fMRI & EEG data summary analysis using MATLAB

Matlab Summer Camp 2013
Logan Trujillo, Instructor

The fMRI portion of this lecture was written by Russ Poldrack, UCLA, 2006
What is an MRI image?

Matrix of intensity values in a slice through the brain

Generally either 8-bit or 16bit

In-plane dimensions generally 64x64 to 256x256

# of slices from 16-128

Generally represented as 3D image (X, Y, & Z dimensions) or 4D (X/Y/Z + time) timeseries.
fMRI Data file formats

• There are a number of common file formats
  – DICOM
    • Standard for data straight from scanner
  – ANALYZE
    • Common standard for analysis programs 3D vs. 4D
  – MINC
    • Extension of NetCDF
  – Nifti
    • Newest standard, developed by consensus committee
## Format comparisons

<table>
<thead>
<tr>
<th></th>
<th>DICOM</th>
<th>ANALYZE</th>
<th>MINC/Nifti</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimension</strong></td>
<td>2D</td>
<td>3D/4D</td>
<td>arbitrary</td>
</tr>
<tr>
<td><strong>Header</strong></td>
<td>Extensive/integrated</td>
<td>Minimal/separate</td>
<td>Extensive/integrated</td>
</tr>
<tr>
<td><strong>Files</strong></td>
<td>Arbitrarily named</td>
<td>*img/*hdr</td>
<td>*mnc/*nii</td>
</tr>
</tbody>
</table>
Interrogating fMRI data in MATLAB

- Many software packages (FSL, SPM, AFNI) provide functions for reading ANALYZE, NIFTI, and other files into MATLAB.

EX: FSL

```
>> fMRI = read_avm ('Test_fMRI_Data.nii');
```
Given that FSL, SPM, AFNI, and other software packages are primarily used for fMRI analysis, what use is MATLAB?

1) Summarizing time courses and/or regional activity into a form amenable for SPSS, Statistica, or other statistical packages.
2) Transforming fMRI data into an easily plottable format (for example, showing distribution of regional activity across timecourses).
3) Certain software packages (aka SPM) are MATLAB-based, and thus knowledge of MATLAB programming enables creations of batch processing scripts.
4) Non-routine transformation of fMRI data, e.g. Principal Components Analysis (PCA), Independent Components Analysis (ICA), Fast Fourier and wavelet-based spectral analysis.
Once loaded, many functions are available to view (via Image Processing Toolbox) or summarize imaging data.

```matlab
>> imagesc(fMRI(:,:,24)) >>
colormap gray

>> hist(reshape(d(:,:,24),1,53*63),100)
```
Plotting timeseries data

>> plot(squeeze(d(32,32,20,:))))
What are EEG data?

Measures of brain-based bioelectrical potential values distributed across scalp/head.

Generally 32 (single) or 64 (double) bit format.

# of electrodes generally range from 32 – 128.

Raw 2D data format where channels = rows and timepoints = columns.

Raw data is continuous and ranges from several minutes to hours.
EEG Data File Formats

- Depends on proprietary equipment/software used to record & analyze data.

Neuroscan - .cnt files
BioSemi Active II - .BDF files

Continuous EEG files often contain header information integrated with data file. An exception are data files used by EEGLAB MATLAB toolbox => .set (header info) and .dat (data info) files are separate.

Proprietary formats can often be converted from one to another, and can be converted into MATLAB-compatible format. EEGLAB is useful for this.

- EEG data in correct format are easily read by proprietary software. However EEG data saved as binary files (.bin) can be directly imported into MATLAB via the fread() function.
Analyzing EEG data in MATLAB

Continuous EEG data are usually “chopped” or broken up into small pieces called “epochs” WRT to a time marker (e.g. stimulus onset, button press, etc).

Epoched EEG data usually stored as a 3D array (N electrodes x T timepoints x E epochs) in MATLAB.
Pre-processing analysis steps of EEG data usually include:

1) artifact rejection

2) temporal filtering

3) re-referencing (i.e. changing the common baseline electrical potential value that scalp potentials are measured WRT at each time point).

4) subtraction of pre-stimulus or whole-epoch baseline values for each individual scalp potential.

5) removal of linear trends.
Event-related potentials (ERPs)

Created by averaging EEG across epochs within a single experimental condition WRT a time marker (e.g. stimulus onset, button press, etc.).

Yields average electrical brain response for the given condition.

Figures modified from (Pansev, 1995)
Spectral Analysis

- analyzing contributions of different signal oscillation frequencies to main EEG signal.

- Usually performed using Fast-Fourier Transforms or wavelets.
Frequency contributions measured in terms of 3 types of “spectral power”:

1) phase-locked: oscillations with same phase across trials.
2) non-phase-locked: oscillations with variable phase across trials
3) total power = phase-locked + non-phase-locked power.

Figure modified from (Pantev, 1995)
EEGLAB MATLAB toolbox

Very useful MATLAB toolbox that allows extensive analysis of EEG data (Delorme & Makeig, 2004); see http://sccn.ucsd.edu/eeglab/

Can read and write data in several different Proprietary, binary, and text file formats.

Can compute ERPs, EEG spectral analysis, Principal and Independent Components Analysis (ICA/PCA), dipole source localization, & more.

Extensive 2D and 3D EEG data plotting capability.

GUI or command prompt interface.

Easily integrated with one’s own MATLAB scripts