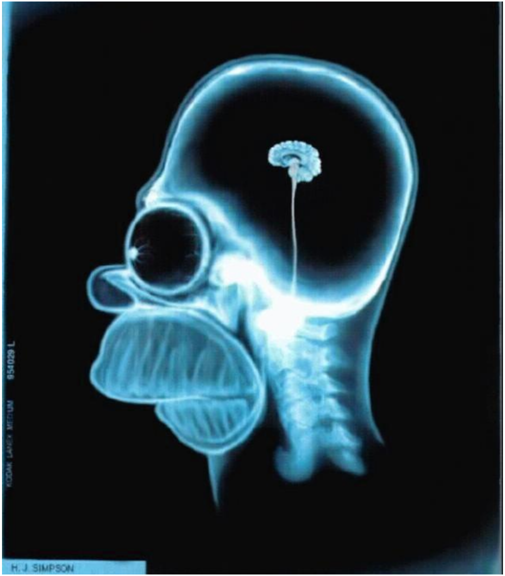
An ecosystem of neuroimaging, statistical learning, and open-source software to make research more efficient, more open, and more fun

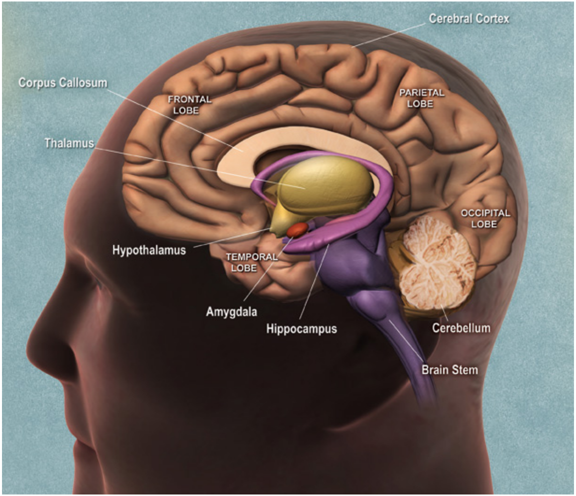
Yaroslav O. Halchenko & Michael Hanke

Department of Psychological and Brain Sciences,
Dartmouth College

Brain? D'oh!

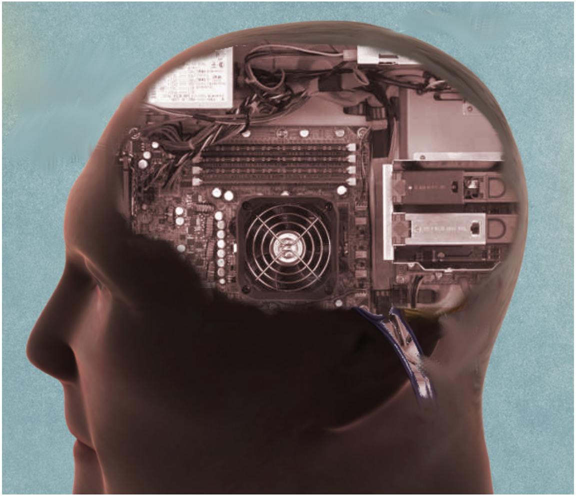


Human Brain



Cerebral Cortex
Corpus Callosum
FRONTAL LOBE
PARIETAL LOBE
Thalamus
OCCIPITAL LOBE
Hypothalamus
TEMPORAL LOBE
Amygdala
Hippocampus
Cerebellum
Brain Stem

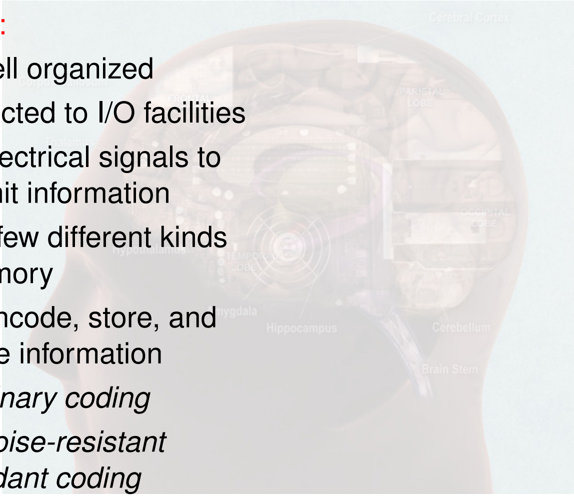
Computer?



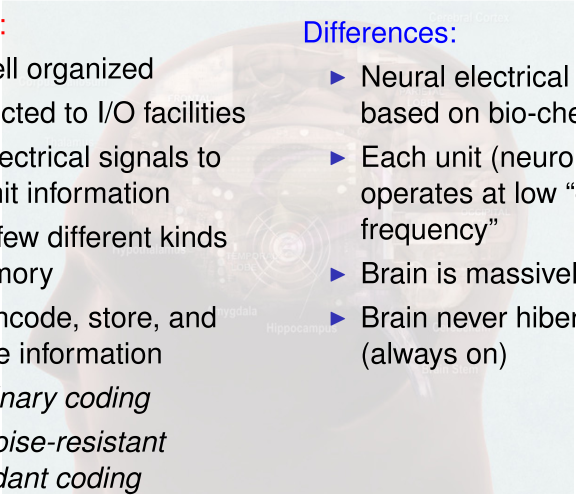
Human Brain vs. Computer

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*



Human Brain vs. Computer



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Differences:

- Neural electrical activity is based on bio-chemistry
- Each unit (neuron) operates at low “clock frequency”
- Brain is massively parallel
- Brain never hibernates (always on)

Human Brain vs. Computer

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Differences:

- Neural electrical activity is based on bio-chemistry
- 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

The Goal of Neuroscience

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

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Behavior — **Brain Activity**

Experimental Setup

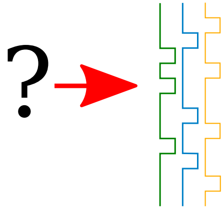
Examples

?

Research Question

- 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?
- …

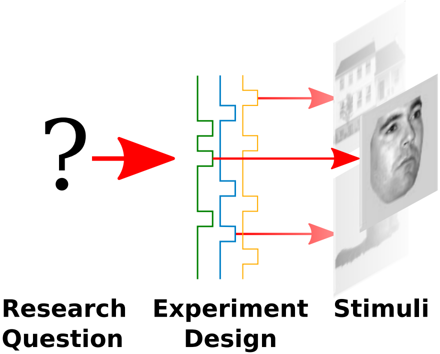
Experimental Setup



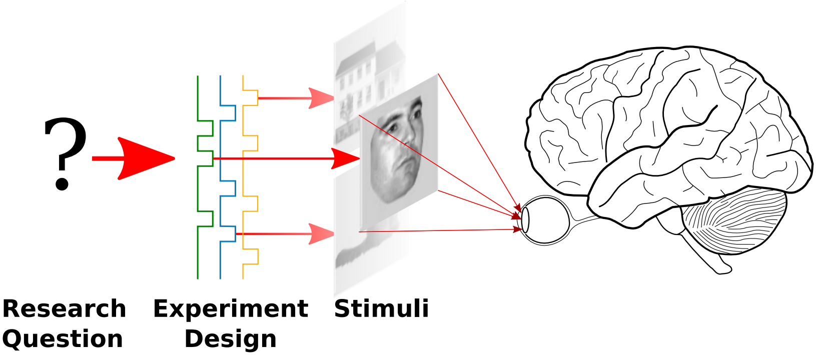
Research Question

Experiment Design

Experimental Setup



Experimental Setup



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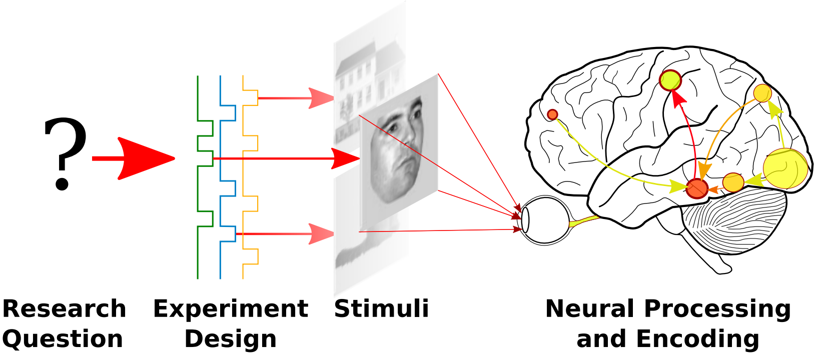


Goals

Localization

Early visual perception

Object recognition

Motor response

. . .

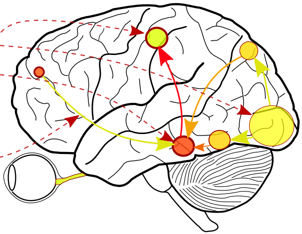
Information flow

Attention

Executive control

Inhibition

. . .



Means of Investigation

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

Behavior

Response time

Accuracy

. . .

Brain Activity

Extracellular Recordings

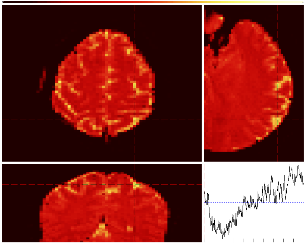
Electroencephalography (EEG)

Magnitoencephalography (MEG)

Functional Magnetic Resonance Imaging (fMRI)

. . .

Means of Investigation: fMRI



Brain Activity

Extracellular Recordings

Electroencephalography (EEG)

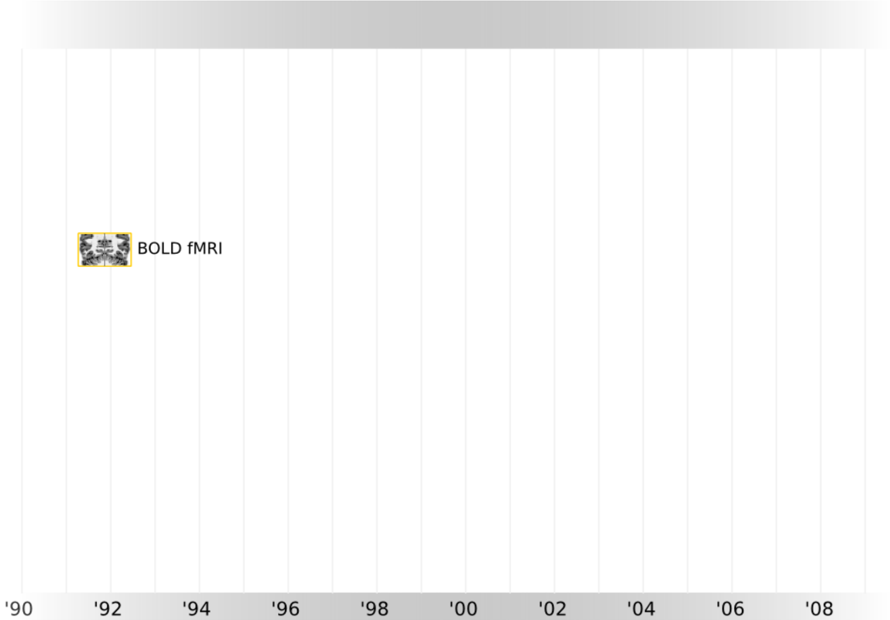
Magnitoencephalography (MEG)

Functional Magnetic Resonance Imaging (fMRI)

. . .

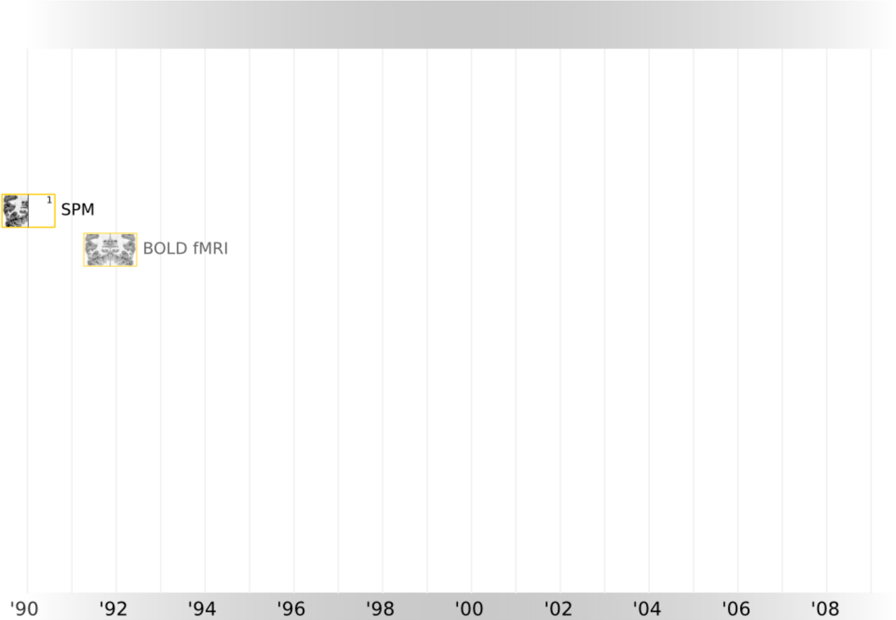
Temporal Resolution:	Low
Spatial Resolution:	High
Invasive:	No
Direct Measurement:	No

BOLD fMRI



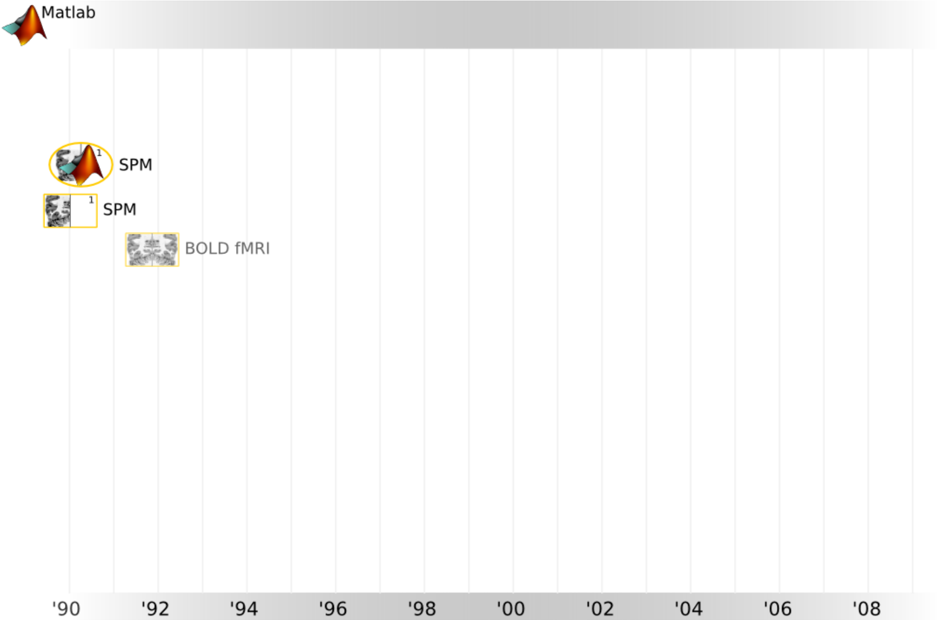
Ogawa et al., MRM 1990; Kwong et al, PNAS 1992; Bandettini et al., MRM 1992

Statistical Parametric Mapping (SPM)



Friston et. al., J. Cereb. Blood Flow Metab. 1990, 1991

Statistical Parametric Mapping (SPM)



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Statistical Parametric Mapping (SPM)

Friston et. al, HBM 1994

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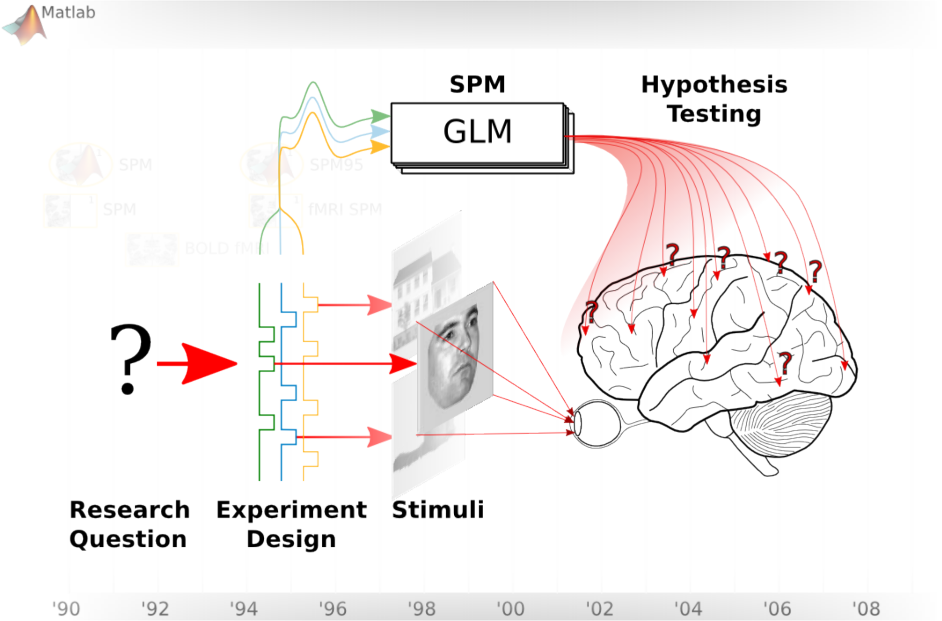

Friston et. al, HBM 1994

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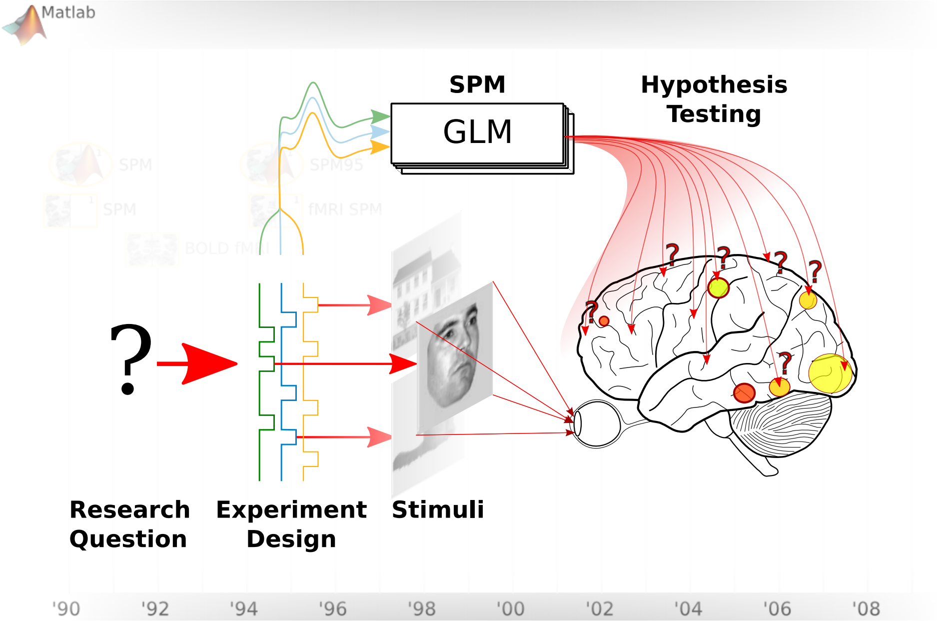
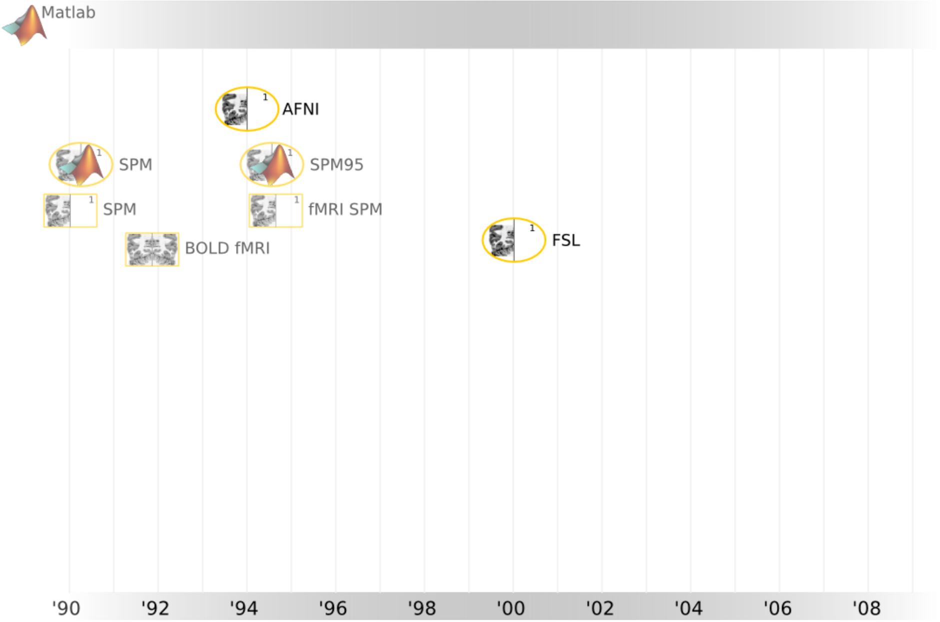


Friston et. al, HBM 1994

(f)MRI Software: For any Taste



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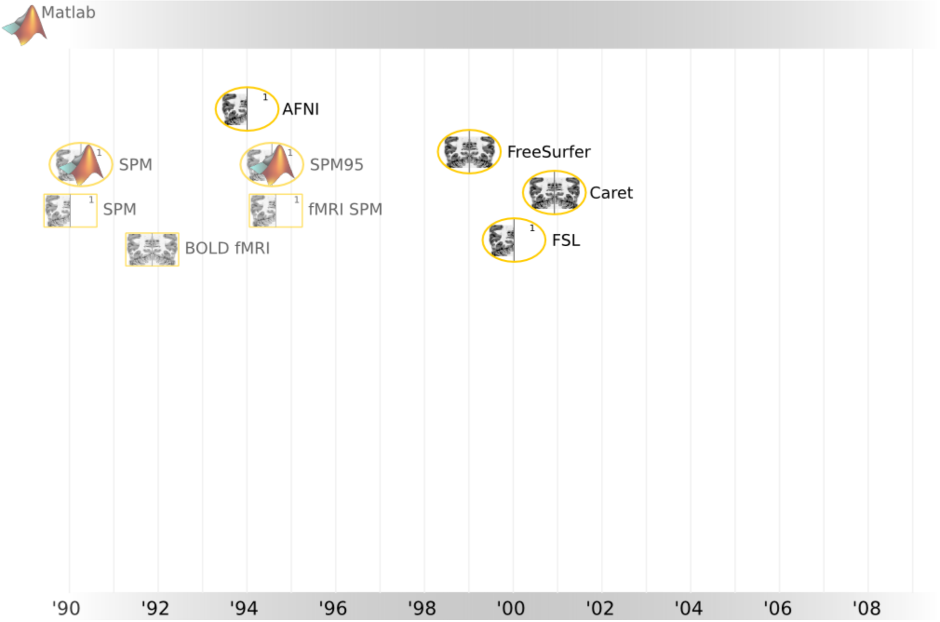

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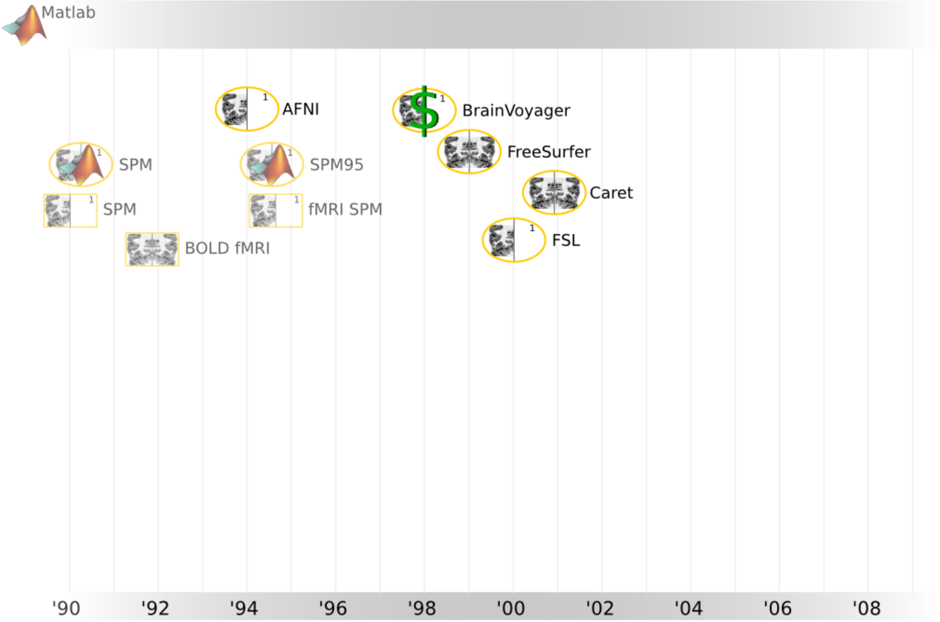

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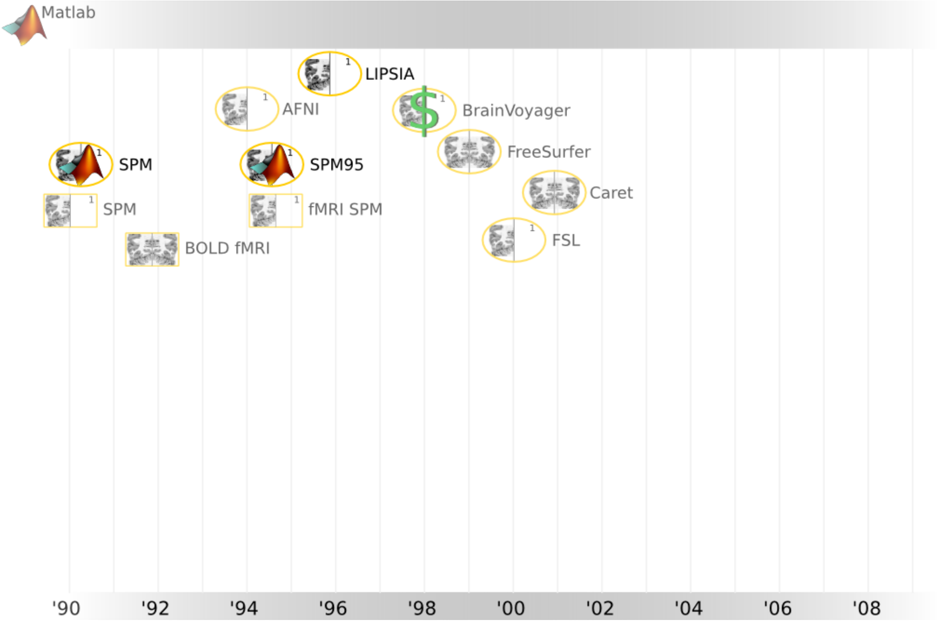

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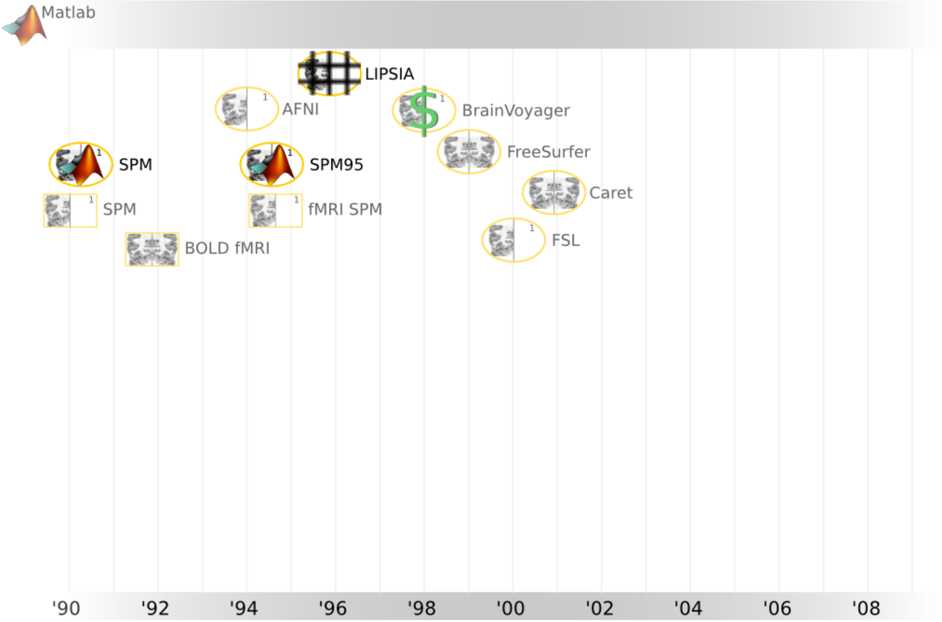

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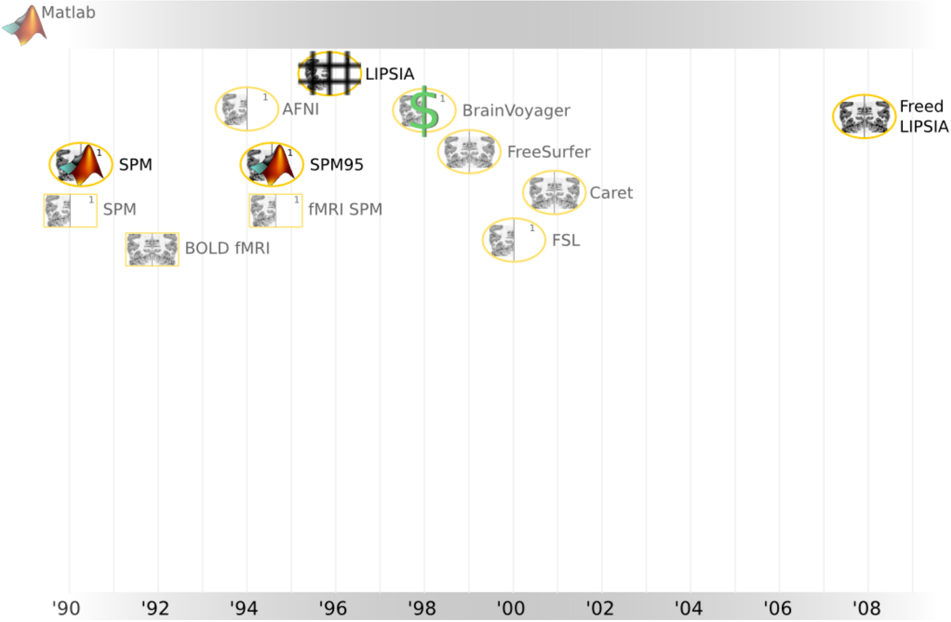
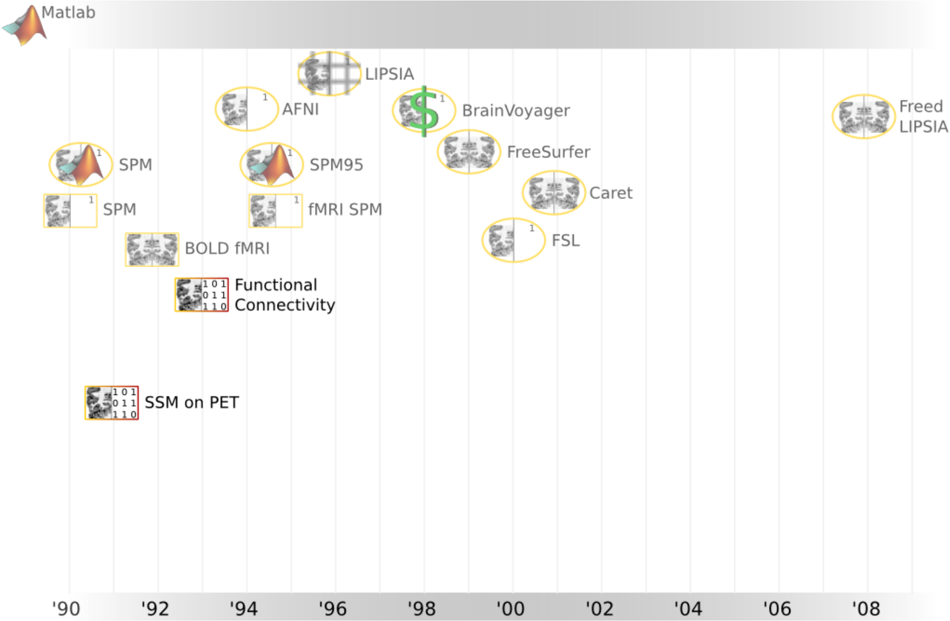
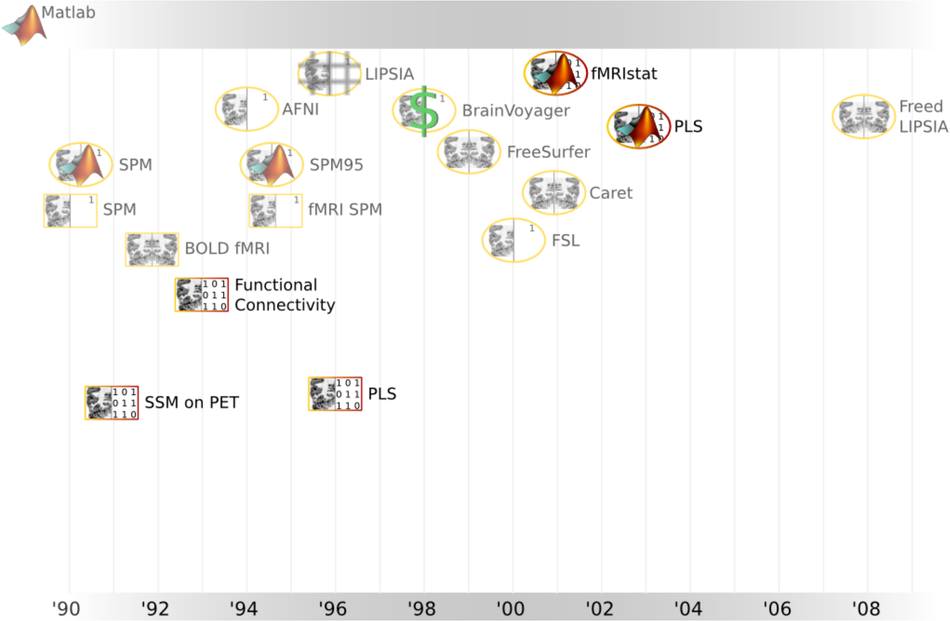


Initial Multivariate Attempts



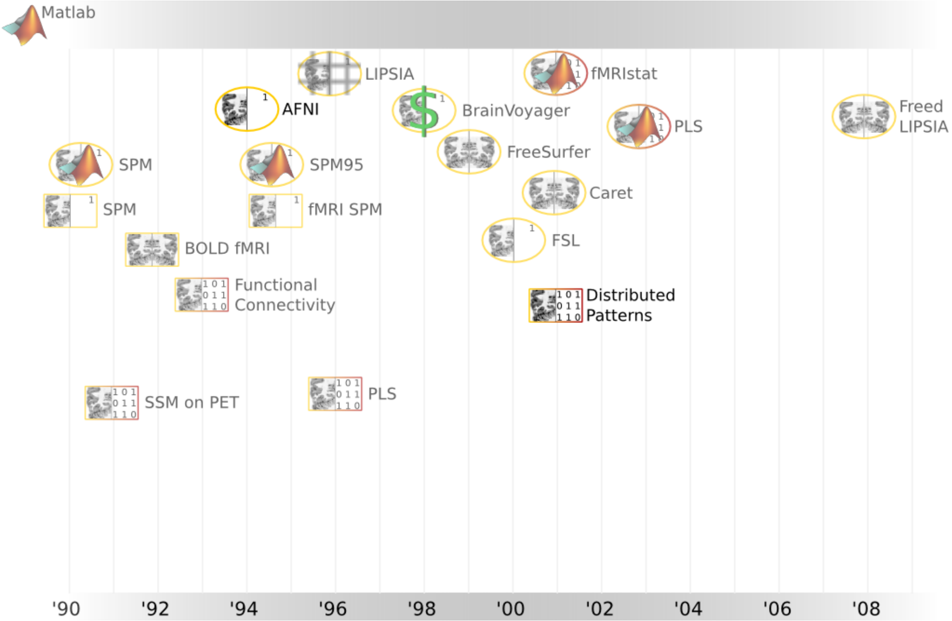
Friston et. al, J. Cereb. Blood Flow Metab. 1993

Elaborated Initial Multivariate Attempts



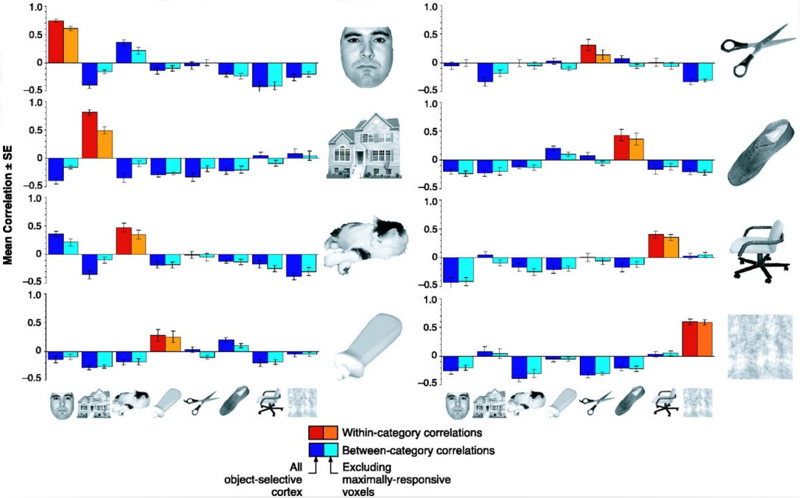
McIntosh et. al., NeuroImage 1996

Distributed Patterns



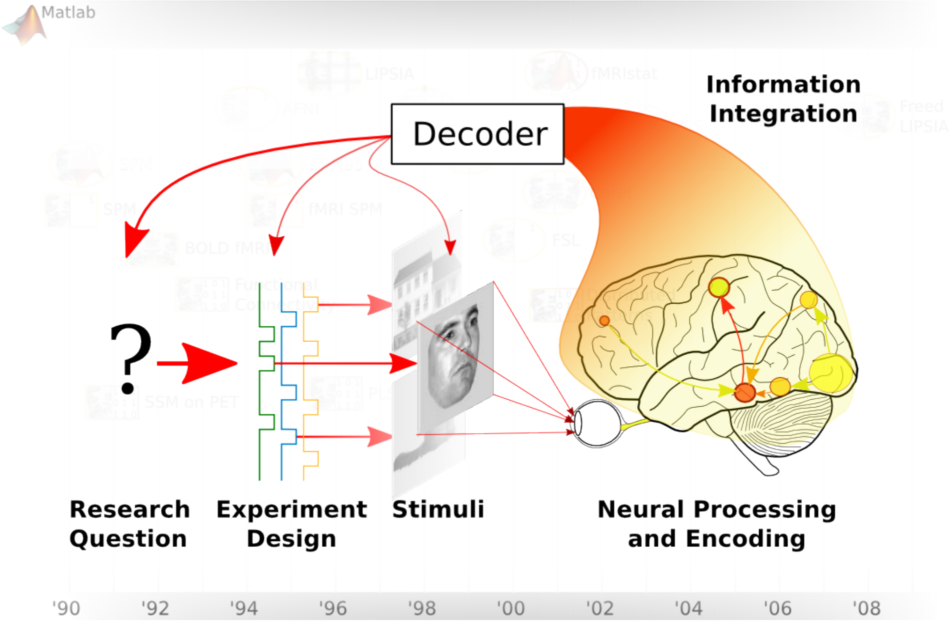
Haxby et. al., Science 2001

Distributed Patterns

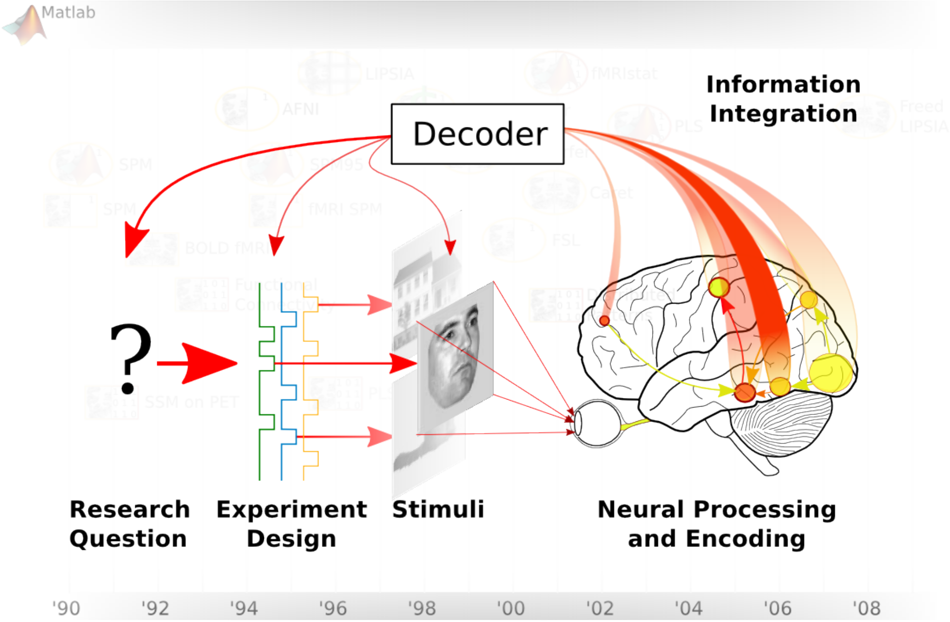


Haxby et. al., Science 2001

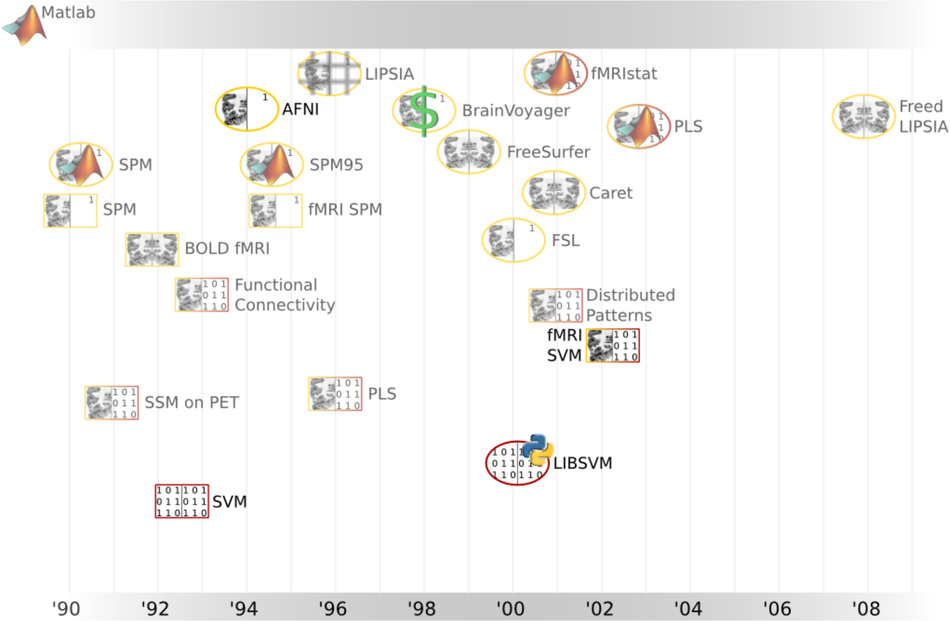
Reverse the Flow



Reverse the Flow: Analysis

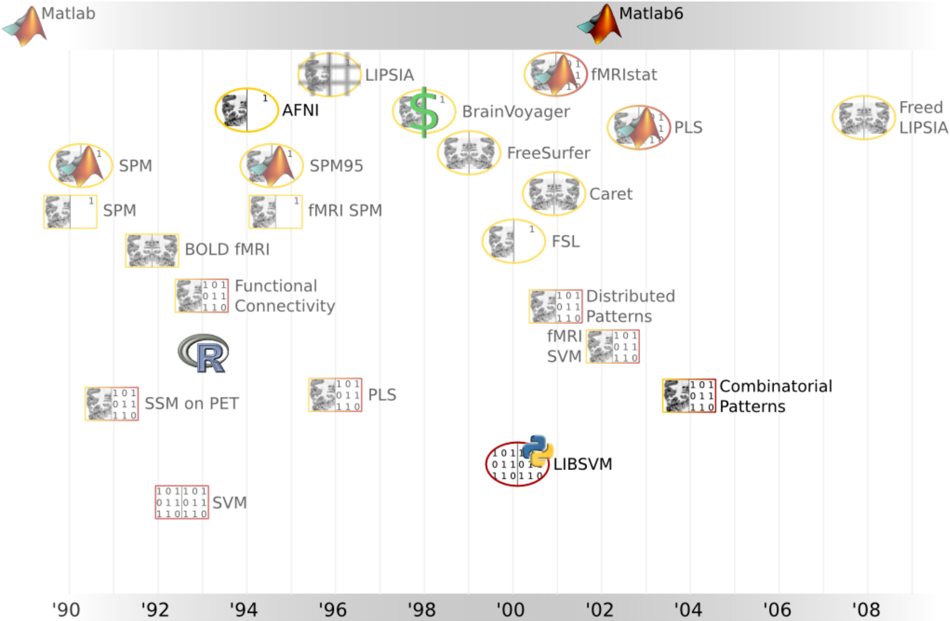


Support Vector Machines & fMRI



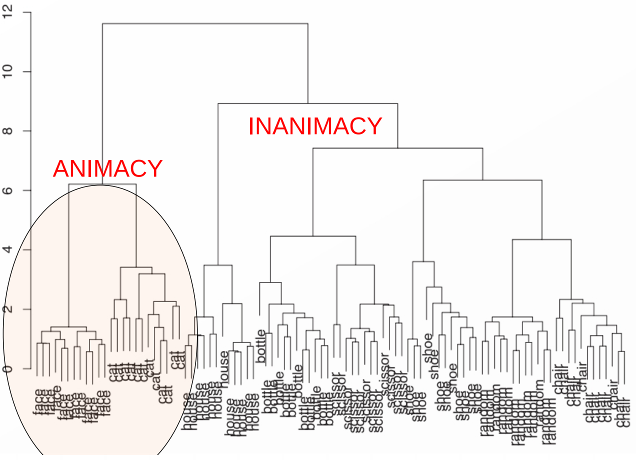
Cox&Savoy, NeuroImage 2003

Combinatorial Coding



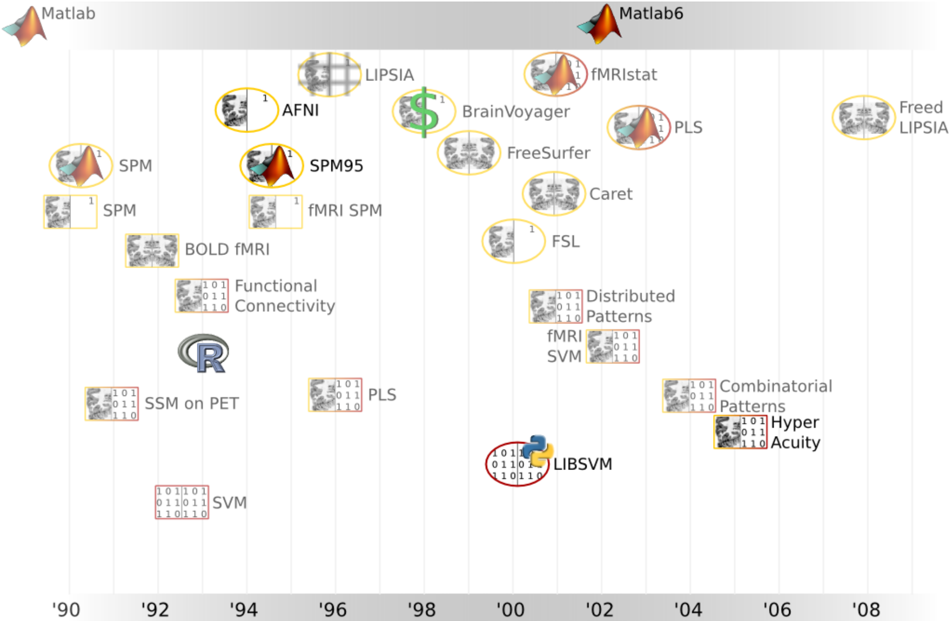
Hanson et. al., NeuroImage 2004

Combinatorial Coding: Animacy Discovered



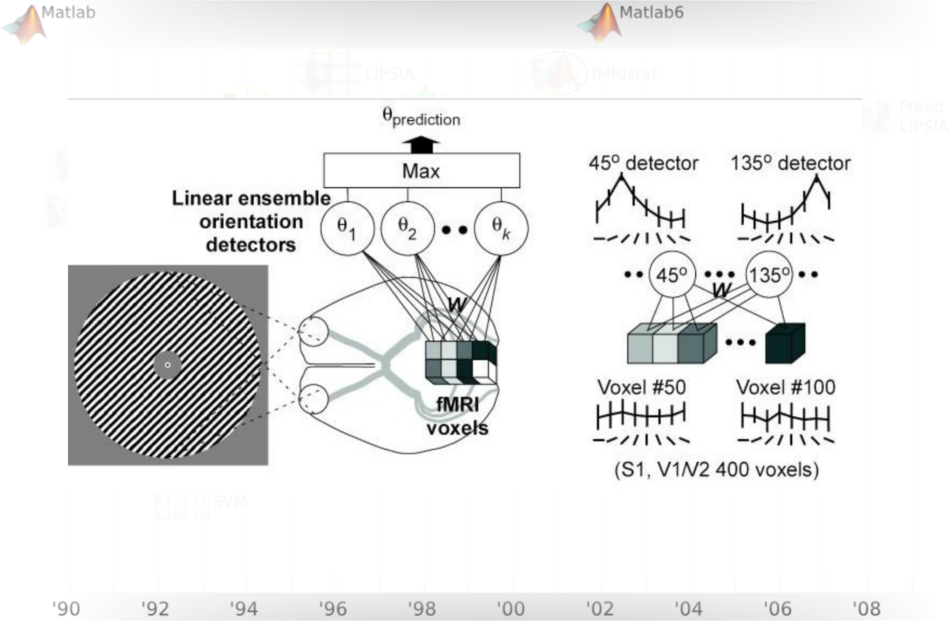
Hanson et. al., NeuroImage 2004

BOLD Hyperacuity



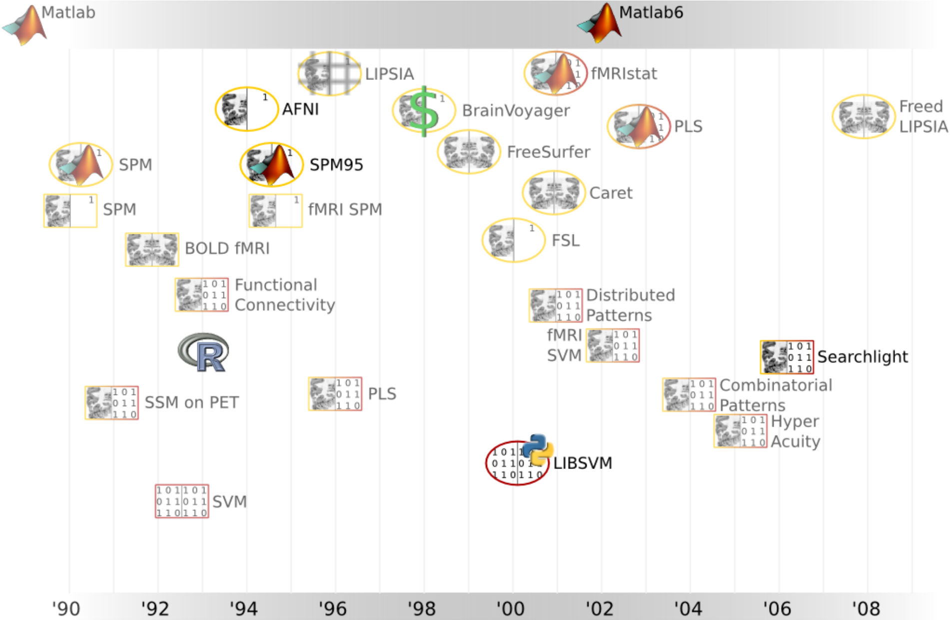
Kamitani&Tong, Nature Neuroscience 2005

BOLD Hyperacuity



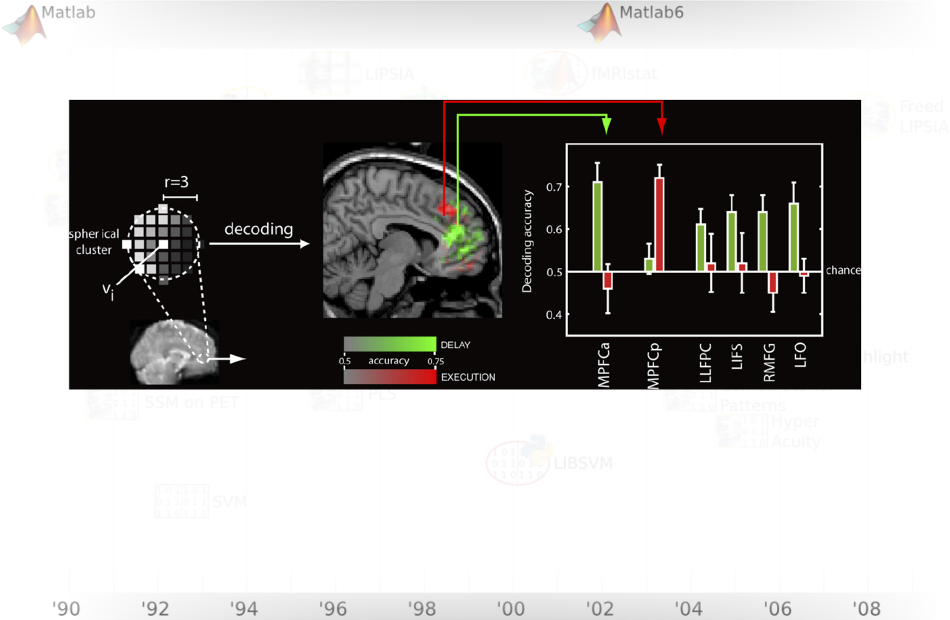
Kamitani&Tong, Nature Neuroscience 2005

Searchlight



Kriegeskorte et. al., PNAS 2006

Searchlight



Kriegeskorte et. al., PNAS 2006 ; Haynes et. al., Current Biology 2006

Searchlight Tarot

nature
neuroscience

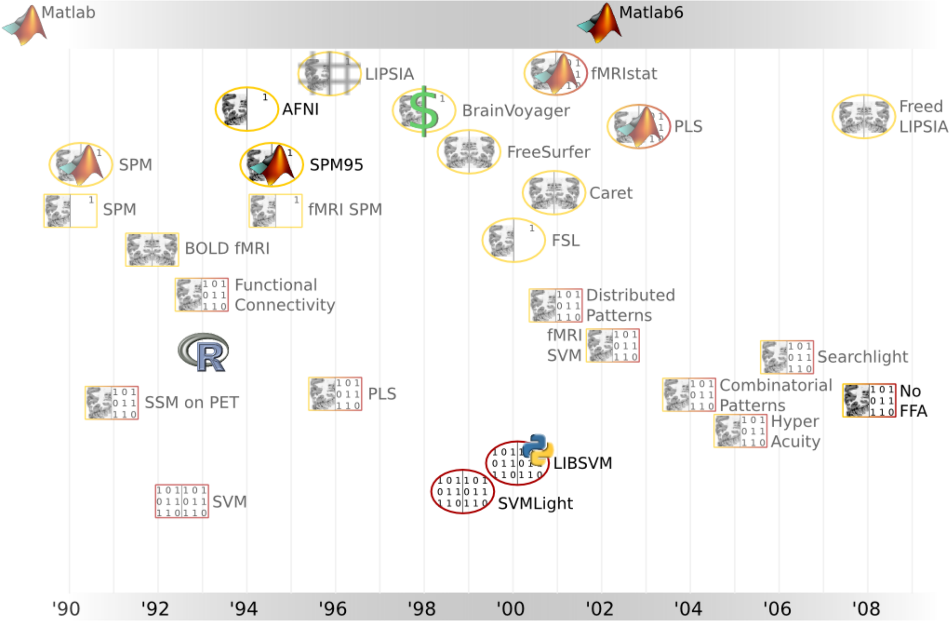
Unconscious determinants of free decisions in the human brain

Chun Siong Soon[1,2], Marcel Brass[1,3], Hans-Jochen Heinze[4] & John-Dylan Haynes[1,2]

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.

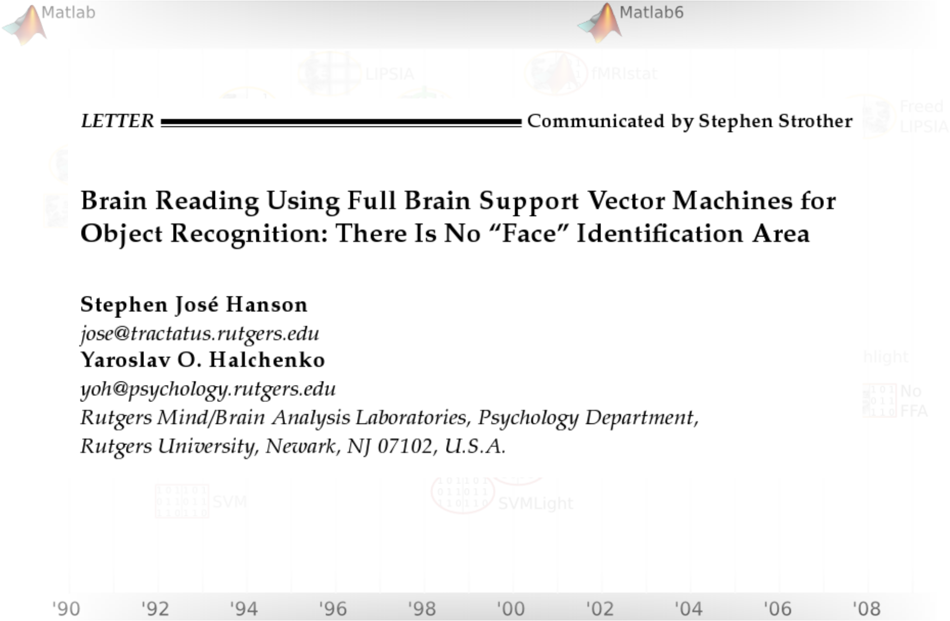
Soon et. al., Nature Neuroscience 2006

Questioning the Specialization Concept



Hanson&Halchenko, Neural Computation 2008

Questioning the Specialization Concept



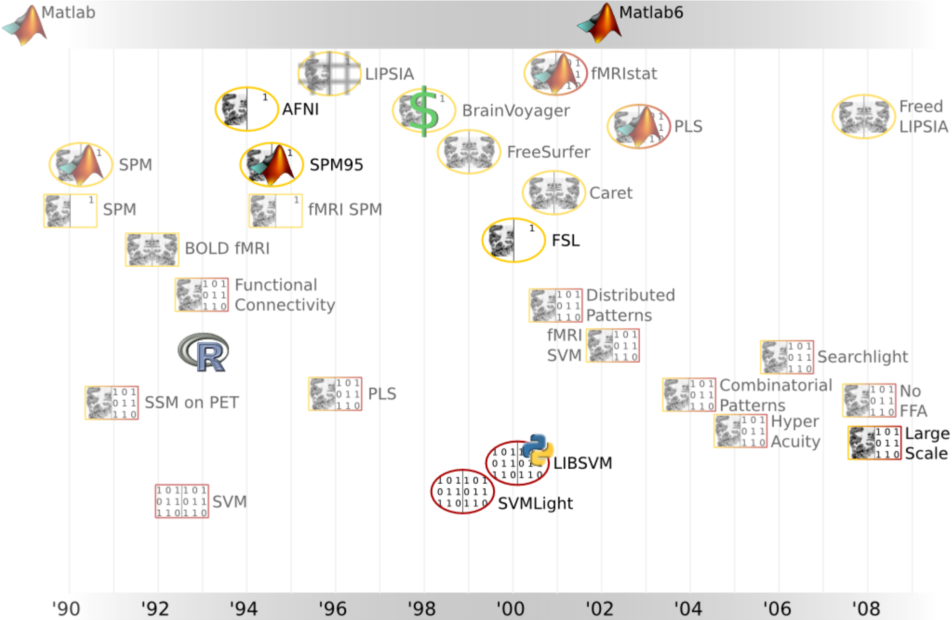
LETTER Communicated by Stephen Strother

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

Stephen José Hanson
jose@tractatus.rutgers.edu
Yaroslav O. Halchenko
yoh@psychology.rutgers.edu
Rutgers Mind/Brain Analysis Laboratories, Psychology Department, Rutgers University, Newark, NJ 07102, U.S.A.

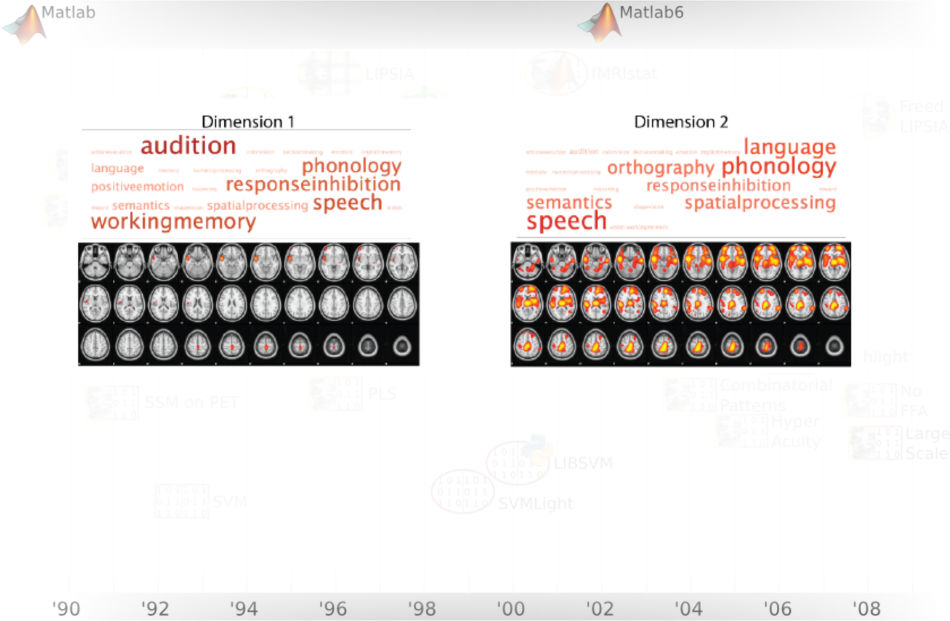
Hanson&Halchenko, Neural Computation 2008

Large Scale Learning



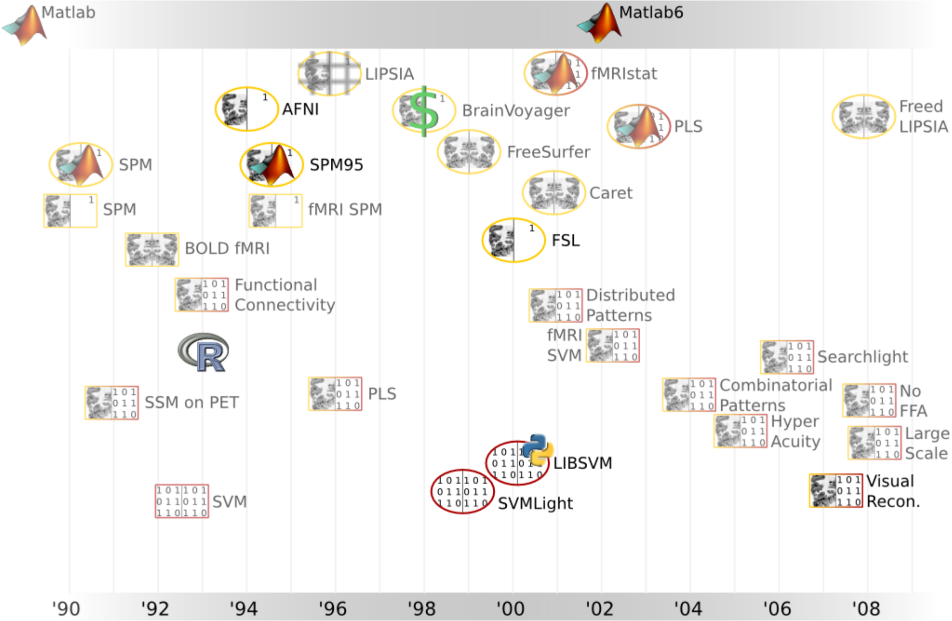
Poldrack et. al, Psychological Science 2009

Large Scale Learning: Ontology



Poldrack et. al, Psychological Science 2009

Visual Image Reconstruction



Miyawaki et. al, Neuron 2008

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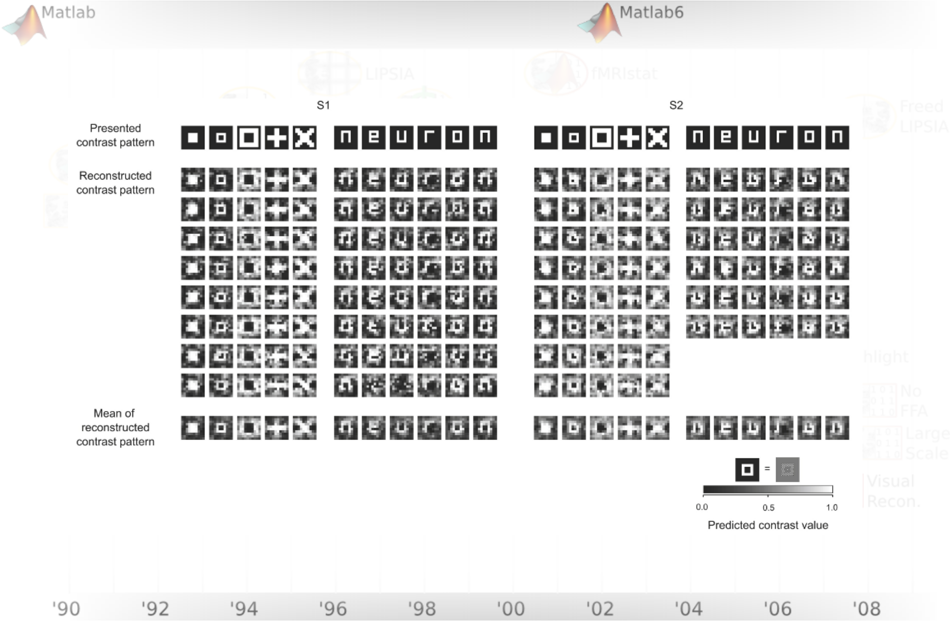
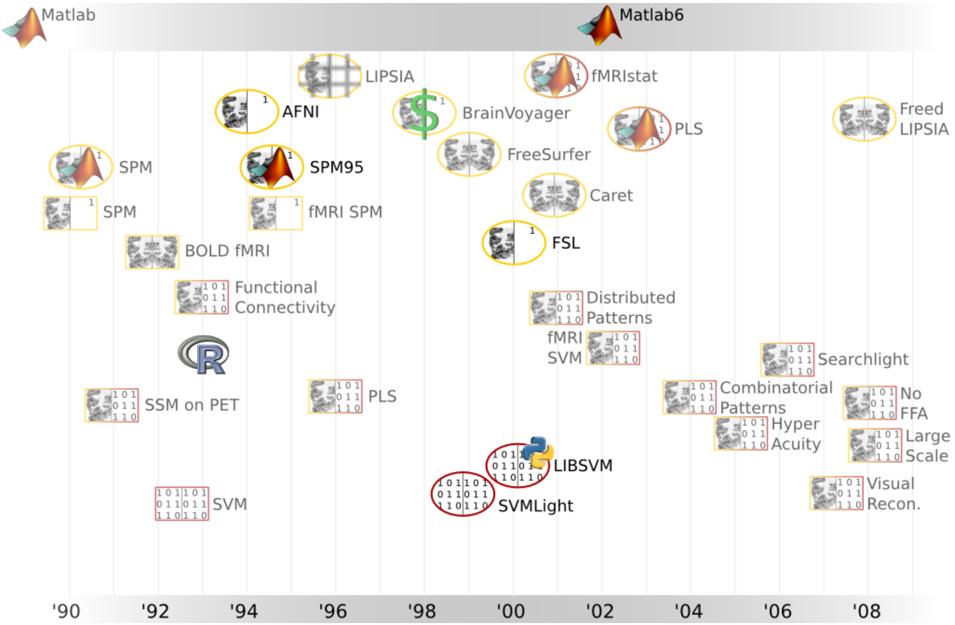


Miyawaki et. al, Neuron 2008

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



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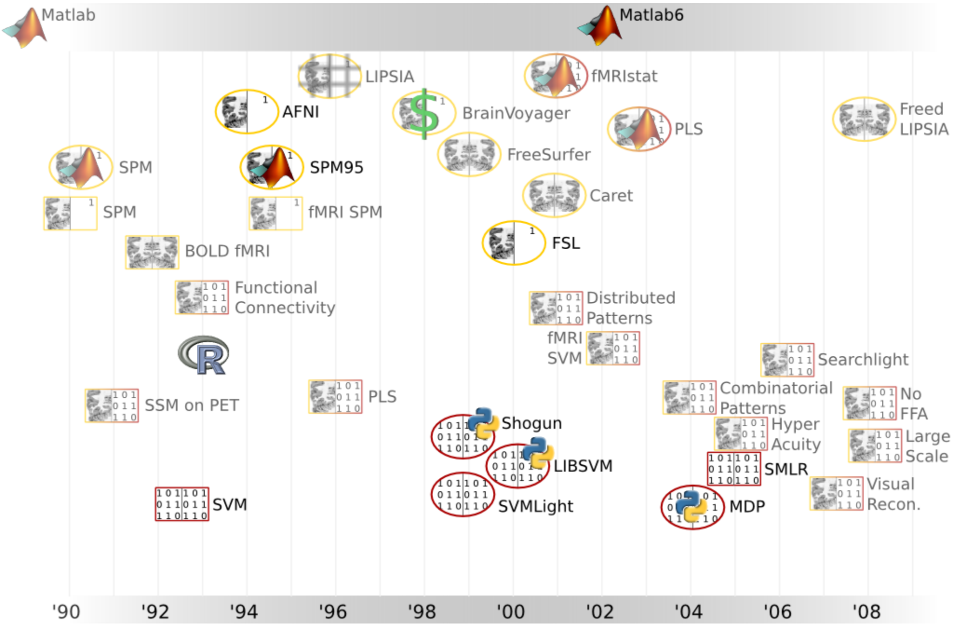
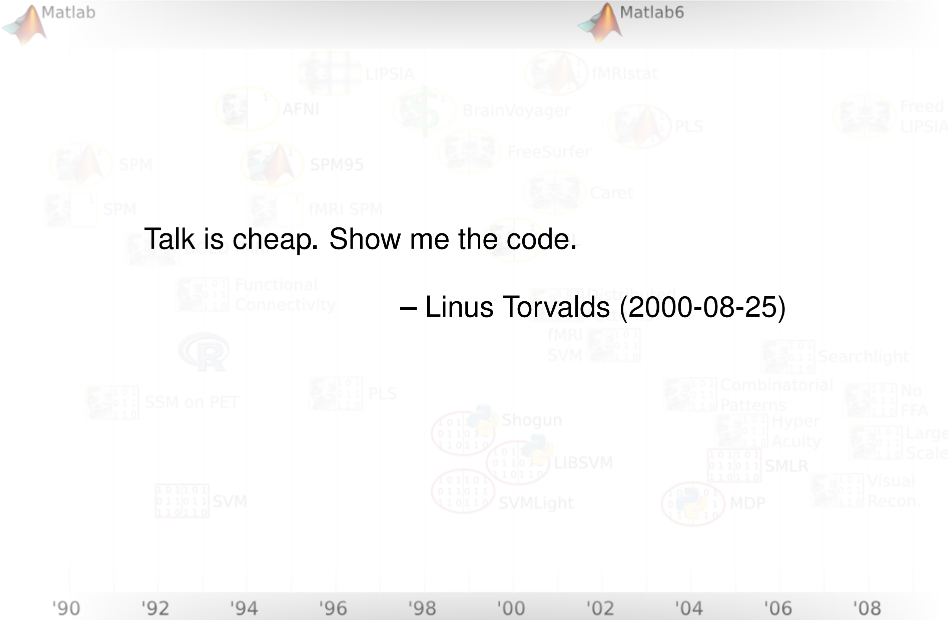


Machine Learning Open-Source Software: `http://mloss.org`

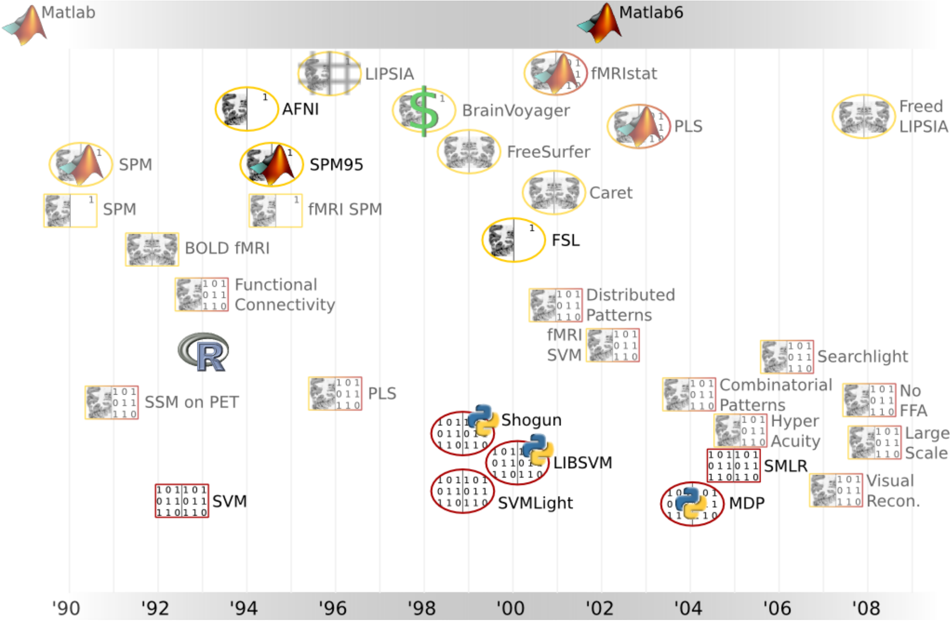
Software Used



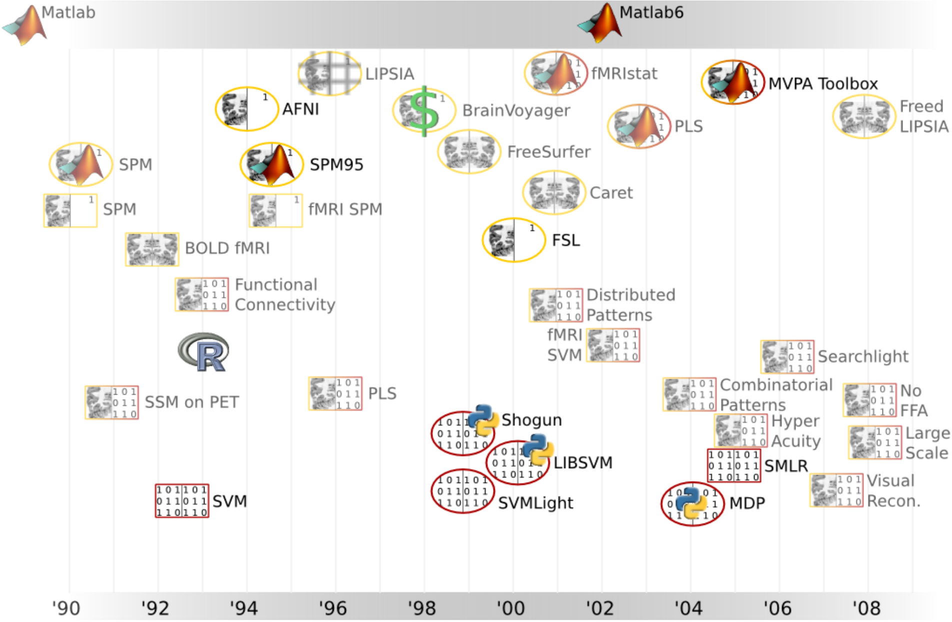
Talk is cheap. Show me the code.

– Linus Torvalds (2000-08-25)

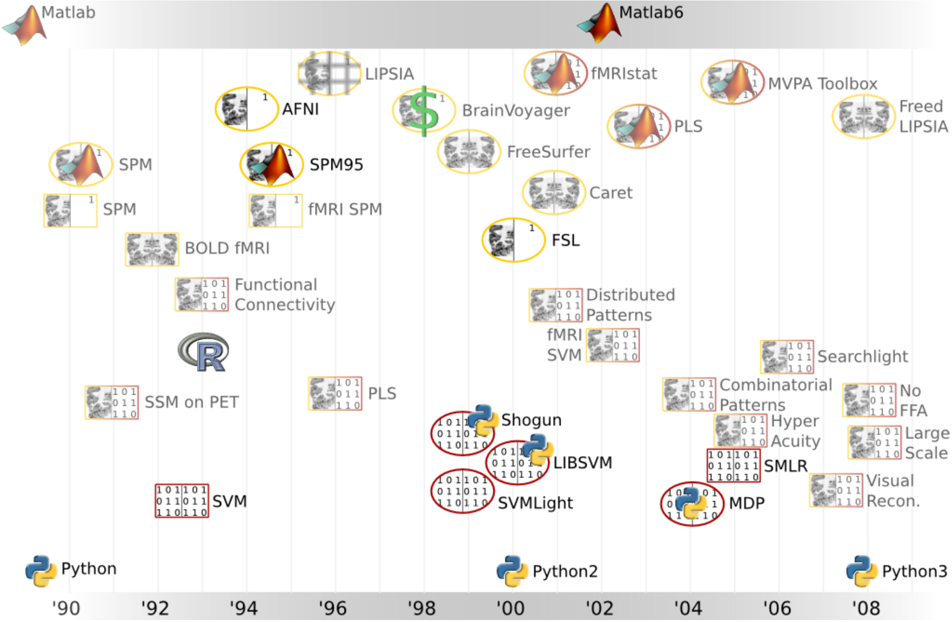
Standing on the Shoulders of Dinosaurs



Standing on the Shoulders of Dinosaurs



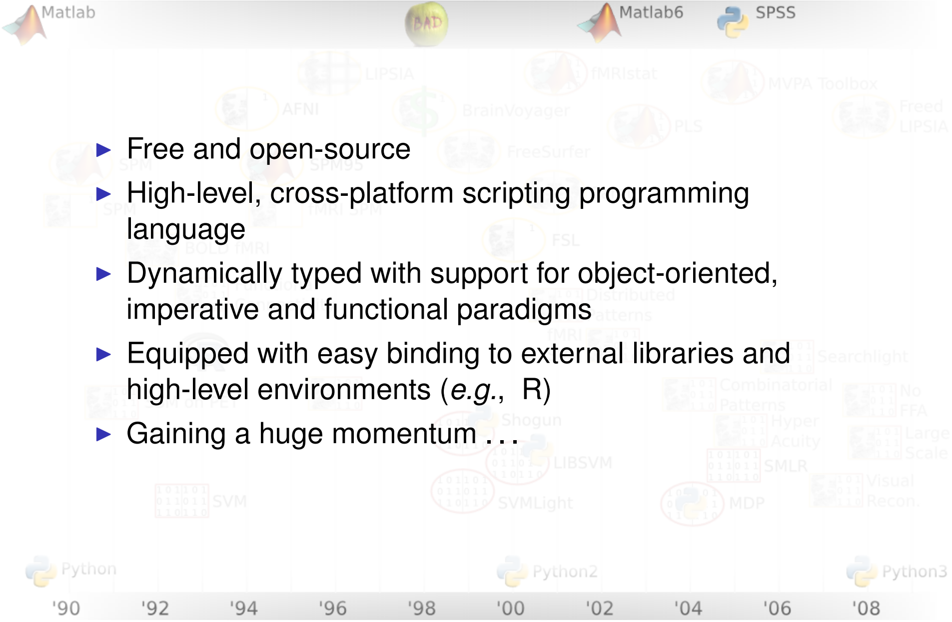
Python World



Why Python? **Not** because it was . . .

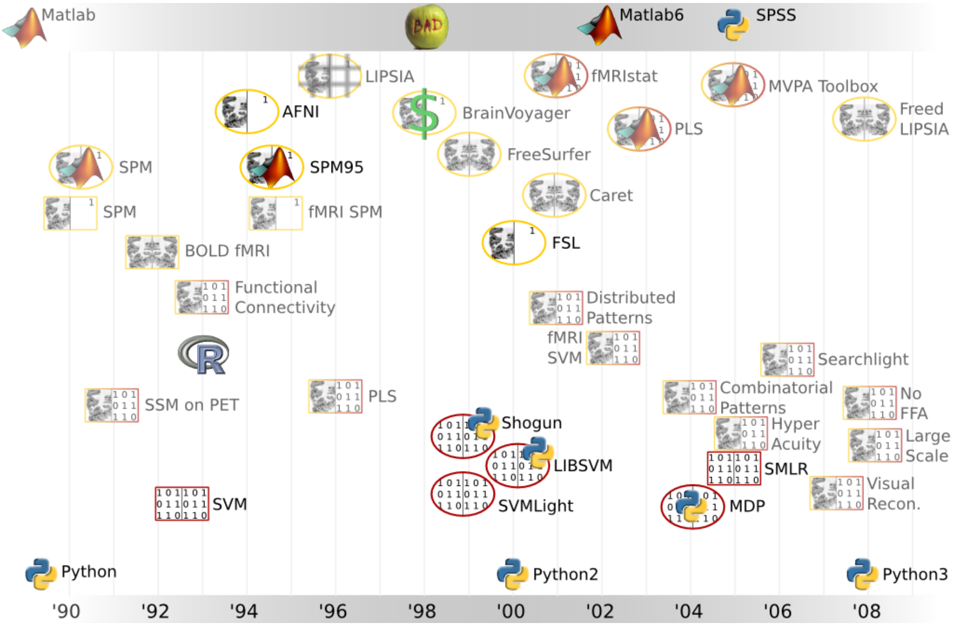
1989	Designed by Guido van Rossum hired by Google in 2005
1998-2002	Had no “big brother” to decide supporting *my* platform (as happened with Matlab on MacOS)
2000	Used by the Hubble Space Telescope team in Baltimore for removing noise generated by cosmic rays from photos of galaxies
2005	Used to replace 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



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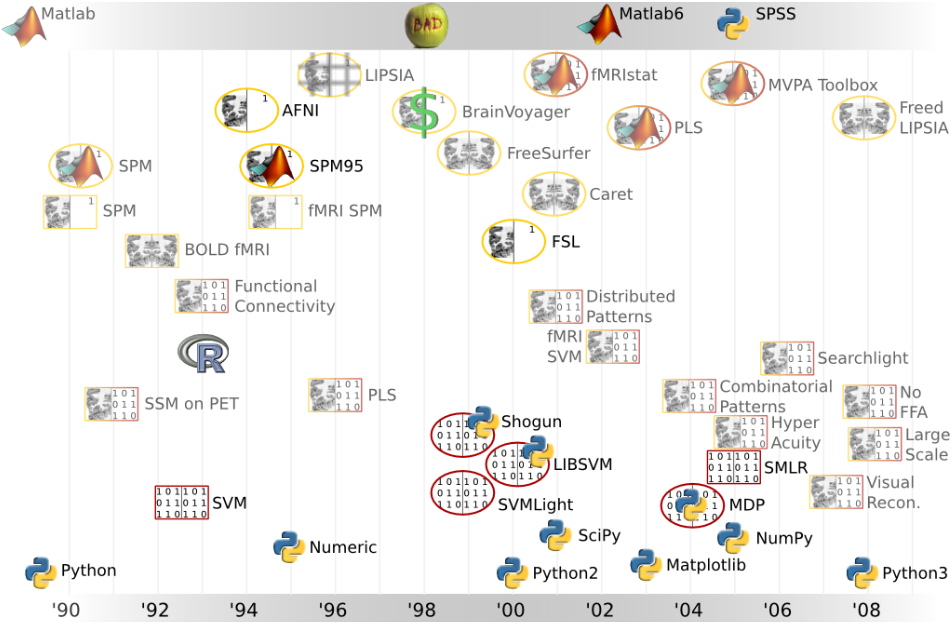
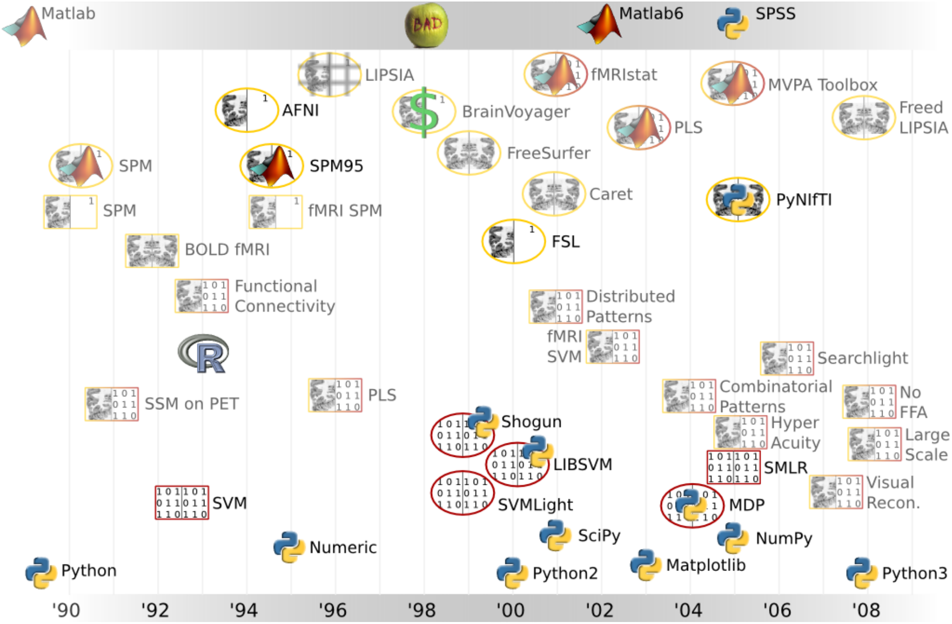
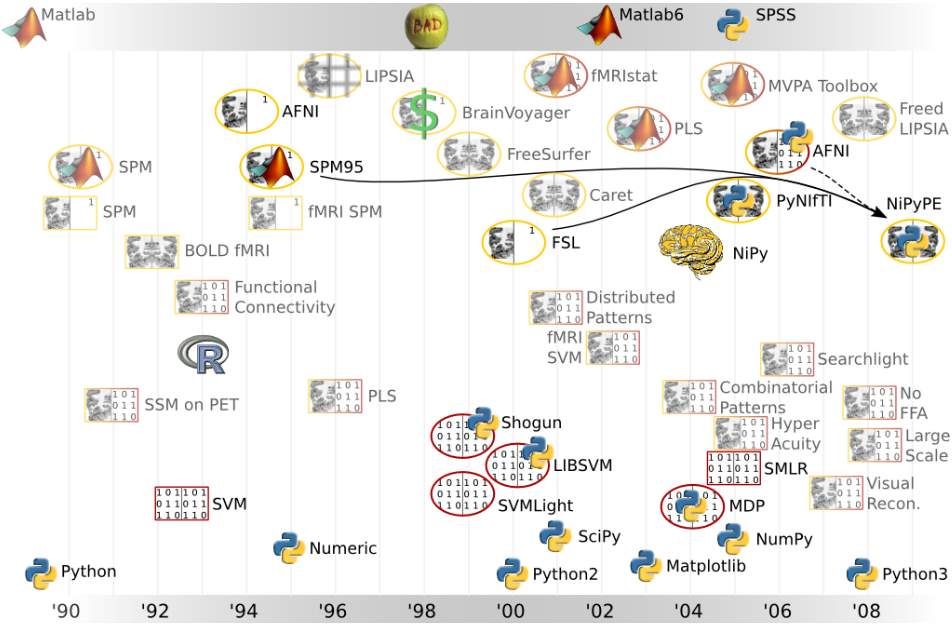


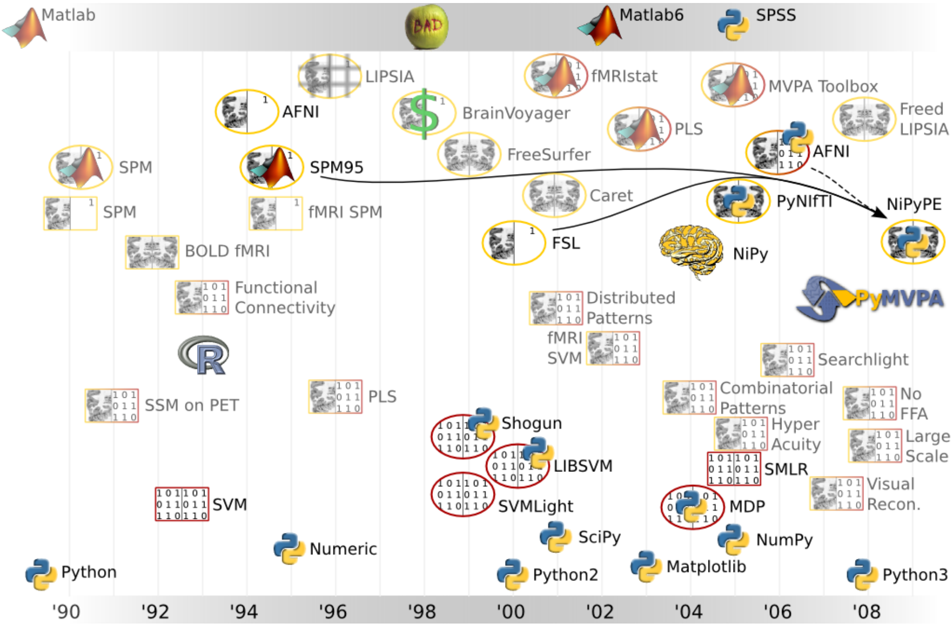
Python Utensils



Reinvent vs. Recycle the Wheel

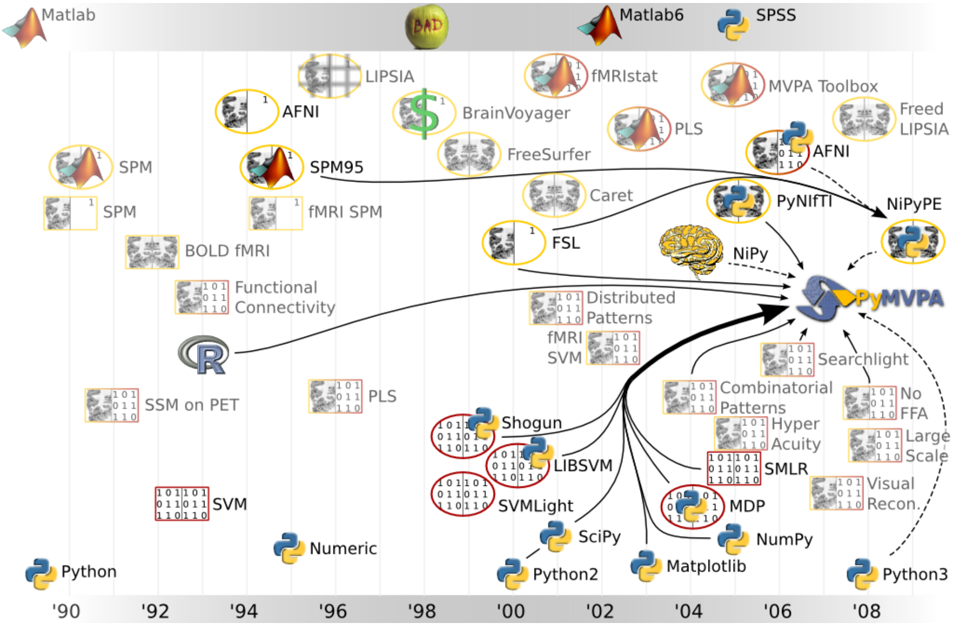


PyMVPA



Hanke et. al. 2009

PyMVPA



Matlab
BAD
Matlab6
SPSS
LIPSIA
fMRIstat
MVPA Toolbox
AFNI
BrainVoyager
PLS
Freed LIPSIA
AFNI
SPM
SPM95
FreeSurfer
Caret
PyNIfTI
NiPyPE
SPM
fMRI SPM
FSL
NiPy
BOLD fMRI
PyMVPA
Functional Connectivity
Distributed Patterns
fMRI SVM
Searchlight
SSM on PET
PLS
Combinatorial Patterns
No FFA
Shogun
Hyper Acuity
Large Scale
LIBSVM
SMLR
SVM
SVMLight
MDP
Visual Recon.
SciPy
NumPy
Numeric
Python
Python2
Matplotlib
Python3
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'92
'94
'96
'98
'00
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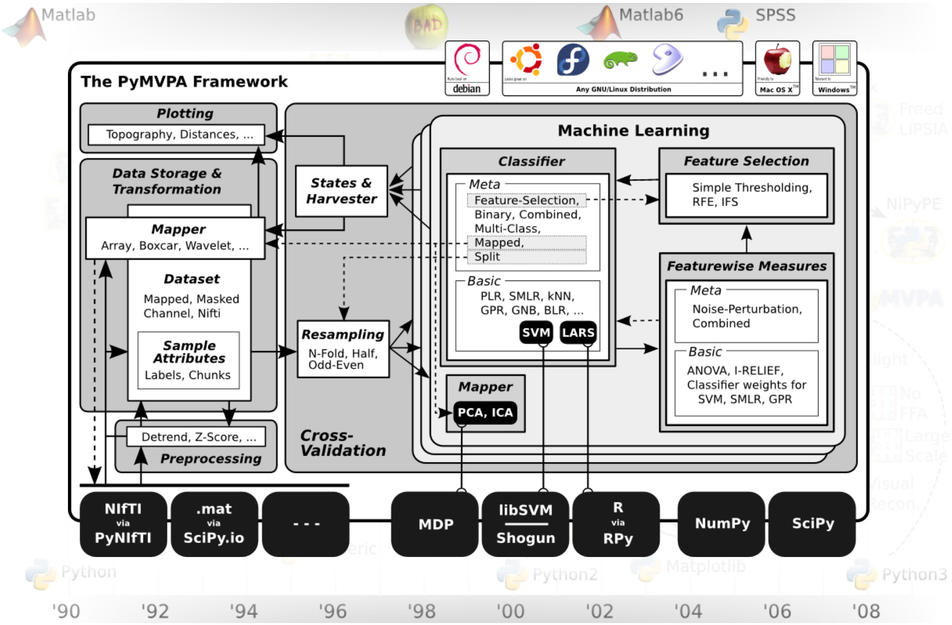
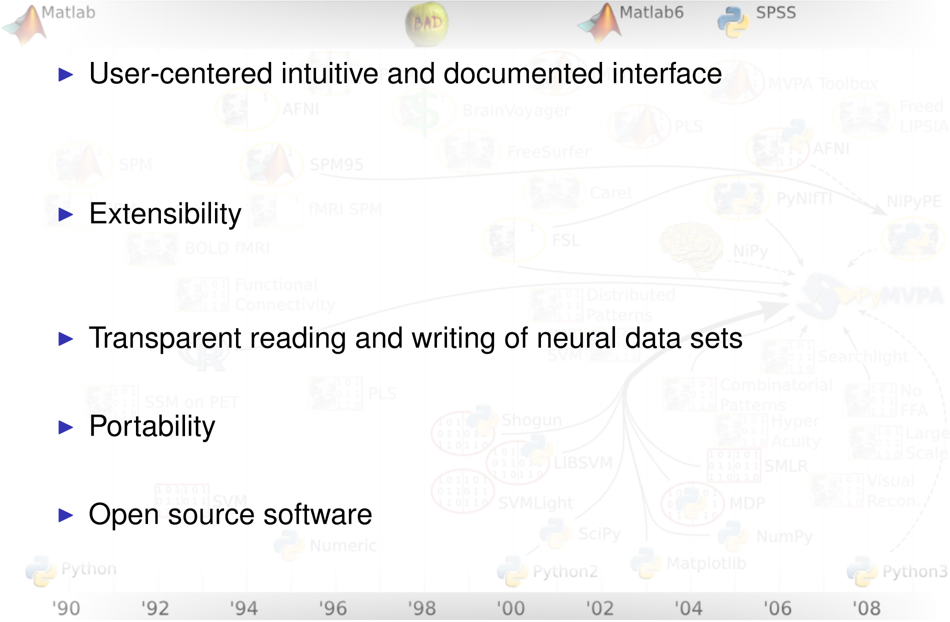
PyMVPA: Framework



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

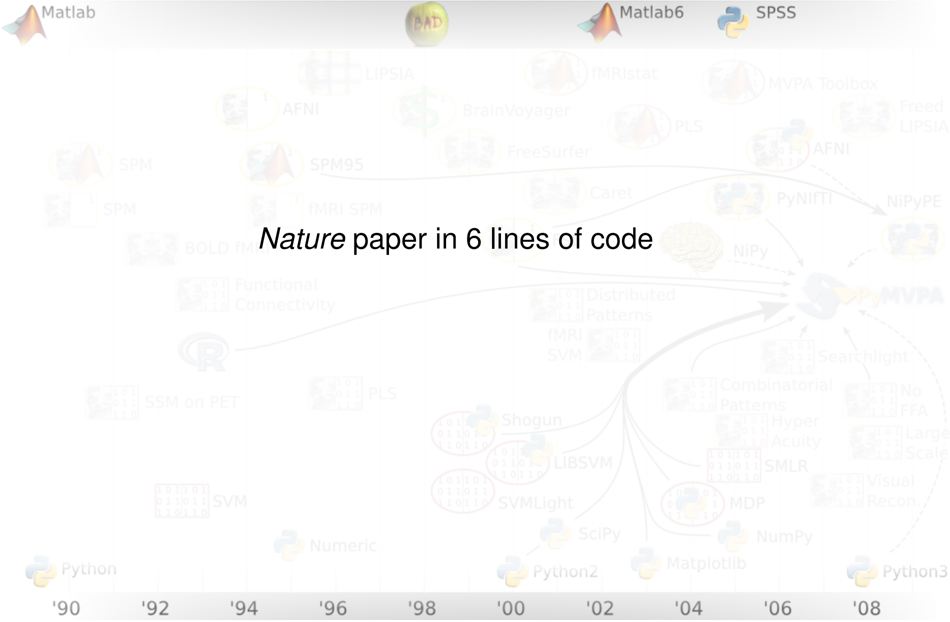
- Portability

  ⇒Runs on anything from mainframes to cell phones

- Open source software

  ⇒MIT-licensed free software

PyMVPA: Fun



Nature paper in 6 lines of code

Full Brain Analysis: Full-brain SVM

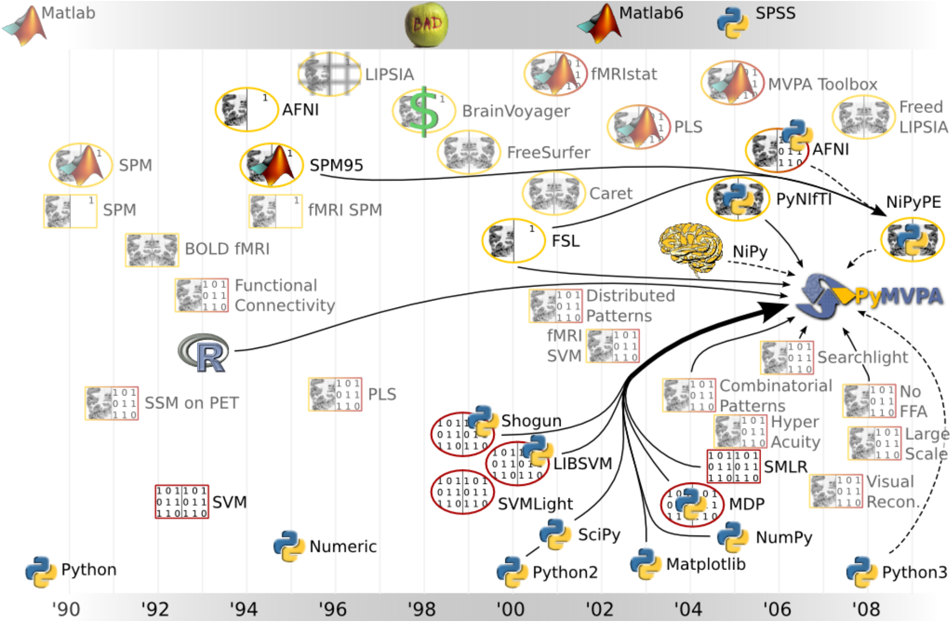
```
attr = SampleAttributes('sample_attr_filename.txt')
dataset = NiftiDataset(
                 samples='subj1_bold.nii.gz',
                 labels=attr.labels, chunks=attr.chunks)

clf = LinearCSVMC()

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

error = cv(dataset)
print cv.confusion
```

Ecosystem


Matlab
BAD
Matlab6
SPSS
LIPSIA
fMRIstat
MVPA Toolbox
AFNI
BrainVoyager
PLS
Freed
LIPSIA
AFNI
SPM
SPM95
FreeSurfer
Caret
PyNIfTI
NiPyPE
SPM
fMRI SPM
FSL
NiPy
BOLD fMRI
Functional
Connectivity
Distributed
Patterns
PyMVPA
fMRI
SVM
Searchlight
Combinatorial
Patterns
No
FFA
SSM on PET
PLS
Shogun
Hyper
Acuity
Large
Scale
LIBSVM
SMLR
SVM
SVMLight
MDP
Visual
Recon.
SciPy
NumPy
Numeric
Python
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Matplotlib
Python3
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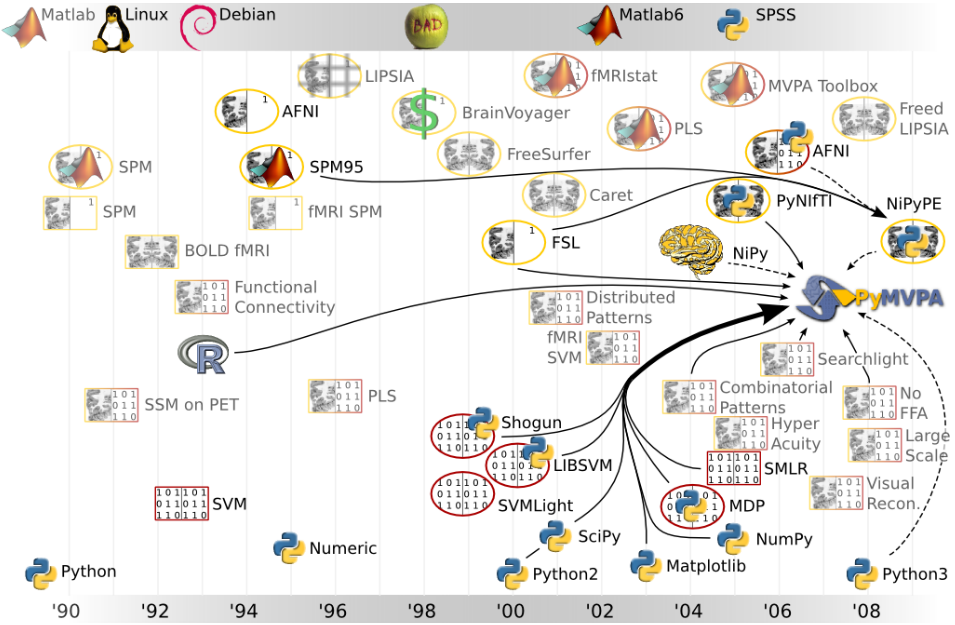
Ecosystem



Matlab
Linux
Debian
BAD
Matlab6
SPSS
LIPSIA
fMRIstat
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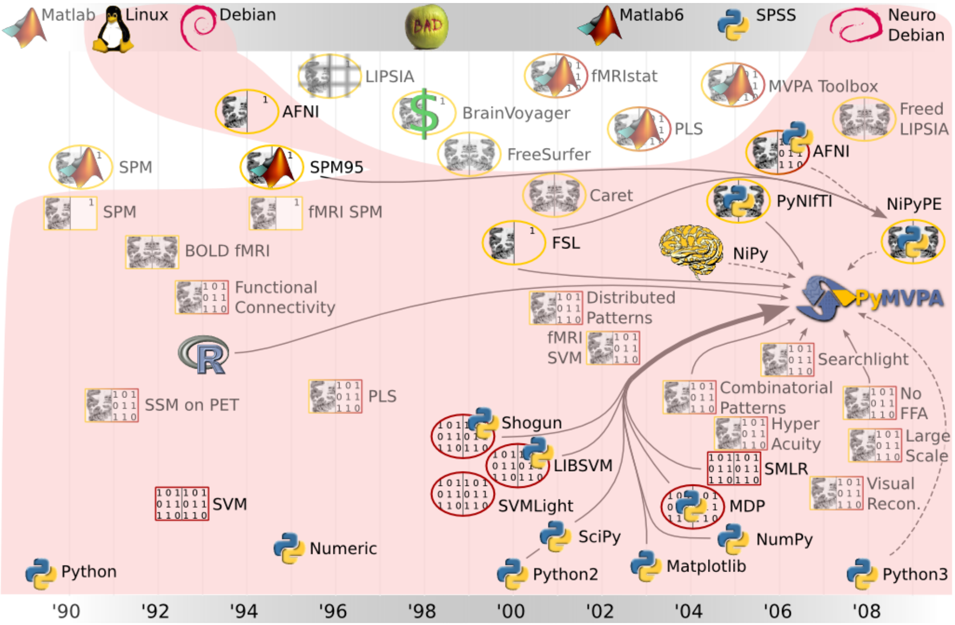
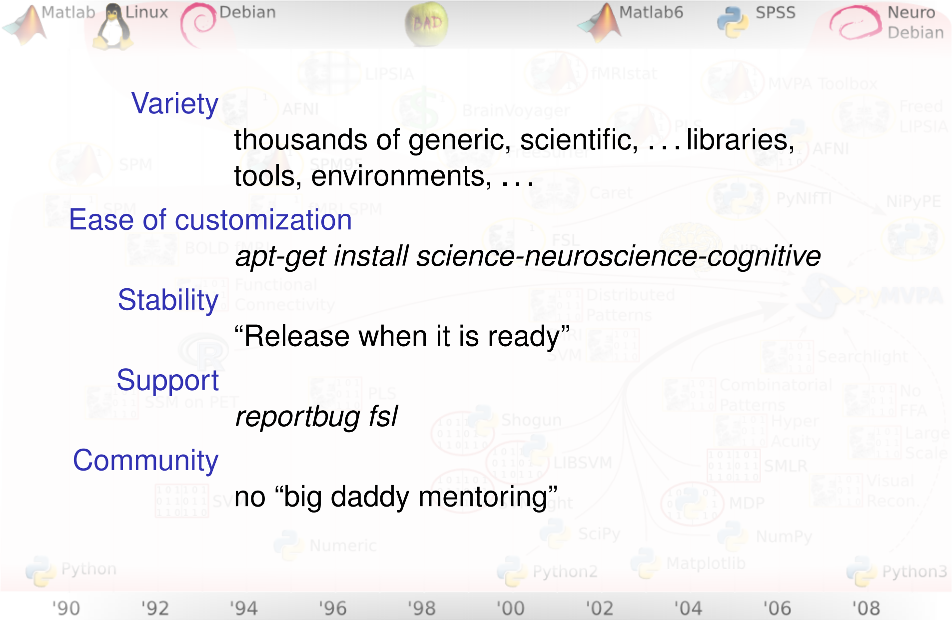
NeuroDebian Ecosystem



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

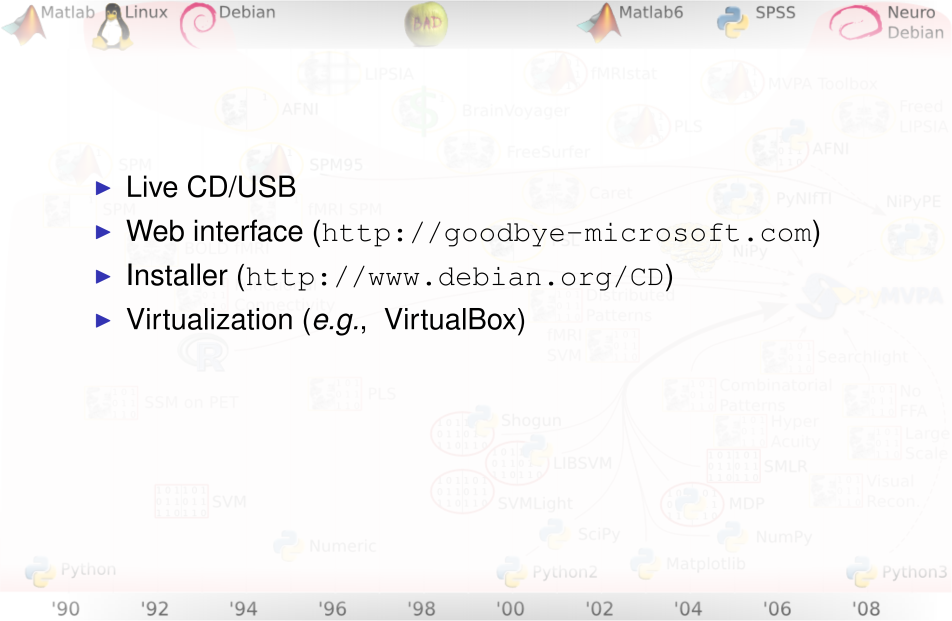
reportbug fsl

Community

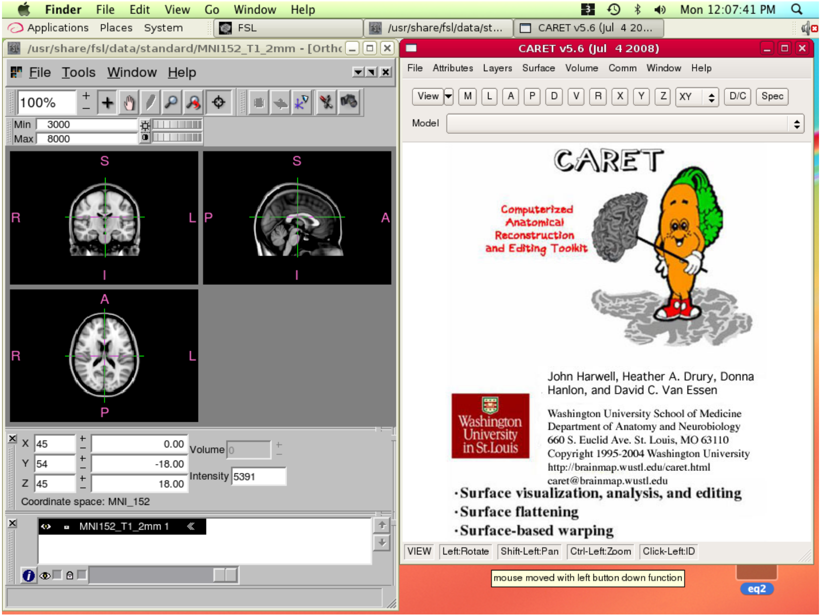
no "big daddy mentoring"

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



PyMVPA Extravaganza 2009 – Dartmouth College

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

...

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