Group ICA fMRI Toolbox (GIFT): New Signal Processing Techniques Applied to Brain Imaging

Eric Egolf[1], Srinivas Rachakonda[1], Vince D. Calhoun[123]

[1]*Olin Neuropsychiatry Research Center, Institute of Living, Hartford, CT,*
[2]*Dept. of Psychiatry, Yale University School of Medicine, New Haven, CT,* [3]*Dept. of Psychiatry, Johns Hopkins University, Baltimore, MD*

AIM

The main focus of this project is to develop the GIFT Toolbox which provides for group inferences from fMRI data using Independent Component Analysis (ICA).

INTRODUCTION

Independent Component Analysis (ICA) is a new technique in signal processing. It is a method of blind source signal separation i.e., ICA allows one to extract unknown source signals from the known mixed signals. The Toolbox contains an implementation of ICA for the analysis of fMRI data. Specifically, the Group ICA fMRI Toolbox allows both means of analysis and display, each using standard input and output file types (3D Analyze format).

There are three main stages to Group ICA; Data Reduction, ICA, and Back Reconstruction (Calhoun et. al). The outputs from these stages are multiple time courses. Each time course has an image map associated with it. The number of time courses to extract is a user defined parameter.

THE DATA REDUCTION STAGE

Each subject's functional data is reduced in size.
- Principal Components Analysis (PCA) is used as a technique to reduce the dimensions
- PCA works by finding directions of maximal variance in data
- A single subject might be reduced from 53*63*34*220 to 53*63*34*50
- The reducing (or dewhitening) matrix is stored for future use in back reconstruction

After each subject's functional data is reduced, they are then concatenated into groups and put through another data reduction step
- The number of subject's to put into each group is a user specified parameter
- PCA is used again as the data reduction technique

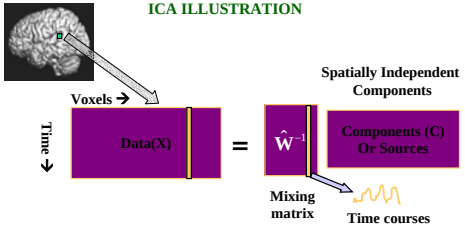
THE ICA STAGE

The reduced data from the data reduction stage is plugged into the ICA algorithm.
- Spatially Independent BOLD signals are calculated.
- Image Maps quantify the relationship between each brain region and the BOLD Signal.
- At this point the units quantifying this relation have no precise meaning

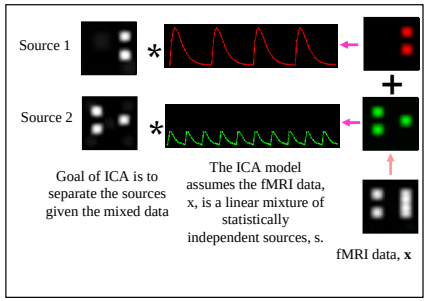
THE BACK RECONSTRUCTION STAGE

Individual subject image maps and time courses are computed using both the results from the ICA stage and from the data reduction stage.
- Using the original functional data as a reference, the image maps and time courses can be scaled according to percent signal change. Thus further quantifying the relationship between the image maps and time course
- Calibrated image maps are computed using the individual image maps and time courses
- Statistical maps are generated

ICA ILLUSTRATION



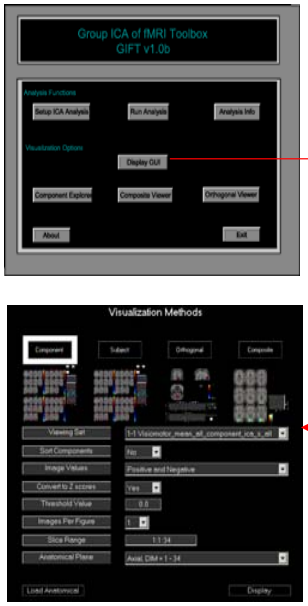
- **As a simple example**



GIFT TOOLBOX OVERVIEW

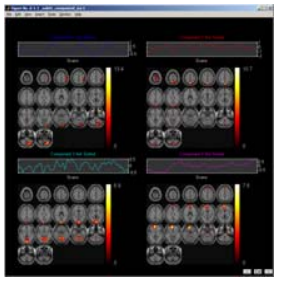
- GIFT consists of mainly analysis and visualization options
  - Set Up Analysis
  - Run Analysis (multiple ICA Algorithms implemented)
  - Analysis Information
- Set Up Analysis
  - User inputs data and this information is stored in a file
  - Parameters are not initialized
- Run Analysis
  - Parameters are initialized
  - Stages of Group ICA
- Visualization Options
  - Component Explorer, Orthogonal Viewer, Composite Viewer
- Platform independent (runs in Matlab R13)

GIFT TOOLBOX



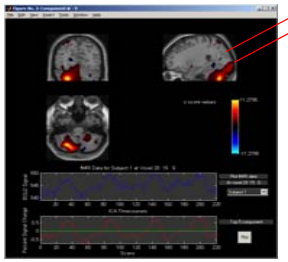
DISPLAY METHODS

1. COMPONENT EXPLORER



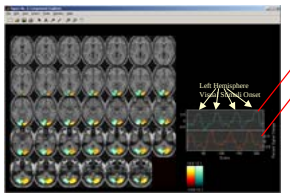
- Displays time courses and their image maps in groupings of 4, 9, 16, 25
- Helps in distinguishing between artifacts and signals of interest

2. ORTHOGONAL VIEWER



- Image Component Overlaid on Template Image
- Upper plot refers to BOLD Signal plot for a select voxel
- Lower plot refers to how well the voxel fits the component's time course

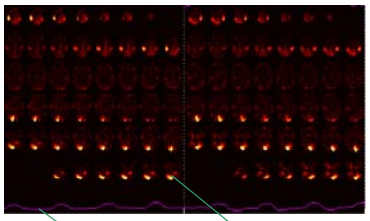
3. COMPOSITE VIEWER



Overlay multiple components of a particular subject's session or mean for that session

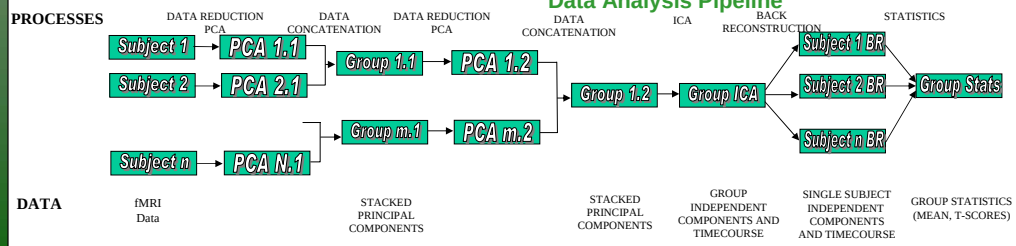
HOW TO INTERPRET IMAGE MAPS AND TIMECOURSES

- For every subject ICA extracts multiple image maps and time courses
- Each time course makes up some portion of the original BOLD signal
- Each voxel in a particular image map has a value. This number quantifies the relationship between that voxel and the corresponding time course



- The picture above shows two time courses and their corresponding image map
- Each image map is made up of horizontal slices of the brain
- The brighter the parts of the brain the more that region's original functional data is related to the time course

Data Analysis Pipeline



CONCLUSIONS

- ICA requires no a priori knowledge about the fMRI time course
- Model based techniques also make a number of assumptions about the nature of the hemodynamic response and how it affects the BOLD signal. In contrast, ICA provides a useful data driven summary of regions and their respective time courses.
- GIFT is currently the only software that allows group ICA analysis, letting the experimenter make inter group inferences.

REFERENCES

Calhoun VD, Adali T, et al.(2002) A method for making group inferences from functional MRI data using independent component analysis. Human Brain Mapping, 2002, Jun 16(2):131

- **More information on GIFT Toolbox can be found at http://icatb.sourceforge.net**
- ***Supported by the National Institutes of Health under grant 1 R01*** *EB000840-01* (to VC)
- **For more information please e-mail to Srinivas Rachakonda at srachak@harthosp.org**