reference |
|---|---|---|---|
| fMRI | sICA | | (McKeown et al., 1998b) |
| fMRI | sICA | | (McKeown et al., 1998a) |
| fMRI | | Demonstration of estimation of noisy ICA with mean field approximation | (Hansen, 1998) |
| fMRI | tICA | | (Biswal and Ulmer, 1999) |
| fMRI | stICA | | (Muraki and Nakai, 1999) |
| fMRI | | Comparison of different analysis methods | (Lange et al., 1999) |
| fMRI | | Separate task and non-task | (Ulmer and Biswal, 2000) |
| fMRI | sICA(?) | Separation of task-related and head movement signal | (Netsiri et al., 2000) |
| fMRI | | | (Matsuo et al., 2000) |
| Dynamic PET | sICA (McKeown) | Determination of arterial input function | (Jang et al., 2000) |
| fMRI | sICA, tICA (FastICA) | Investigates sICA and tICA capability to separate paradigm signal | (Calhoun and Pekar, 2000) |
| fMRI | sICA with FastICA | Artifact detection: Gradient waveform corruption, bistable mean signal intensity change, Nyquist ghosting, high frequency, motion | (Beckmann et al., 2000a) |
| EEG | | | (Jung et al., 2001) |
| fMRI | sICA, tICA, stICA | Comparison of different ICA methods | (Caprihan and Anderson, 2001) |
| fMRI | | Model selection | (Beckmann et al., 2001a) |
| fMRI | FastICA | Compares ICA with GLM modeling | (Beckmann et al., 2001b) |
| fMRI | | Compared ICA with GLM modeling | (Calhoun et al., 2001b) |
| fMRI | | Identification of motion artifacts | (Bannister et al., 2001) |
| fMRI | ? | Group inference | (Calhoun et al., 2001a) |
| fMRI | sICA | Artifact detection | (Chuang and Chen, 2001) |
| fMRI | sICA infomax | Investigation of variation in the hemodynamic response function | (Duann et al., 2002a, 2001b,a) |
| efMRI | stICA | with “skewed probability density functions” | (Stone et al., 2002) |
| fMRI | Complex Infomax | | (Calhoun et al., 2002b,c,a; Calhoun and Adalı, 2002) |
| pMRI | | | (Tasciyan et al., 2001) |

Table 1: Independent component analysis in functional neuroimaging. sICA is spatial ICA, tICA is temporal ICA and stICA is spatiotemporal ICA.

### 2.1.2 Comparisons

Petersen et al. (2000) and Petersen (2000) compared spatial and temporal ICA with the infomax, DCA and Molgedey-Schuster (MS-ICA): MS-ICA was found to be much faster than BS-ICA and DCA and DCA much slower. BS-tICA and MS-sICA both had difficulties in separating the 'interesting' component. Esposito et al. (2002) compared the Bell and Sejnowski (1995) algorithm with the Hyvärinen (1999).

# 3 Tools in functional neuroimaging

Table 2 display some of the programs that are in use for independent component analysis of brain signals.

| Tool | Implementation | Description | Reference |
|---|---|---|---|
| AnalyzeFMRI | R | FastICA implementation(?) | http://www.stats.ox.ac.uk/~marchini-/software.html |
| BrainVoyager | Compiled for Windows, UNIX, Linux, Mac | "Cortex-based ICA" | http://www.brainvoyager.com/ |
| EEGLAB | Matlab | EGG processing including ICA with GUI. Related to FMRLAB. | (Delorme and Makeig, 2003), http://www.sccn.ucsd.edu/eeglab/ |
| FMRLAB | Matlab | Extended Infomax Algorithm | http://www.sccn.ucsd.edu/fmrlab/, (Duann et al., 2002b; Bell and Sejnowski, 1995; Amari, 1999; Lee et al., 1999) |
| GIFT | Matlab | "Group ICA of fMRI Toolbox" | (Egolf et al., 2004), http://icatb.sourceforge.net/ |
| ICA:DTU toolbox | Matlab | Implements Bell and Sejnowski Maximum likelihood (Infomax) ICA and Mean Field ICA as well as Molgedey-Schuster ICA. With model selection. | http://mole.imm.dtu.dk/toolbox/ica/, (Kolenda et al., 2000; Petersen et al., 2000; Hansen et al., 2001, 2000; Kolenda et al., 2001; Højen-Sørensen et al., 2002) |
| Lyngby | Matlab | The Bell-Sejnowski and Molgedey-Schuster algorithms are presently implemented | (Hansen et al., 1999b), http://hendrix.imm.dtu.dk/software-/lyngby/ |
| MELODIC | C | Part of FSL. Model order selection (number of sources). Inference on image map with mixture modelling | http://www.fmrib.ox.ac.uk/fsl-/melodic2/ (Beckmann et al., 2000a,b, 2001a,b; Beckmann and Smith, 2002a,b, 2003) |

Table 2: ICA tools in functional neuroimaginging.

Apart from those listed in the table there are other programs that is not specifically targeted for neuroimaging applications, e.g., ICALAB (http://www.bsp.brain.riken.jp/ICALAB/).

# 4 Application

| Area | Type | Description | Reference |
|---|---|---|---|
| EEG | tICA | | (Makeig et al., 1997) |
| Visual-Perception Task | | GLM used in the same study | (Calhoun et al., 2001b) |
| ERP/EEG | | ERP linked to phase resetting in the alpha rhythm | (Makeig et al., 2002, 2001) |
| fMRI | Bell and Sejnowski ICA | Dynamic complex visual scences | (Zeki et al., 2003) |

Table 3: Application

(Makeig et al., 2002, 2001) used ICA to show that event-related potentials (ERPs) are linked to "stationary" EEG (alpha) activity of the brain through "partial phase resetting of the EEG processes".

A further ICA application is (Moritz et al., 2005).

# 5 Unclassified

- (Shi et al., 2004).
- (Arfanakis et al., 2000)
- (Calhoun and Pekar, 2000): "'self-evident" spatiotemporal components' .
- (Calhoun et al., 2001c)
- (Calhoun et al., 2001d)
- V. D. Calhoun, T. Adali, G. D. Pearlson, "Independent component analysis applied to fMRI data: A generative model for validating results," to appear Journal of VLSI Signal Processing Systems for Signal, Image, and Video Technology, Special Issue: Data Mining and Biomedical Applications of Neural Networks.
- (Dodel et al., 2001)
- (Esposito et al., 2001): rank ordering of ICs.
- (Formisano et al., 2004, 2001): Cortex-based ICA.
- (Friston, 1998)
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- Independent Component Analysis with Joint Speedup and Supervisory Concept Injection: Applications to Brain fMRI Map Distillation Yasuo Matsuyama, Ryo Kawamura, Naoto Katsumata (Waseda University), ICA2003

- Blind Identification of SEF Dynamics from MEG Data by using Decorrelation Method of ICA Kuniharu Kishida, Kenji Kato (Gifu University), Kazuhiro Shinosaki, Satoshi Ukai (Osaka University Graduate School of Medicine), ICA2003

- Classification of Single Trial EEG Signals by a Combined Principal + Independent Component Analysis and Probabilistic Neural Network Approach Tetsuya Hoya, Gen Hori, Hovagim Bakardjian (BSI RIKEN), Tomoaki Nishimura, Taiji Suzuki (Dept. of Mathematical Engi., and Info. Physics Sch. of Engi., Univ. Tokyo), Yoichi Miyawaki, Arao Funase (BSI RIKEN), Jianting Cao (Dept. Elec. Engi., Saitama Institute of Technology), ICA2003

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