Computational Neuroscience Laboratory

Machine Learning for Neuroimaging

Autumn 2023

10/18/2023

Hands on Statistics & ML (Python)

Intro into Jupyter Notebook

- Jupyter Notebook is an open-source web application
- Create and share documents that contain live code, equations, visualizations, and text
- The name, **Jupyter**, comes from the core supported programming languages: Julia, Python, and R

Getting Started with Jupyter

- Install Jupyter using pip (or Anaconda)

Shell

```
$ pip install jupyter
```

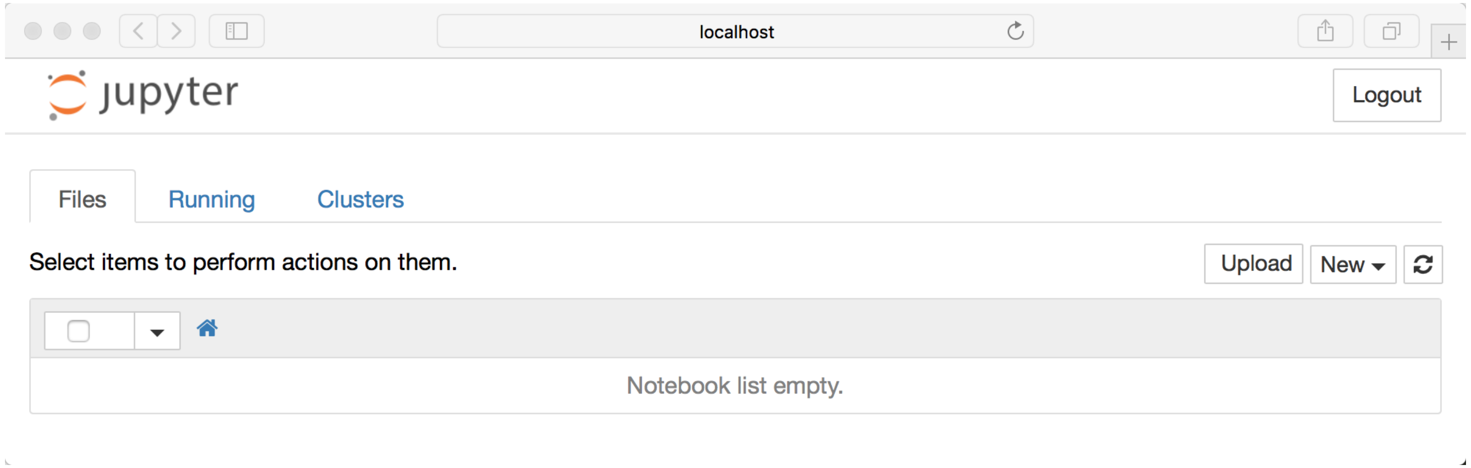
- Run Jupyter

Shell

```
$ jupyter notebook
```

Create New Notebook

- Jupyter will run on your default browser (or open a new tab) to the following URL: http://localhost:8888/tree



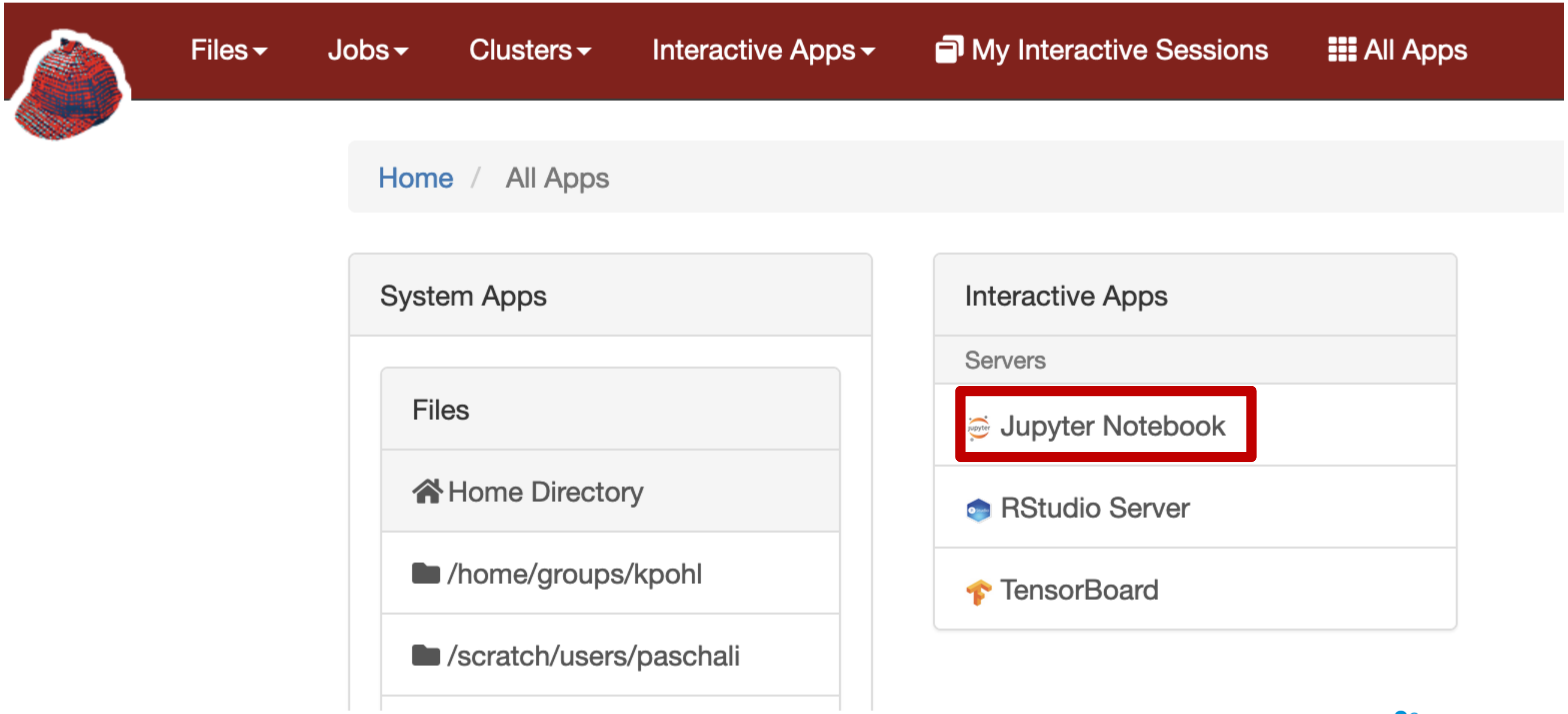
Select items to perform actions on them.

Notebook list empty.

- Click ‘New’ to create a new Jupyter Notebook

Jupyter on Sherlock

https://login.sherlock.stanford.edu/pun/sys/dashboard



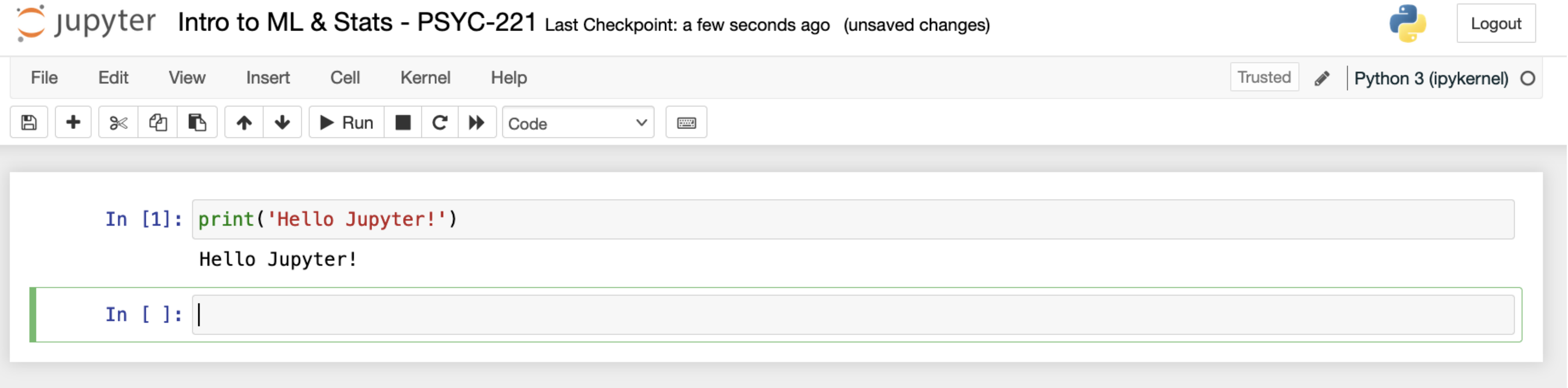
Running your first cell

- Add Python code to the cell and try running its contents

Jupyter Python Cell

```
print('Hello Jupyter!')
```

⇧Shift + Enter ↩


jupyter
Intro to ML & Stats - PSYC-221 Last Checkpoint: a few seconds ago (unsaved changes)
Logout
File
Edit
View
Insert
Cell
Kernel
Help
Trusted
Python 3 (ipykernel)
Run
Code

```
In [1]: print('Hello Jupyter!')
        Hello Jupyter!

In [ ]: |
```

Requirements

Install in a virtual environment or load modules in Sherlock

- numpy==1.24.4
- pandas==2.0.2
- scikit-image==0.22.0
- scikit-learn==1.2.2
- scipy==1.11.0
- seaborn==0.12.2
- torch==2.0.1 (PyTorch)
- nibabel==5.1.0
- nilearn==0.10.1

CNS LAB

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Part 1:
Data Preparation and Hypothesis Testing

pandas

SciPy

Outline

1. Load the data
2. Handle missing values and remove outliers
3. Test hypothesis on preconceptions we may have
4. Residualization: dealing with co-founder effects
5. Save processed data frame

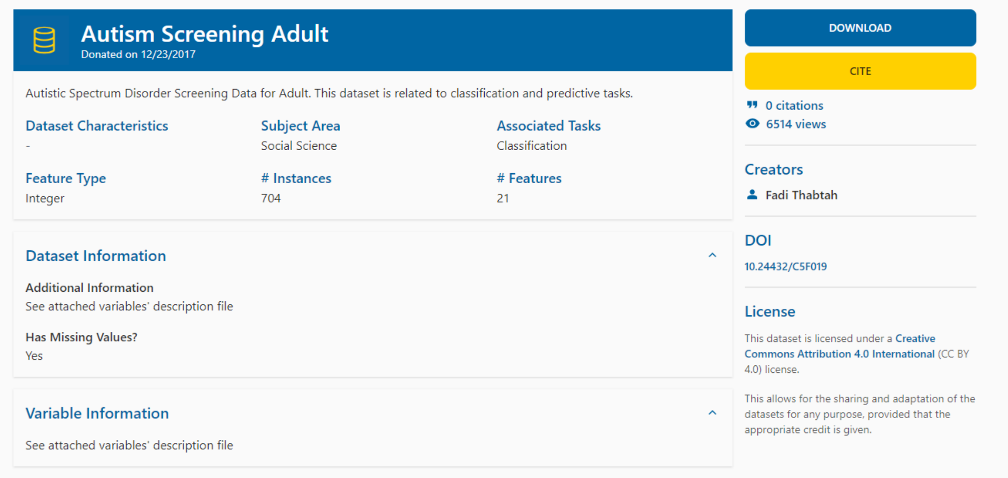
Autism Screening on Adults

- Autism spectrum disorder (ASD) is a developmental disability
- Diagnosing ASD can be difficult because there is no test, e.g. blood test, to diagnose the disorder
- Many adults can and do have ASD. But it’s only recently that doctors have begun diagnosing them with it

https://www.cdc.gov/ncbddd/autism/screening.html

Autism Screening on Adults - Dataset

- Dataset contains survey results for more than 700 subjects
- Results from a quick referral guide for adults with suspected autism
- Download dataset from here



Autism Screening Adult

Donated on 12/23/2017

Autistic Spectrum Disorder Screening Data for Adult. This dataset is related to classification and predictive tasks.

Dataset Characteristics	Subject Area	Associated Tasks
-	Social Science	Classification

Feature Type	# Instances	# Features
Integer	704	21

0 citations
6514 views

Creators

Fadi Thabtah

DOI

10.24432/C5F019

Dataset Information

Additional Information
See attached variables' description file

Has Missing Values?
Yes

License

This dataset is licensed under a Creative Commons Attribution 4.0 International (CC BY 4.0) license.

This allows for the sharing and adaptation of the datasets for any purpose, provided that the appropriate credit is given.

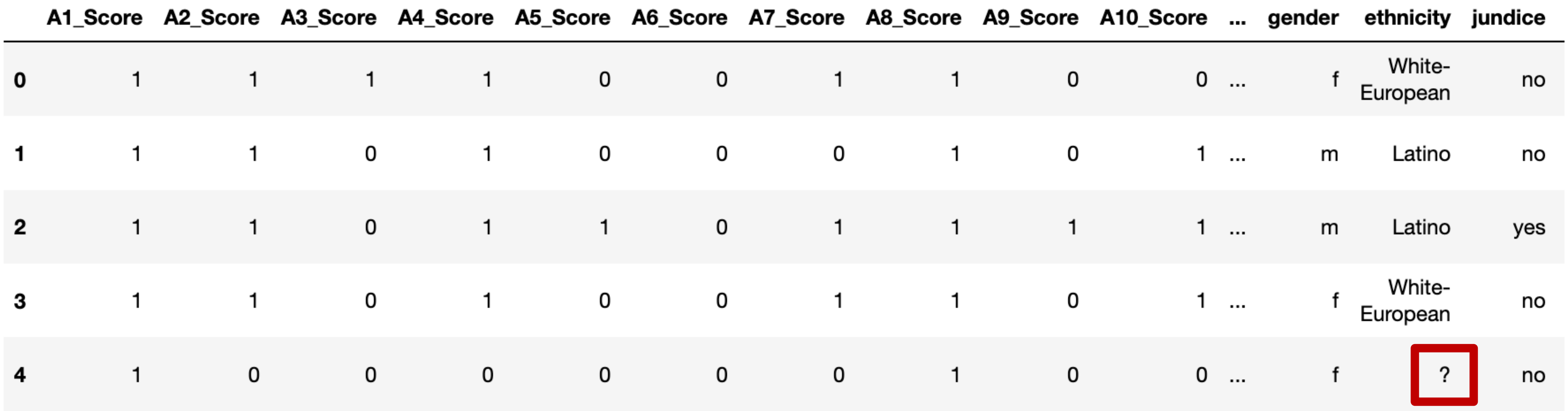
Variable Information

See attached variables' description file

1) Thabtah, F. (2017). Autism Spectrum Disorder Screening: Machine Learning Adaptation and DSM-5 Fulfillment. Proceedings of the 1st International Conference on Medical and Health Informatics 2017, pp.1-6. Taichung City, Taiwan, ACM.
2) Thabtah, F. (2017). ASDTests. A mobile app for ASD screening. www.asdtests.com [accessed December 20th, 2017].
3) Thabtah, F. (2017). Machine Learning in Autistic Spectrum Disorder Behavioural Research: A Review. To Appear in Informatics for Health and Social Care Journal. December, 2017 (in press)

Data Loading

- Load csv file
- Visualize the top five rows (*head*)
- Notice data types, column values, empty cells



	A1_Score	A2_Score	A3_Score	A4_Score	A5_Score	A6_Score	A7_Score	A8_Score	A9_Score	A10_Score	...	gender	ethnicity	jundice
0	1	1	1	1	0	0	1	1	0	0	...	f	White-European	no
1	1	1	0	1	0	0	0	1	0	1	...	m	Latino	no
2	1	1	0	1	1	0	1	1	1	1	...	m	Latino	yes
3	1	1	0	1	0	0	1	1	0	1	...	f	White-European	no
4	1	0	0	0	0	0	0	1	0	0	...	f	?	no

Data Cleaning

- Remove row with outlier age
- Look for missing values
  - Empty cells
  - Cells with '?'
- Count amount of missing values
  - 2 missing age values
  - 95 missing ethnicities
  - 95 missing relations

Data Imputation

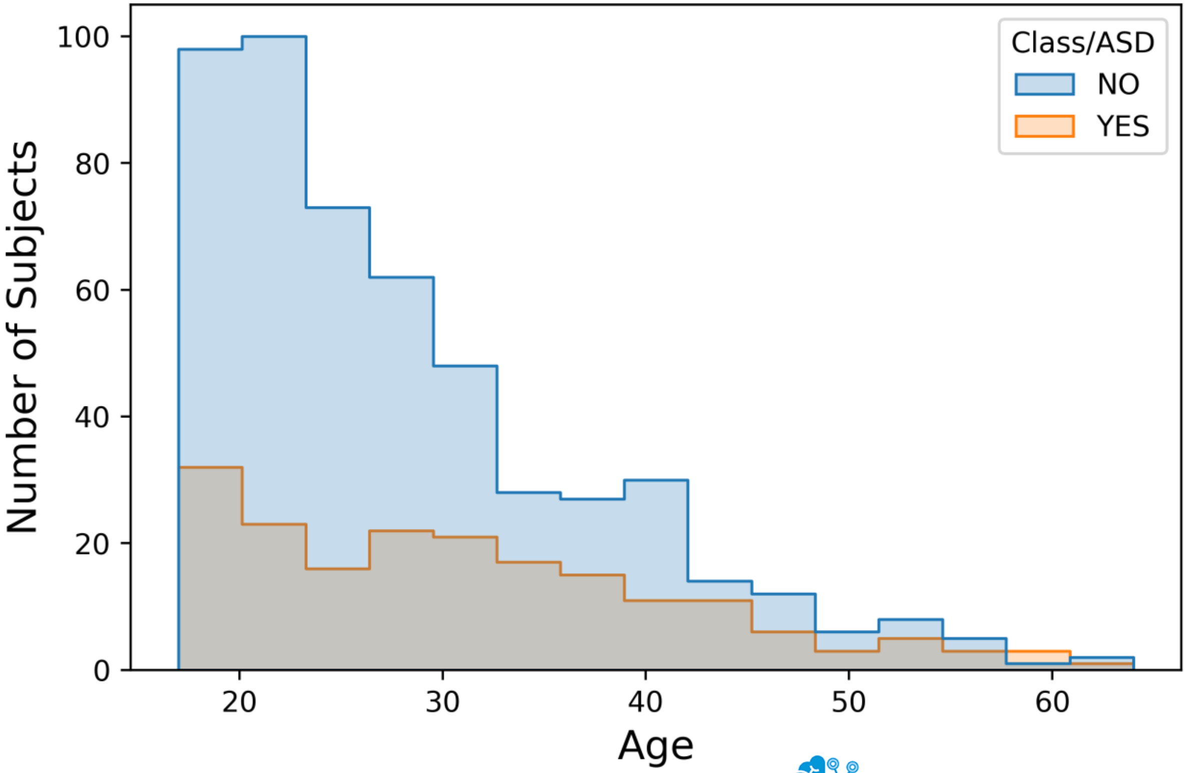
- Fill out missing age values with column mean
  - **Important!** This step comes after we have removed the outliers

- Replace missing ethnicities and relations with 'Other’
  - We do not know the actual values

Hypothesis Testing

- Dataset is split into two cohorts: controls and positive for autism (ASD)
- Null hypothesis: the **age** distribution of the two cohorts is equal

- Histograms of ages of two cohorts
- Hard to visually compare



Compare age of cohorts

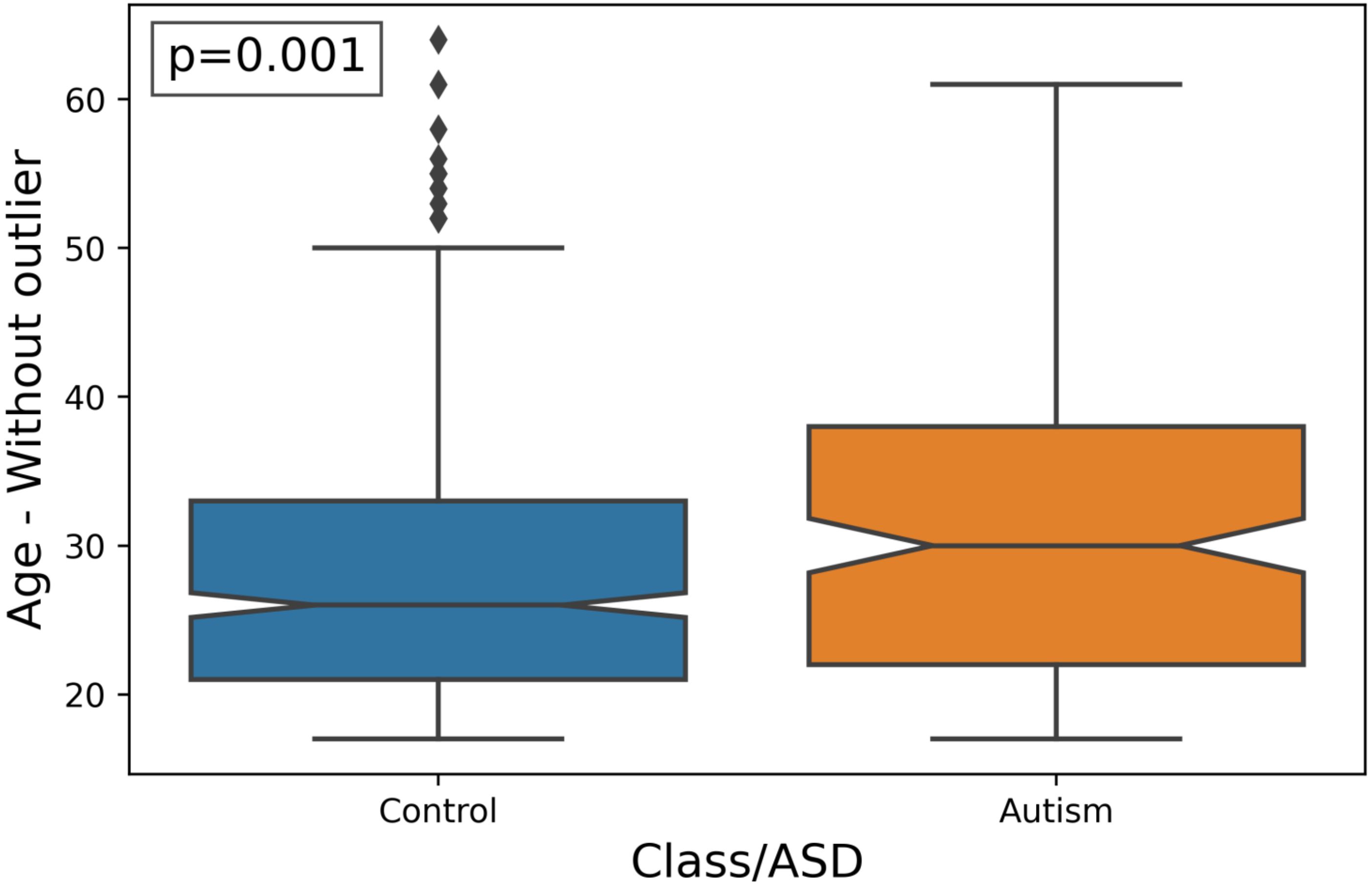
- Mann-Whitney U-Test
- Tests whether the distributions of two independent samples are equal
- Nonparametric test
- $p < 0.05$ → We reject the null hypothesis

Jupyter Python Cell

```
U1, p = mannwhitneyu(controls["age"], autism["age"])
```

Compare age of cohorts

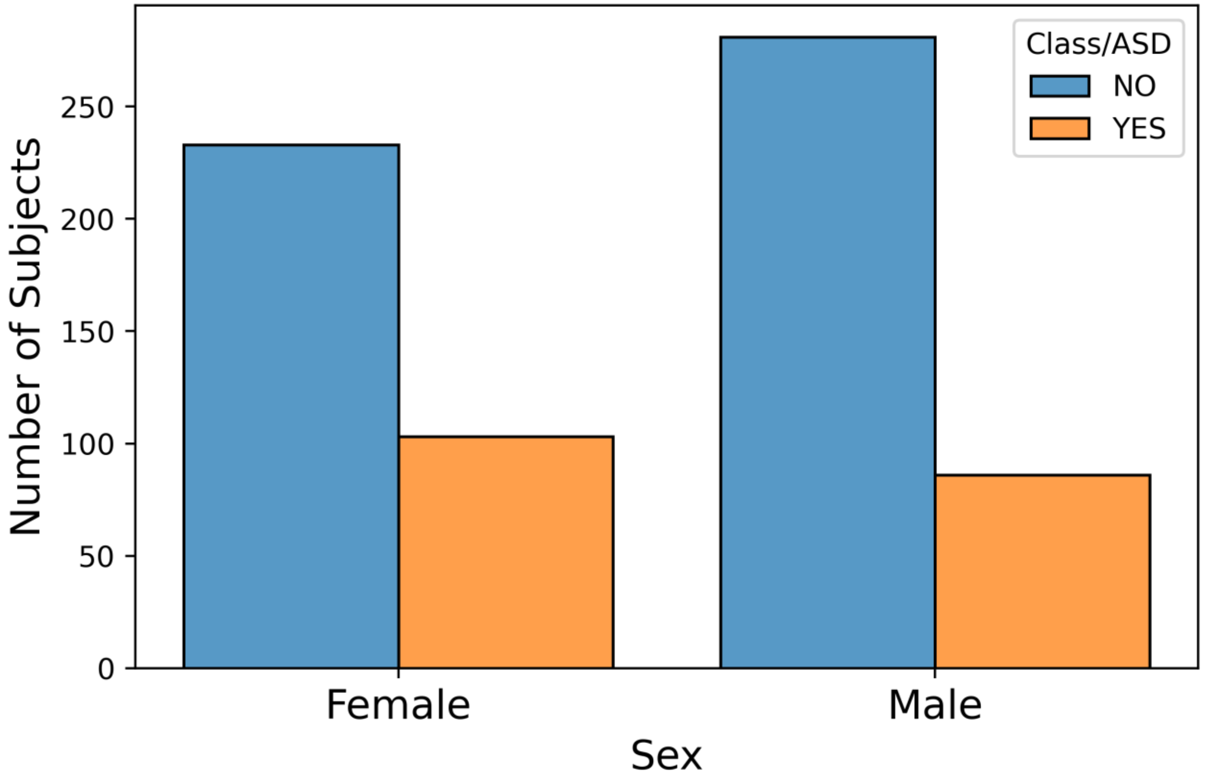
- The notches in the box plot do not overlap
- We can conclude, with 95% confidence that the true medians differ



Hypothesis Testing

- Dataset is split into two cohorts: controls and positive for autism (ASD)
- Null hypothesis: the frequency of autism is the same across sexes

- Histograms of subjects of the two cohorts
- Is there a difference between Females and Males?



Compare autism across sexes

- Null hypothesis: the frequency of autism is the same across sexes
- Chi-squared test
- $p < 0.05$ → We reject the null hypothesis

Contingency Table

	Control	**ASD**	**Total**
Male	280	86	366
Female	232	103	335
Total	512	189	701

Removing the effect of age and sex

- Remove the effect of age and sex
  - Subtract $\beta_{age}age$ and $\beta_{sex}sex$ from raw measurements
  - Adjust ‘reference point’ to $\overline{age}$ and $\overline{sex}$

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Part 2:
Classifier Training and Evaluation with PyTorch

Outline

1. Adapt data to serve as PyTorch input
2. Design a PyTorch architecture
3. Train and evaluate models
4. Save and restore models
5. Compare two models

Autism Classification

- Train a model f that given an input x predicts a classification label y
- In this problem x denotes the input features of the questionnaire
- y is the subject classification to control and ASD based on their responses
- We will compare two ML classifiers

Data Preparation

- Use the questionnaire answers A1 to A10 **after residualization** as input x to our classifier
- Transform the ‘YES/NO’ labels into integers

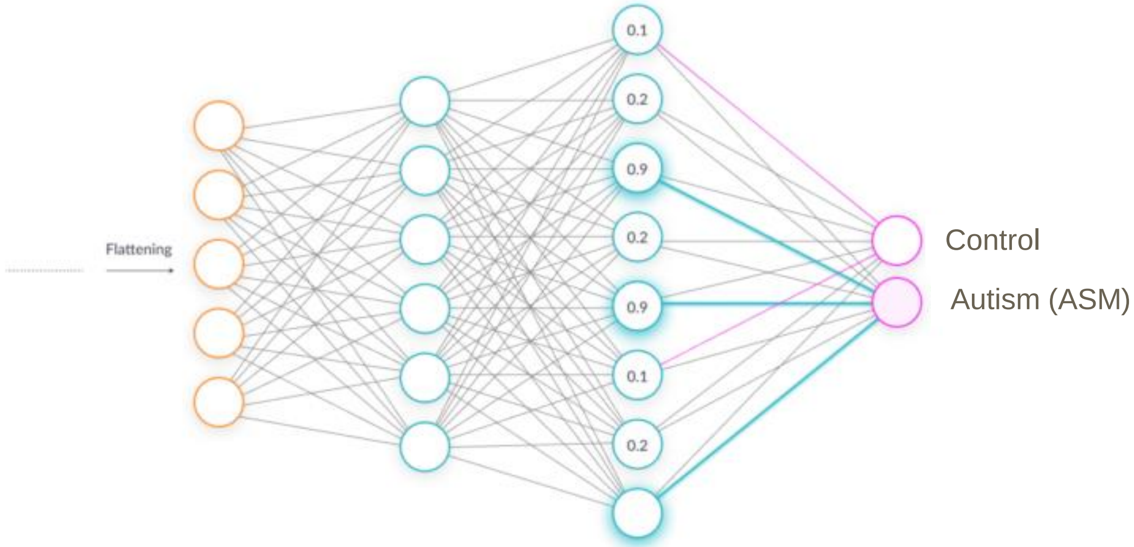
Country	Category #
Control	NO
Autism	YES

→

Class
0
1

Fully-connected Deep Neural Network

- Fully connected feedforward artificial neural network
- Consists of an input layer, hidden layers and an output layer



https://towardsdatascience.com/a-simple-guide-to-convolutional-neural-networks-751789e7bd88

Classifier Comparison

- Null hypothesis: the two models are equally accurate on the same cohort
- McNemar's Test
- $p < 0.05$ → We reject the null hypothesis

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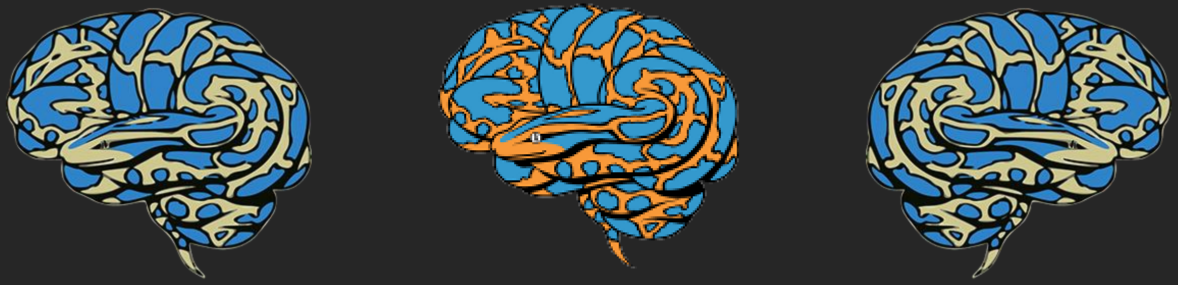
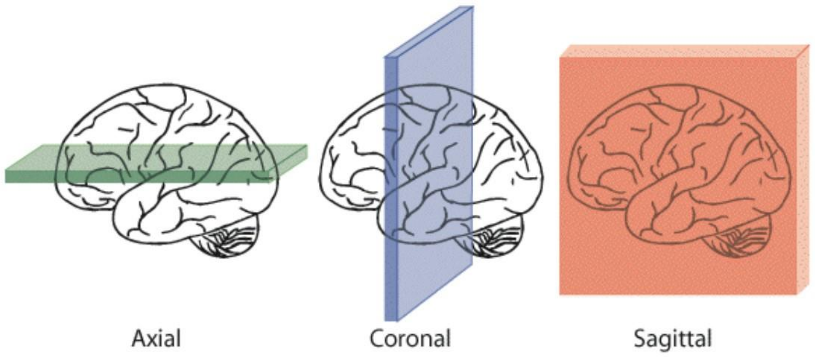
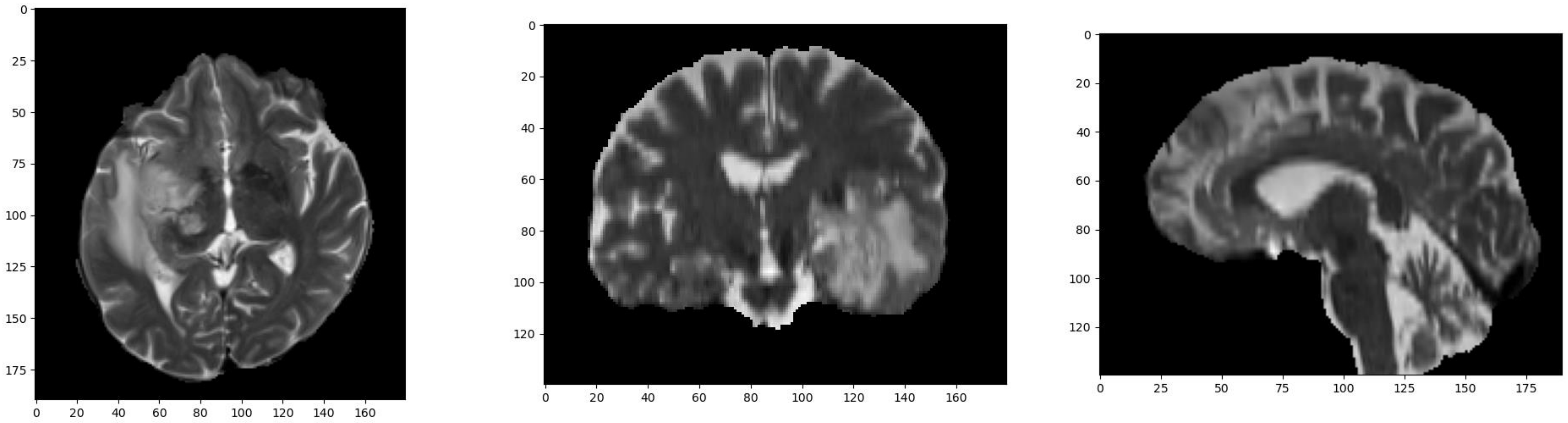
Part 3:
Visualization of MRI Data



Visualization of an MRI

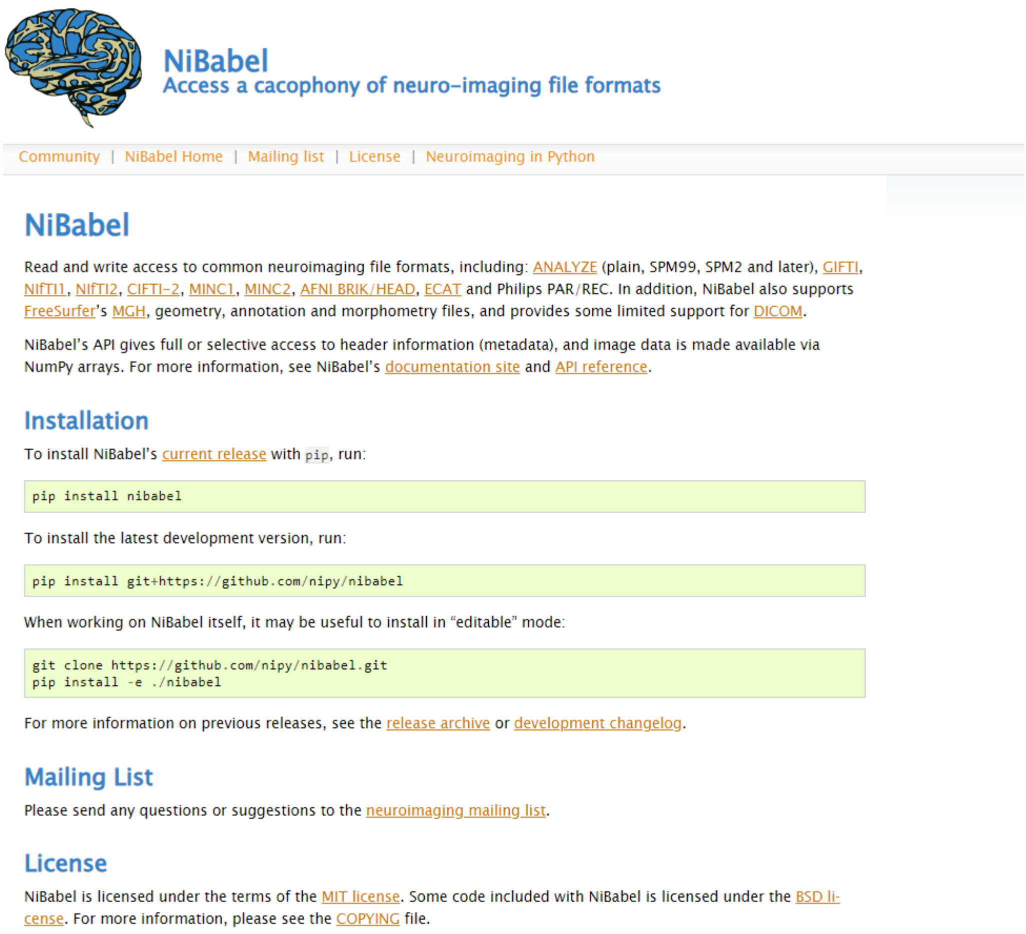




Goschke, T.: VL Kognitionspsychologie: Denken, Problemlösen, Sprache - Methoden der Kognitiven Neurowissenschaft: Kurze Einführung in die funktionelle Bildgebung (Summer 2013). Technical University Dresden, Dresden (2013)

Libraries for Neuroimaging Files

Loading, Processing and Visualization


NiBabel
Access a cacophony of neuro-imaging file formats
Community | NiBabel Home | Mailing list | License | Neuroimaging in Python

NiBabel

Read and write access to common neuroimaging file formats, including: ANALYZE (plain, SPM99, SPM2 and later), GIFTI, NIfTI1, NIfTI2, CIFTI-2, MINC1, MINC2, AFNI BRIK/HEAD, ECAT and Philips PAR/REC. In addition, NiBabel also supports FreeSurfer's MGH, geometry, annotation and morphometry files, and provides some limited support for DICOM.

NiBabel's API gives full or selective access to header information (metadata), and image data is made available via NumPy arrays. For more information, see NiBabel's documentation site and API reference.

Installation

To install NiBabel's current release with `pip`, run:

```
pip install nibabel
```

To install the latest development version, run:

```
pip install git+https://github.com/nipy/nibabel
```

When working on NiBabel itself, it may be useful to install in "editable" mode:

```
git clone https://github.com/nipy/nibabel.git
pip install -e ./nibabel
```

For more information on previous releases, see the release archive or development changelog.

Mailing List

Please send any questions or suggestions to the neuroimaging mailing list.

License

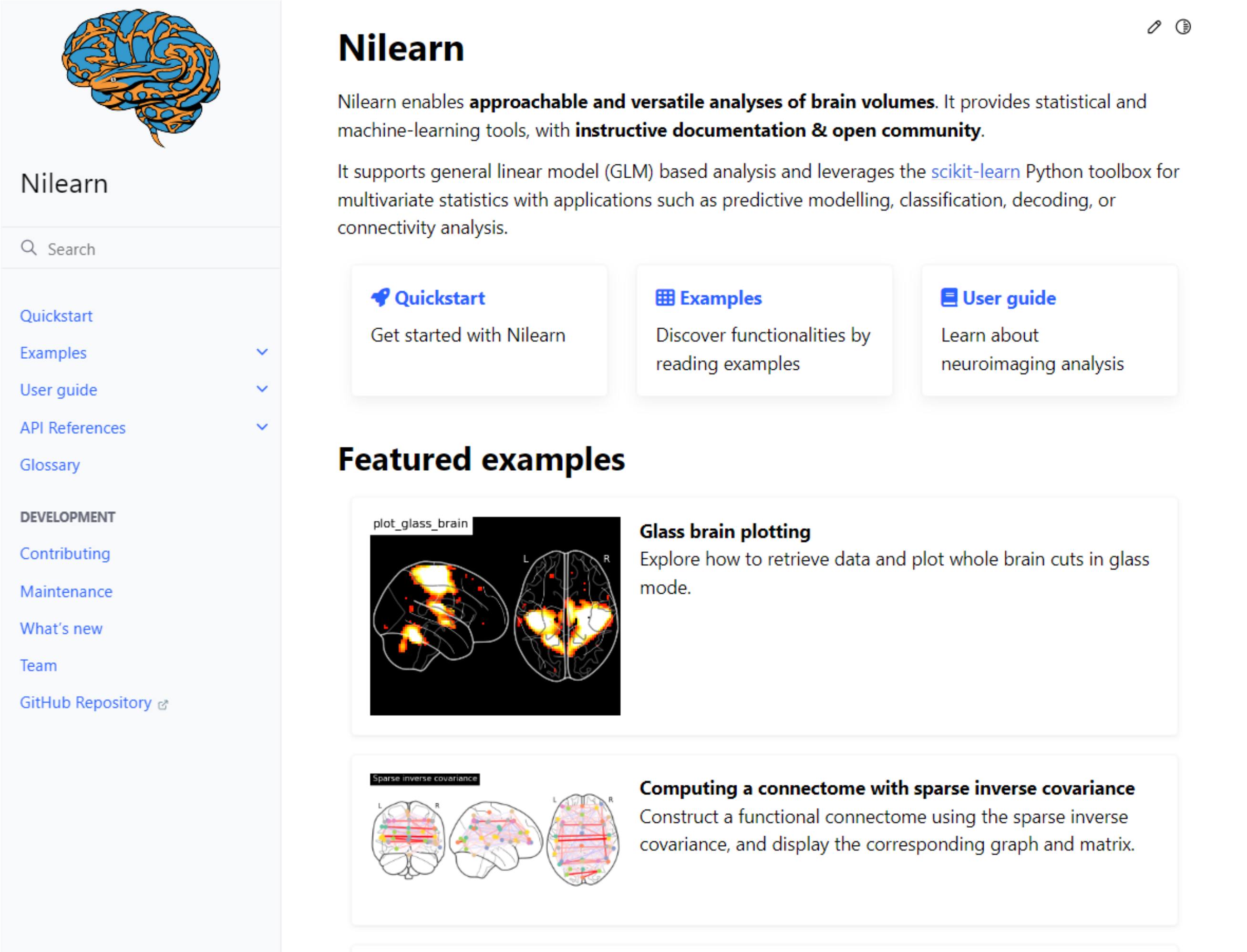
NiBabel is licensed under the terms of the MIT license. Some code included with NiBabel is licensed under the BSD license. For more information, please see the COPYING file.

NiBabel

- Read and write access to common neuroimaging file formats; access header and image data

Libraries for Neuroimaging Files

Loading, Processing and Visualization



Nilearn

Search

- Quickstart
- Examples
- User guide
- API References
- Glossary

DEVELOPMENT

- Contributing
- Maintenance
- What's new
- Team
- GitHub Repository

Nilearn

Nilearn enables **approachable and versatile analyses of brain volumes**. It provides statistical and machine-learning tools, with **instructive documentation & open community**.

It supports general linear model (GLM) based analysis and leverages the scikit-learn Python toolbox for multivariate statistics with applications such as predictive modelling, classification, decoding, or connectivity analysis.

Quickstart
Get started with Nilearn

Examples
Discover functionalities by reading examples

User guide
Learn about neuroimaging analysis

Featured examples

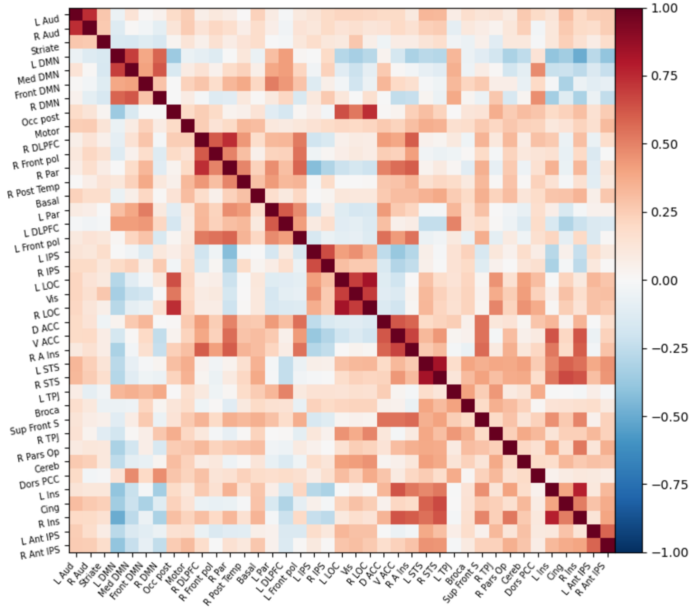
Glass brain plotting
Explore how to retrieve data and plot whole brain cuts in glass mode.

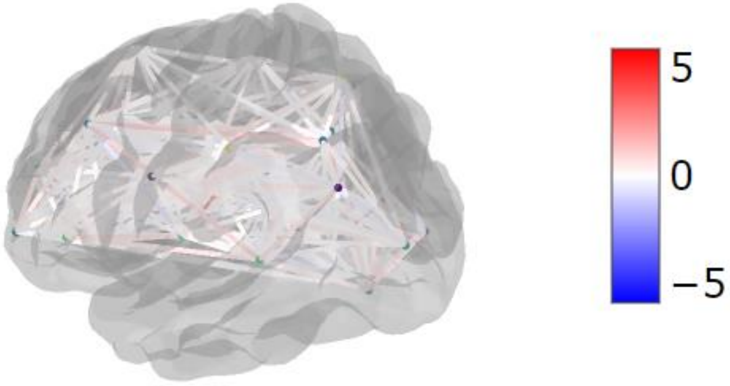
Computing a connectome with sparse inverse covariance
Construct a functional connectome using the sparse inverse covariance, and display the corresponding graph and matrix.

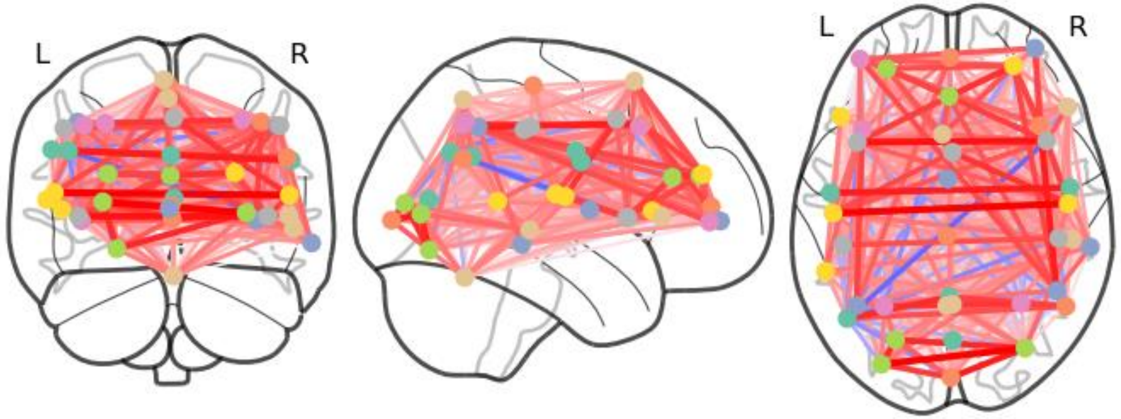
Nilearn

- Glass and surface plotting
- Very rich gallery of examples!

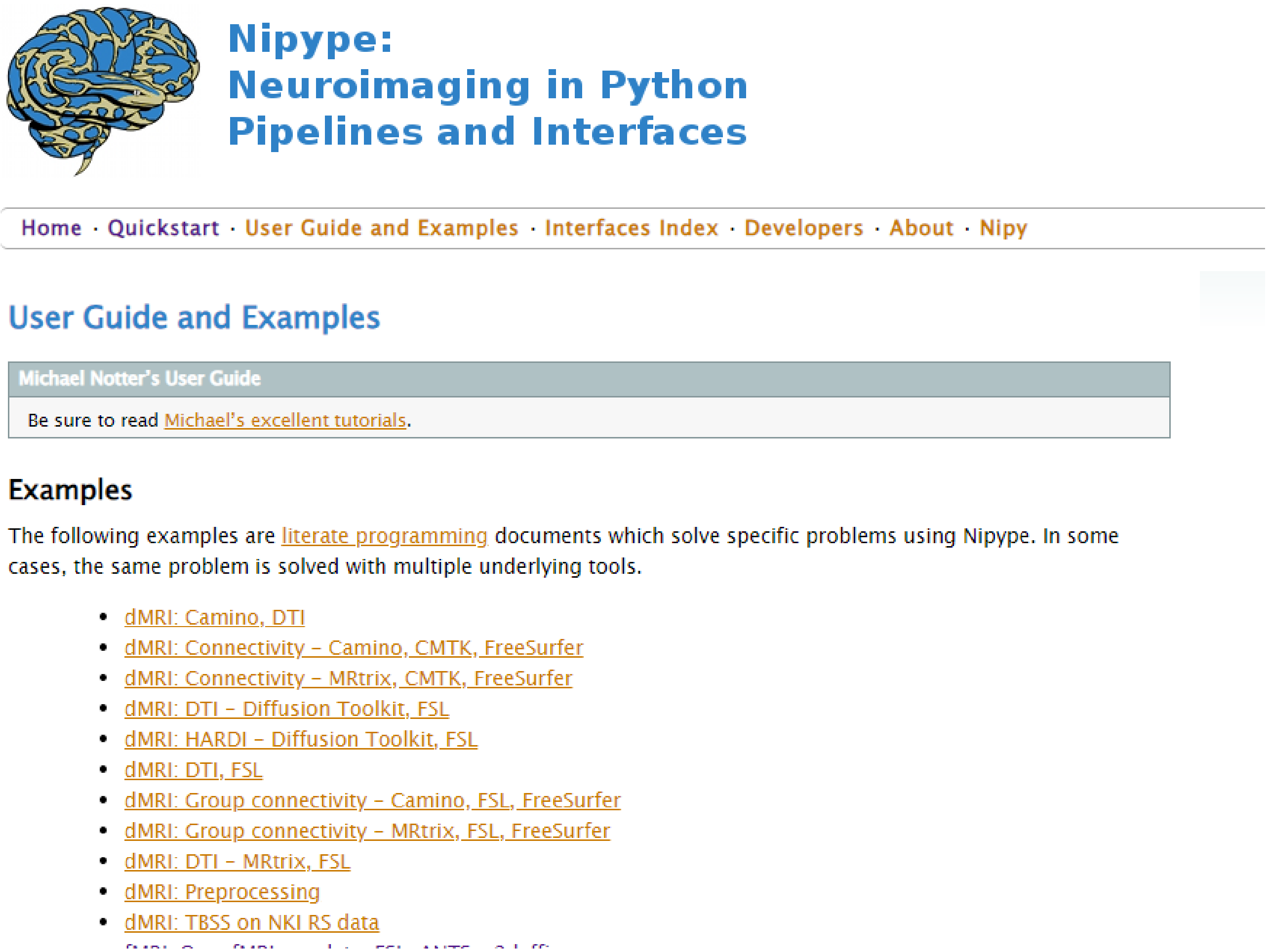
Visualizations of an fMRI







Libraries for Neuroimaging Files
Loading, Processing and Visualization



Nipype:
Neuroimaging in Python
Pipelines and Interfaces

Home · Quickstart · User Guide and Examples · Interfaces Index · Developers · About · Nipy

User Guide and Examples

Michael Notter's User Guide

Be sure to read Michael's excellent tutorials.

Examples

The following examples are literate programming documents which solve specific problems using Nipype. In some cases, the same problem is solved with multiple underlying tools.

- dMRI: Camino, DTI
- dMRI: Connectivity – Camino, CMTK, FreeSurfer
- dMRI: Connectivity – MRtrix, CMTK, FreeSurfer
- dMRI: DTI – Diffusion Toolkit, FSL
- dMRI: HARDI – Diffusion Toolkit, FSL
- dMRI: DTI, FSL
- dMRI: Group connectivity – Camino, FSL, FreeSurfer
- dMRI: Group connectivity – MRtrix, FSL, FreeSurfer
- dMRI: DTI – MRtrix, FSL
- dMRI: Preprocessing
- dMRI: TBSS on NKI RS data

Nipype

- Load, preprocess and analyze diffusion, structural and functional MRIs