An ecosystem of neuroimaging, statistical learning, and open-source software to make research more efficient, more open, and more fun

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Brain? D’oh!
Computer?
Human Brain vs. Computer

Similarities:
- Are well organized
- Connected to I/O facilities
- Use electrical signals to transmit information
- Carry few different kinds of memory
- Can encode, store, and decode information
- *Use binary coding*
- *Use noise-resistant redundant coding*

Differences:
- Neural electrical activity is based on biochemistry
- Each unit (neuron) operates at low “clock frequency”
- Brain is massively parallel
- Brain never hibernates (always on)
- Details of the brain functioning are not completely understood
Human Brain vs. Computer

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Experimental Setup

Examples

- What is the network of areas responsible for object specific processing, memory, conciseness, self-awareness, etc.?
- What is the basis of object specific processing?
- What top-down mechanisms impact our behavior?
- What are peculiarities of processing in a specific (e.g., autistic) population?
- ...
Experimental Setup

Research Question → Experiment Design
Experimental Setup
Experimental Setup

Research Question → Experiment Design → Stimuli
Goals

Localization
- Early visual perception
- Object recognition
- Motor response

Information flow
- Attention
- Executive control
- Inhibition
The task of neural science is to explain behavior in terms of the activities of the brain

*Eric Kandel, Principles of Neural science, 4th ed., 2000*

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Brain Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response time</td>
<td>Extracellular Recordings</td>
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<tr>
<td>Accuracy</td>
<td>Electroencephalography (EEG)</td>
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<tr>
<td></td>
<td>Magnitoencephalography (MEG)</td>
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<tr>
<td></td>
<td>Functional Magnetic Resonance Imaging (fMRI)</td>
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<tr>
<td></td>
<td>...</td>
</tr>
</tbody>
</table>
Means of Investigation: fMRI

**Temporal Resolution:** Low
**Spatial Resolution:** High
**Invasive:** No
**Direct Measurement:** No

**Brain Activity**
- Extracellular Recordings
- Electroencephalography (EEG)
- Magnetoencephalography (MEG)
- Functional Magnetic Resonance Imaging (fMRI)

...
BOLD fMRI

Ogawa et al., MRM 1990; Kwong et al, PNAS 1992; Bandettini et al., MRM 1992
Statistical Parametric Mapping (SPM)

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Friston et al., HBM 1994
Statistical Parametric Mapping (SPM)

Friston et. al, HBM 1994
Statistical Parametric Mapping (SPM)

Matlab

SPM

GLM

Hypothesis Testing

Research Question

Experiment Design

Stimuli

Friston et. al, HBM 1994

'90  '92  '94  '96  '98  '00  '02  '04  '06  '08
(f)MRI Software: For any Taste
(f)MRI Software: For any Taste
(f)MRI Software: For any Taste
(f)MRI Software: For any Taste
(f)MRI Software: For any Taste
Initial Multivariate Attempts


Matlab

SPM

AFNI

LIPSIA

BrainVoyager

FreeSurfer

Caret

FSL

BOLD fMRI

Functional Connectivity

SSM on PET

'90  '92  '94  '96  '98  '00  '02  '04  '06  '08
Elaborated Initial Multivariate Attempts

McIntosh et. al., NeuroImage 1996
Distributed Patterns

Haxby et. al., Science 2001
Reverse the Flow
Reverse the Flow: Analysis

Decoder

Information Integration

Research Question  Experiment Design  Stimuli  Neural Processing and Encoding

'90  '92  '94  '96  '98  '00  '02  '04  '06  '08
Support Vector Machines & fMRI

Cox&Savoy, NeuroImage 2003
Combinatorial Coding

Hanson et. al., NeuroImage 2004
Combinatorial Coding: Animacy Discovered

Hanson et. al., NeuroImage 2004
BOLD Hyperacuity

Kamitani&Tong, Nature Neuroscience 2005
BOLD Hyperacuity

Kamitani&Tong, Nature Neuroscience 2005
Searchlight

Kriegerkorte et. al., PNAS 2006; Haynes et. al., Current Biology 2006
Unconscious determinants of free decisions in the human brain

Chun Siong Soon¹,², Marcel Brass¹,³, Hans-Jochen Heinze⁴ & John-Dylan Haynes¹,²

There has been a long controversy as to whether subjectively ‘free’ decisions are determined by brain activity ahead of time. We found that the outcome of a decision can be encoded in brain activity of prefrontal and parietal cortex up to 10 s before it enters awareness. This delay presumably reflects the operation of a network of high-level control areas that begin to prepare an upcoming decision long before it enters awareness.

Soon et. al., Nature Neuroscience 2006
Questioning the Specialization Concept

Hanson & Halchenko, Neural Computation 2008
LETTER

Communicated by Stephen Strother

Brain Reading Using Full Brain Support Vector Machines for Object Recognition: There Is No “Face” Identification Area

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Yaroslav O. Halchenko
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Rutgers Mind/Brain Analysis Laboratories, Psychology Department, Rutgers University, Newark, NJ 07102, U.S.A.
Large Scale Learning

Poldrack et al., Psychological Science 2009
Visual Image Reconstruction

Miyawaki et. al, Neuron 2008
Summary: MVPA Can . . .

- do “Mind Reading”
- do per-trial analysis
- account for various sources of variance and covariance/causal structure
- relax modeling assumptions of the signals
- rely on the models of the brain functioning
- provide validity testing (via cross-validated)
- test hypothesis across subjects and experimental paradigms
- assess diagnostic characteristics of the input units
- harvest information at sub-voxel resolution
Software Used

Software Used

Talk is cheap. Show me the code.

– Linus Torvalds (2000-08-25)
Standing on the Shoulders of Dinosaurs

Matlab

SPM

LIPSIA

SPM95

fMRI SPM

AFNI

BrainVoyager

FreeSurfer

Caret

FSL

Distributed Patterns

fMRI SVM

Searchlight

Combinatorial Patterns

Hyper Acuity

SMLR

No FFA

Large Scale

Visual Recon.

SVMLight

SVMLight

LIBSVM

Shogun

MDP

PLS

Functional Connectivity

BOLD fMRI

SSM on PET

SSM on PET

SVM

SVM

'90

'92

'94

'96

'98

'00

'02

'04

'06

'08
Standing on the Shoulders of Dinosaurs
Why Python? **Not** because it was . . .

1989  Designed by Guido van Rossum hired by Google in 2005

1998-2002  Had no “big brother” to decide supporting *my* platform (as happened with Matlab on MacOS)

2000  Used by the Hubble Space Telescope team in Baltimore for removing noise generated by cosmic rays from photos of galaxies

2005  Used to replace in SPSS 14 the less functional SAX Basic ”scripts” for most purposes

...  Used by Google, YouTube, Airbus, Maya, OpenOffice.org, CERN, NASA, Yahoo, Trac, . . .
Why Python? Because it is . . .

- Free and open-source
- High-level, cross-platform scripting programming language
- Dynamically typed with support for object-oriented, imperative and functional paradigms
- Equipped with easy binding to external libraries and high-level environments (e.g., R)
- Gaining a huge momentum . . .
Python Utensils
Python Utensils
Reinvent vs. Recycle the Wheel
PyMVPA: Efficient

- User-centered intuitive and documented interface
- Extensibility
- Transparent reading and writing of neural data sets
- Portability
- Open source software
PyMVPA: Efficient

- User-centered intuitive and documented interface
  ⇒ Concise scripting interface in Python, illustrated user manual

- Extensibility
  ⇒ Modular architecture to connect extensions in multiple languages

- Transparent reading and writing of neural data sets
  ⇒ e.g., NIfTI support for input and output

- Portability
  ⇒ Runs on anything from mainframes to cell phones

- Open source software
  ⇒ MIT-licensed free software
PyMVPA: Fun

Nature paper in 6 lines of code
attr = SampleAttributes('sample_attr_filename.txt')
dataset = NiftiDataset(
    samples='subj1.Bold.nii.gz',
    labels=attr.labels, chunks=attr.chunks)

clf = LinearCSVMC()

cv = CrossValidatedTransferError(
    TransferError(clf),
    NFoldSplitter(),
    enable_states=['confusion'])

error = cv(dataset)
print cv.confusion
Ecosystem
NeuroDebian Ecosystem: Efficient Thus Fun

Variety
thousands of generic, scientific, ... libraries, tools, environments, ...

Ease of customization
apt-get install science-neuroscience-cognitive

Stability
“Release when it is ready”

Support
reportbug fsl

Community
no “big daddy mentoring”
NeuroDebian Ecosystem: Deployment

- Live CD/USB
- Web interface (http://goodbye-microsoft.com)
- Installer (http://www.debian.org/CD)
- Virtualization (e.g., VirtualBox)
NeuroDebian on OS X

CARET

Computerized Anatomical Reconstruction and Editing Toolkit

John Harwell, Heather A. Drury, Donna Hanlon, and David C. Van Essen

Washington University School of Medicine
Department of Anatomy and Neurobiology
660 S. Euclid Ave. St. Louis, MO 63110
Copyright 1995-2004 Washington University
http://brainmap.wustl.edu/caret.html
caret@brainmap.wustl.edu

- Surface visualization, analysis, and editing
- Surface flattening
- Surface-based warping

mouse moved with left button down function
Developer talks, Monday Nov 30th

Yarik & Michael (DC)
  PyMVPA: Where we are now, and where we are going

Tiziano Zito (BCCN, Germany)
  MDP inside out

Valentin Haenel (BCCN, Germany)
  Profiling PyMVPA

Emanuele Olivetti (Fondazione Bruno Kessler, Italy)
  Supervised Tract Segmentation
Global Positioning Coordinates

Websites

http://www.pymvpa.org
http://neuro.debian.net

Developers
Michael Hanke, Yaroslav O. Halchenko

Contributors
Per B. Sederberg, Emanuele Olivetti, Valentin Haenel, James M. Hughes, Scott Gorlins

Mentors
S. J. Hanson, J. V. Haxby, S. Pollmann


Poldrack, R., Halchenko, Y., & Hanson, S. (in press). Decoding the large-scale structure of brain function by classifying mental states across individuals. *Psychological Science*. 
PyMVPA Multivariate Pattern Analysis in Python 0.2.0

by yarikoptic - May 29, 2008, 16:43:21 CET

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