Contents

()

MRI
MNE/pythonfreesurfer

…MNEpython…

MNE/pythonfreesurfer…

elektaMEGelekta

MNE

- /
-
- MRIfreesurfer

()

MNE/python
MNE/freesurferOS

qiita[1]

[1] SNS

/

2

()[3]

4

MRI
MNEpython

5

unix

…

- hoge:
  fuga,piyo
  foobar
- :()
- :
- :Mac

[2] http://www.elekta.co.jp/products/functionalmapping.html
[3]
[4] fMRINIRSfMRINIRS
[5] http://biorxiv.org/content/early/2017/03/29/121764

- .bash_profile:
  .bashrc
  ()
- :

pythonpython

- python(anaconda)MNE/python

- MEG
  python(anaconda)MNE/python

- MRI
  freesurfermricrogl(mricron)

  python
- MEG/EEG+MRI
  MEGMRI
  MRI
  †† …

MNE/python

python[6]numpy,scipy
()

WaveletICAPermutation
…

CMNE/C
MNEpython
MNE-C
MNE/python 0.16.1
freesurfer6.0pythonpython3.7

MNEpython3
pythonpython3.6
python2

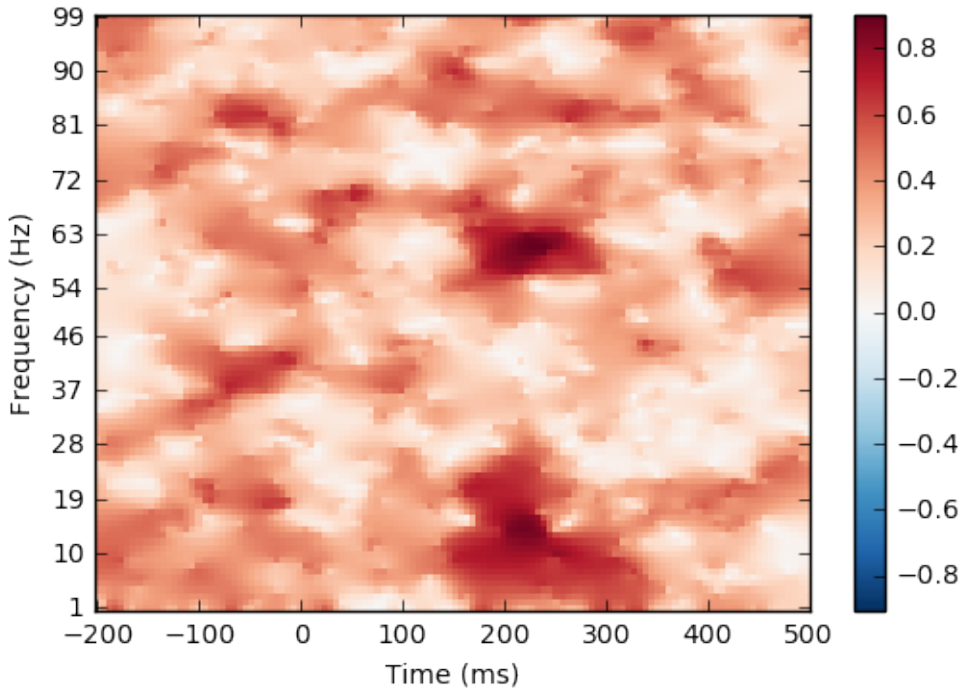


Figure 1: wavelet

[6]MATLABpythonWeb

freesurfer

MRI
fMRI

UnixOS
CPU
MRI

office

MNEpython
unix

MNE		
anaconda,pip,homebrew		app store,google play,
spyder,jupyter		word,excel,
python		
MNE		excel
mricron		,
freefurfer/freeview	MRI	

MRIELEKTA

††

††

10openBCI[7]

…

MRI

24

…

8

CPU

GPU()
nVidia
AMD
GPUCPU
freesurferOSCPU

OS

OSlinuxMACwindows
MNEpython
Unixfreesurfer
WSL2linux…
debianlinux
UBUNTU[9]MAC

linuxlinux
CUDA

7

8

[9]UBUNTUCanonicallinuxdebian

debianapt
MACapt homebrew https://brew.sh/index_ja.html
UBUNTU16.04LTSmacos10.12
UBUNTU16.04LTS

Ubuntu https://www.ubuntulinux.jp/ubuntu

linux
…

- freesurfer
-

MNEdocker[10]

anaconda[11]
pipenv[12]windows

Anaconda https://www.continuum.io/downloads

anaconda23python23
anaconda3python2
anacondajupyterrepl[13]spyderIDE[14]

[10]
[11] anacondaContinuumAnalyticspythonpipenv
[12] pythonanacondapython
[13]
[14]

spyder

IDEipython

jupyter, ipython

replshell

- web
- cythonR
-

-
-
-
-

jupyterIDE

atom, vscode

atomvscode
pythonpythonIDE

-
-

-
-

-
-

?

- jupyter
- anaconda
- vscode

  mneanaconda
  visual studio code
  jupyter

pipenvvim
()

vscode

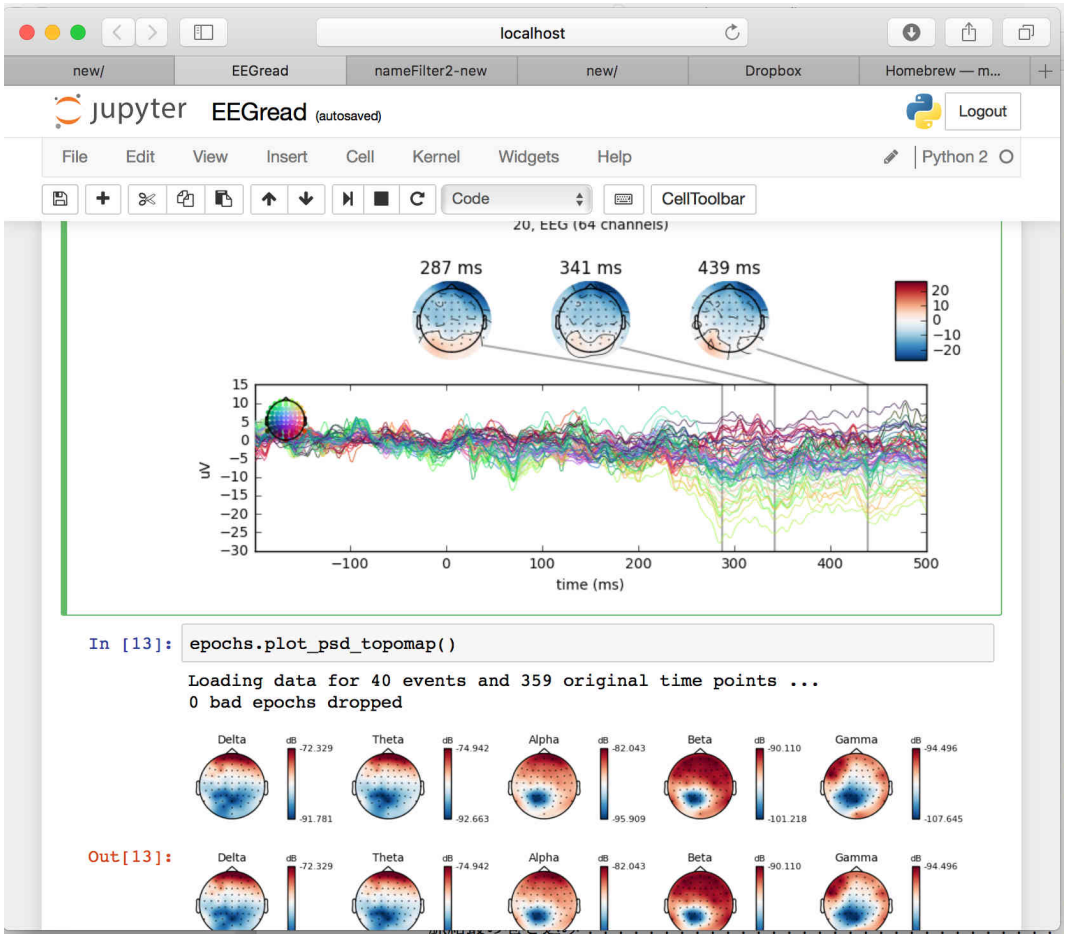


Figure 2: jupyterwebgit

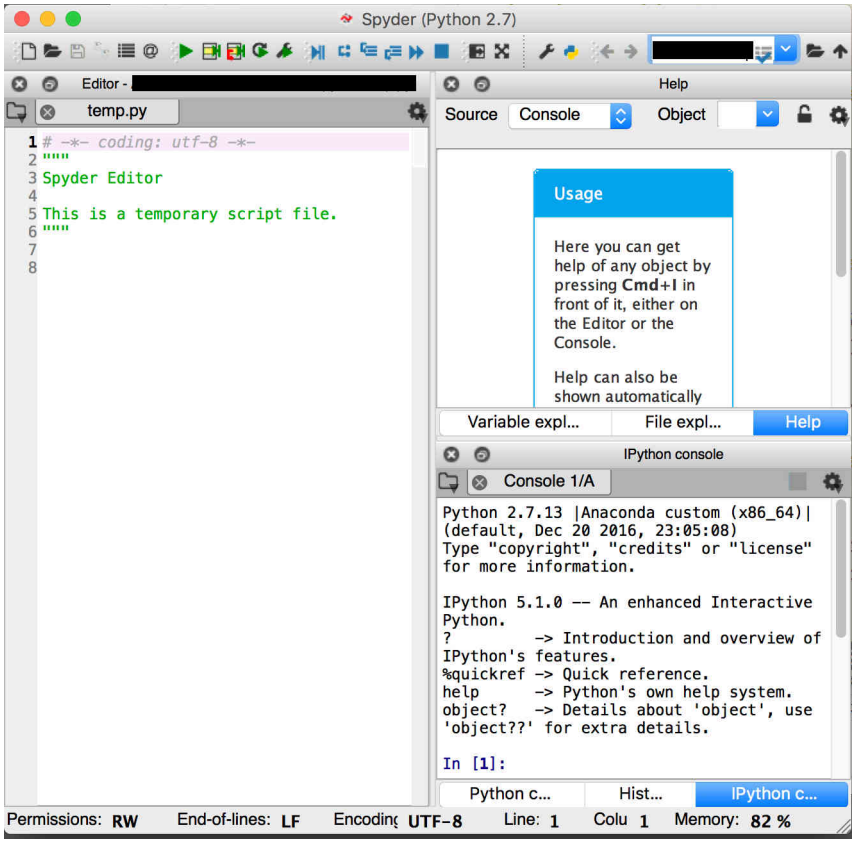


Figure 3: spyderIDE

MACanaconda
linuxanaconda
bashsh

```
bash Anaconda3-hoge-Linux-x86_64.sh
```

pipenv

jupyter

jupyter

```
conda install -c conda-forge jupyter_contrib_nbextensions
jupyter contrib nbextension install --user
```

```
3 ipcluster nbextension enable --user
```

extensionjupyter

jupyterplot

jupyterplot
jupyter

jupyter

```
1 %matplotlib inline
```

python2

```
1 %matplotlib qt
```

python3
python3python2qt
qt5

```
1 %matplotlib qt5
```

(mayavi)

```
1 %gui qt
```

anaconda

mnepython3freesurferpython2
mne

MNEanaconda
anacondapython[15]

[15] pipenvanaconda

ipython
hogepython3.6jupyter

```
ipython kernel install --user
conda create -n hoge python=3.6 anaconda
conda activate hoge
ipython kernel install --user
conda info -e
```

1

1. pythonjupyter
2. condapython
3.
4. jupyter
5.

conda activatepython
jupyter

```
conda remove -n python3 --all
```

Rjupyter

anacondaR

```
conda install libiconv
conda install -c r r-essentials
conda install -c r rpy2
```

R
R
[16]

jupyter

```
%load_ext rpy2.ipython
```

```
%%R -i input -o output
hogehoge
```

[16] matlabCjupyter

hogehogeRplot
-i
Rpandas

```
import pandas as pd
data=pd.Dataframe([])
```

```
%%R -i data
print(summary(data))
```

pythonR

CUDA

CUDA
GPU1Nvidia
GPGPU
MNEpython
…
Ubuntu

MacNvidia

Nvidia

Nvidia https://developer.nvidia.com/cuda-downloads

OSCUDA
ubuntudeb(network)

()

```
sudo dpkg -i cuda-repo-ubuntu1604_9.1.85-1_amd64.deb
sudo apt-key adv --fetch-keys http://hogehoge.pub
sudo apt-get update
sudo apt-get install cuda
```

bashrc

CUDA

```
export PATH=/usr/local/cuda-9.1/bin${PATH:+:${PATH}}
export LD_LIBRARY_PATH=/usr/local/cuda-9.1/lib64\
      ${LD_LIBRARY_PATH:+:${LD_LIBRARY_PATH}}
```

CUDA
bash
MNEpythonCUDA
http://martinos.org/mne/stable/advanced_setup.html#advanced-setup

```
sudo apt-get install nvidia-cuda-dev nvidia-modprobe
git clone http://git.tiker.net/trees/pycuda.git
cd pycuda
./configure.py --cuda-enable-gl
git submodule update --init
make -j 4
python setup.py install
cd ..
git clone https://github.com/lebedov/scikit-cuda.git
cd scikit-cuda
python setup.py install
```

python

```
import mne
mne.cuda.init_cuda()
```

Enabling CUDA with 1.55 GB available memory…

MNEpython

```
pytest test_filter.py
```

MNEpython
anacondalib/python3/site-package/mne/tests

…
MNEpythonCUDA
…

git

git
gitgithub desktopsource tree
git

git-guide http://www.backlog.jp/git-guide/

git

gitgit
Microsoftgithub

public
github

jupyter()

jupytergit

…

1()

```
1 jupyter notebook --generate-config
```

jupyter
/home/user/.jupyter
URL

http://jupyter-notebook.readthedocs.io/en/latest/extending/savehooks.html
jupyterpython
git[17]

2()

gitgit
jq
.gitattibute

```
*.ipynb diff=ipynb
```

.git/config

```
[diff "ipynb"]
textconv=jq -r .cells[] |{source,cell_type}
prompt = false
```

.gitignore

```
.ipynb_checkpoints/
```

jupyter notebookgit
…

[17] GUI

1

18

19

3

- fixation
- Web Camera
- eye tracker

fixation

…

Web CameraWeb Camera

Web Camera

18

19

2MEG

MEGMEG

…

-
-

1

2

……

3

resting state / Default mode

- :
- MRI: MRI

MRIresting…

?

30ms

…

- picoscope2000windows
  21µs
  25000
- RPM22PB200amazon
  µs
- 5V
-

BNC
BNC

2

…

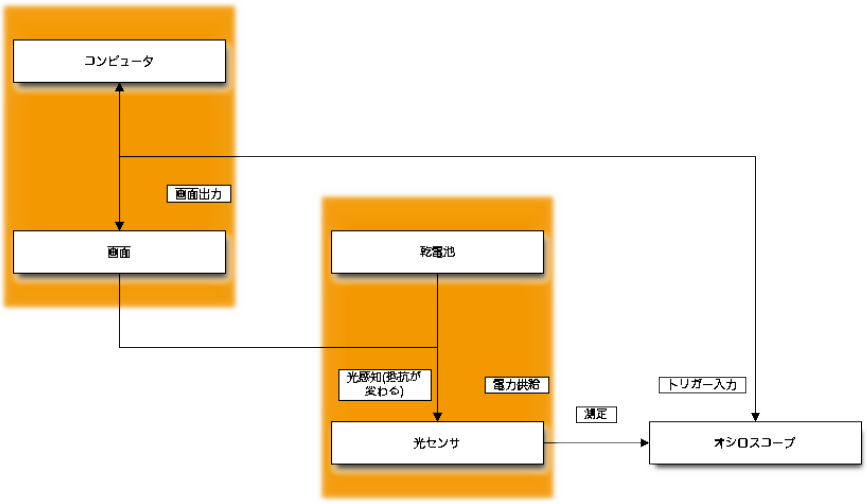


Figure 4:

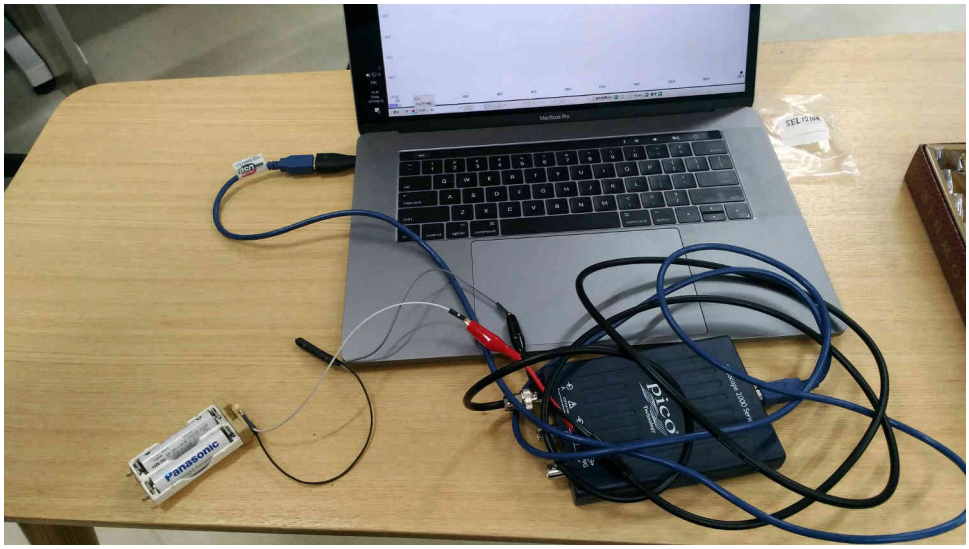


Figure 5: 3

maxfilter(elekta)

maxfilterMEG

MNEpythonelektamaxfilter
elekta…
elektaMNE
MNE

Elekta

- ElektaMEG…
- Redhatlinux(Docker)
- bad

MNE

-
-
-

DANAmaxfilterELEKTA
Redhat5CentOs564bit
DockerMNEUbuntu
ELEKTAredhat linux

docker[20]centos5

```
docker run -it --name centos5 -v ~:/home/hoge centos:5
```

centos5centos5
ELEKTA32bit,64bit
32bit64bitfortranwhich
neuromagneuro

```
yum install compat-libf2c-34.i386
yum install compat-libf2c-34.x86_64
yum install which
useradd neuromag
groupadd neuro
```

20

```
6 usermod -a neuromag neuro
```

DANAmaxfilter

```
1 sh install
```

HDD

```
1 /neuro/bin/admin/license_info
```

ELEKTA

/neuro/databases/sss/sss_cal.dat
/neuro/databases/ctc/ct_sparse.fif
2
elektamaxfilter

freesurfer

freesurfer
urlwindows[21]

```
1 https://surfer.nmr.mgh.harvard.edu/fswiki/DownloadAndInstall
```

```
1 tar -C /usr/local -xzvf hoge.tar.gz
```

Mac

unix
.

[21] MicrosoftWSL(Windows Subsystem for Linux)

freesurferSetup & Configuration
.bash_profile
.bashrc

bash

MRI
(subject_dir)

```
export SUBJECTS_DIR=hoge
```

subject_dir

freesurfer
freesurfer

freesurfer

MNE/python()

MNEanaconda
anaconda()

yaml
MNE http://martinos.org/mne/stable/install_mne_python.html
pipenvdockerfile

mne 0.16

MNE http://martinos.org/mne/stable/install_mne_python.html

anaconda

```
$ conda --version && python --version
conda 4.4.10
Python 3.6.4 :: Continuum Analytics, Inc.
```

…

- curl[22]environment.yml
- conda env create -f environment.yml

mne
mne

```
conda activate mne
```

mne[23]

.bashrc.bash_profile

```
conda activate mne
```

…
pythonpython4

python2

```
conda create -n python2 python=2.7 anaconda
```

mne

```
conda activate mne
```

python2

```
conda activate python2
```

```
conda deactivate
```

mac

[22]unix
[23]source activateanacondaconda activate

```
pip install --upgrade pyqt5>=5.10
```

MNE

MNE
MNE

curlenvironment.yml
enviroment.yml

```
name: mne
```

jupyter kernel

jupyterjupyter

```
conda activate mne
```

jupyter

```
ipython kernel install --user --name hoge
```

```
ipython kernelsupec uninstall hoge
```

CUDA

CUDA[24](GPGPU)
CUDAnvidiaGPU

[24] nVidiaGPU

nvidia

.bash_profile.bashrc

```
export LD_PRELOAD='/usr/$LIB/libstdc++.so.6'
export DISPLAY=:0
```

jupyter

```
%gui qt
```

MNE/C

mne-python

MNE-C http://www.nmr.mgh.harvard.edu/martinos/userInfo/data/MNE_register/index.php

MNE-C http://martinos.org/mne/stable/install_mne_c.html

```
tar zxvf MNE-hogehoge
mv MNE-hogehoge MNE-C
cd MNE-C
export MNE_ROOT=/home/fuga/MNE-C
. $MNE_ROOT/bin/mne_setup_sh
```

MNE-C

1-SNS

```

SNSSNS

SNS
twitterMEGMRI

twitter

()
```

freesurfer(MRI)

TLDR;

```
recon-all -i ./hoge.nii -subject () -all -parallel -openmp [CPU_CORE]
```

bash

- cd :
- ls :

MRI
DATA

```
cd DATA
```

freesurfer
hoge.nii

```
recon-all -i ./hoge.nii -subject () -all
```

4

```
recon-all -i ./hoge.nii -subject () -all -parallel
```

-openmp

freesurfer

recon-all(freesurfer)

recon-all
[25]

[25] openMPopenMP

MNEpython
freesurfer
pythonsh[26]

freesurfer

freeview

freeview

()

```
freeview -v <subj>/mri/orig.mgz \
hoge/mri/aparc+aseg.mgz:colormap=lut:opacity=0.4
```

orig.mgz
aparc+aseg.mgz

recon-all

```
asegstats2table --subjects hoge1 hoge2 hoge3 ...\
  --segno hoge1 hoge2 hoge3 ... --tablefile hoge.csv
```

subjectsubject()
segno
$FREESURFER_HOME/FreeSurferColorLUT.txt

hoge.csv

freesurfer

[26] vimmervimshvimvim

freesurfer6.0
python2()
python3

python2

freeview

Tutorials http://freesurfer.net/fswiki/Tutorials

freesurfer

-
  - freeviewrecon-all()
-
  - freeviewrecon-all()
- (controlpoint)
  - freeviewrecon-all()
-
  - recon-all()
- freesurfer
  - freeviewcontrolpointsrecon-all()

freesurfer

SkullStrip

FreesurferSkull Strip
watershedmethod[27]

[27]

brainmask.mgz
Brush value 255Eraser value1Recon editing
shift

```
recon-all  -s <subject>   -autorecon-pial
```

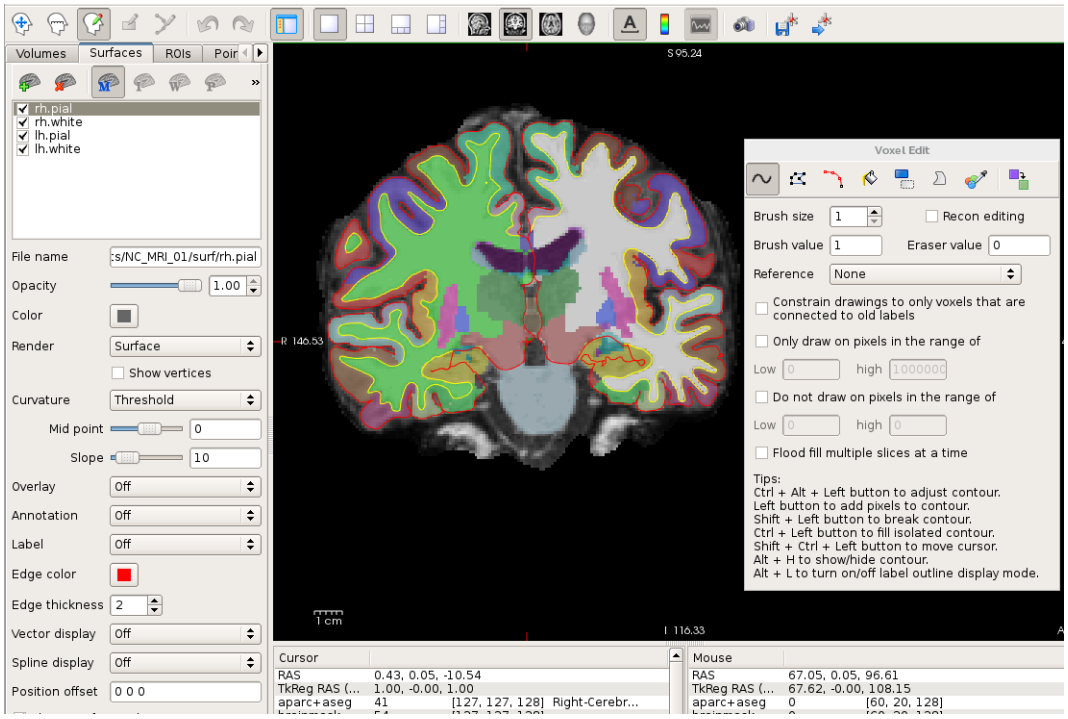


Figure 6: freeview

```
recon-all   -s <subject>  -autorecon2-wm   -autorecon3
```

```
recon-all  -skullstrip  -wsthresh 35  -clean-bm  -no-wsgcaatlas  -s <subj>
```

-wsthreshwatershedmethod
2535

freeview
wm.mgzT1
Brush value 255Eraser value1
Recon editing

```
recon-all -autorecon2-wm -autorecon3 -subjid <hoge>
```

freesurferbrainmask.mgz110

brainmask.mgzrecon-all

File -> New Point Set
Control pointsOK

```
recon-all   -s <subject>   -autorecon2-cp   -autorecon3
```

mricron/crogl(MRI)

mricronUBUNTU

```
sudo apt install mricron
```

MAChttp://www.mccauslandcenter.sc.edu/crnl/mricron/
mricrondcm2nii
MRI

mricrogl
mricron

http://www.mccauslandcenter.sc.edu/mricrogl/

freesurfer/MNE/python
jupyter

mricronMRI

mricronmricroglmri
dcm2nii
mricrondcm2niiguimricroglimport

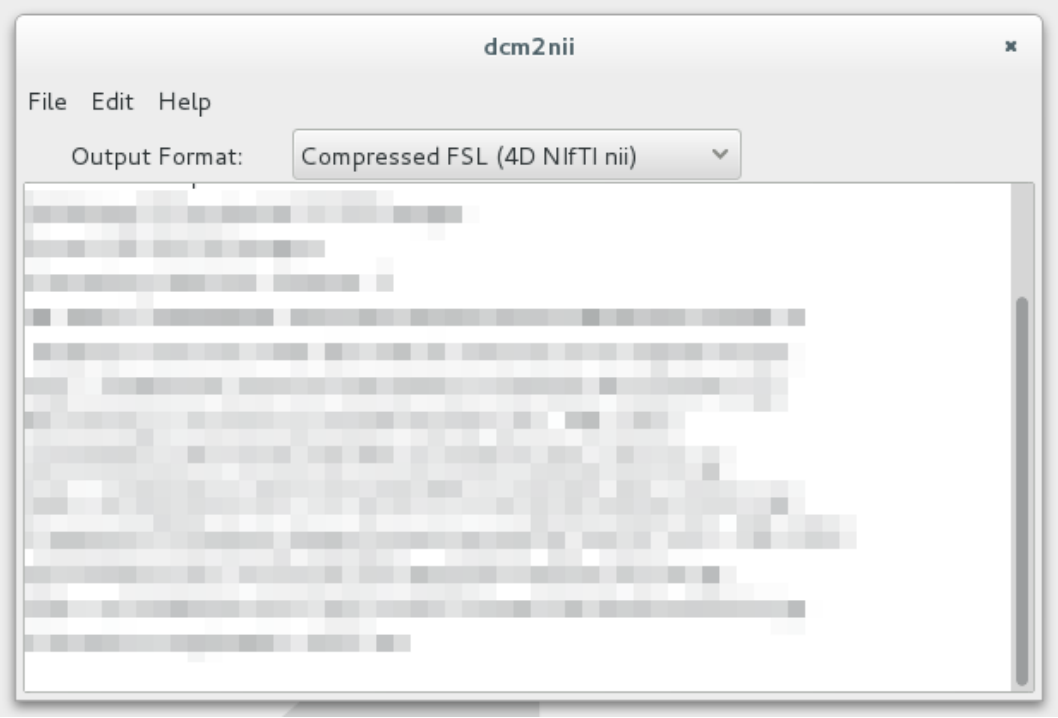


Figure 7: dcm2nii

mricronmri

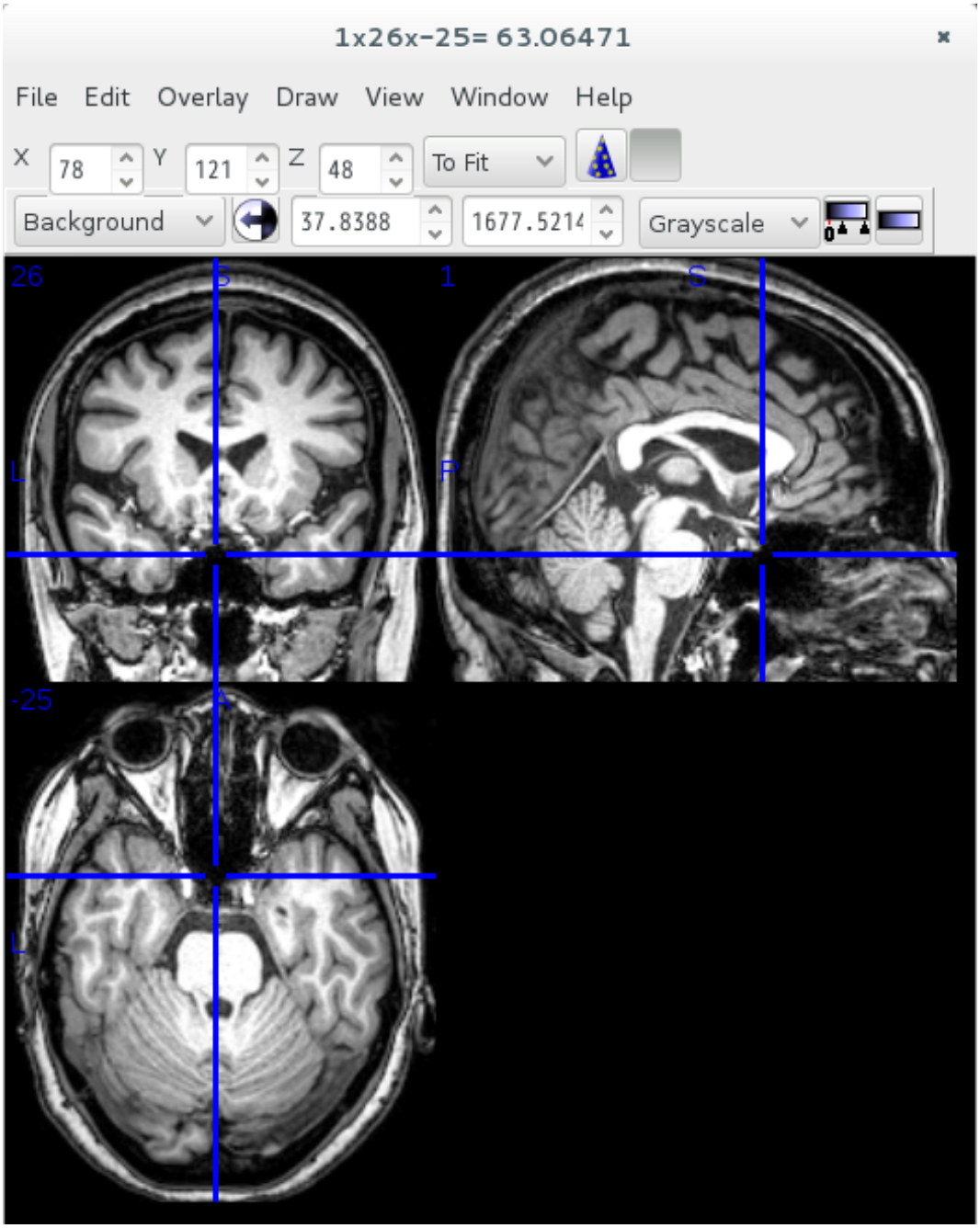


Figure 8: mricron3DMRI

MRIdicomNIFTI
dcm2niiguidicom

3

- hogehoge:nifti
- ohogehoge:
- cohogehoge:

MNE

MNE…
pythonista

http://martinos.org/mne/stable/tutorials.html
http://martinos.org/mne/stable/auto_examples/index.html
http://martinos.org/mne/stable/python_reference.html

notepad.exe
Mac
spyder…
atomvisual studio code
vimmer[28]vim

Jupyter

jupyter

```
jupyter notebook
```

URL
http://localhost:8888

[28]vimvimvim

jupyter
lanjupyter

```
jupyter notebook --ip hoge
```

jupyterctr-c
newpython

MNEpython

pythonnumpy[29]
mne/python

- matplotlib(seaborn)
- pandas(pythonexcel)
  2

pandasscikit-learn
python

Python
http://www.python-izm.com/

python

python

3[30]

- mypy(python)
- pep8(python)

[29] python
[30]

numpy

numpy

…

Python NumPy
http://rest-term.com/archives/2999/

```
import numpy as np
a = np.array([5, 6])
b = np.array([7, 8])
```

1numpynp
ab5, 67, 8

```
print(a+b)
```

```
[12, 14]
```

numpypythonpython

```
a = [5, 6]
b = [7, 8]
print(a + b)
```

```
[5, 6, 7, 8]
```

numpylistlistnumpy.array
numpy.arange

```
import numpy as np
np.arange(5, 13, 2)
```

```
array([5, 7, 9, 11])
```

5132
MNEpython
numpyMNE

warning!

unix
python
python

jupyter

python
jupyteripython

jupyter/ipython

```
%matplotlib inline
%gui qt
```

%matplotlib inlinejupyter
[31]inline
python3

```
%matplotlib qt5
```

python2

```
%matplotlib qt
```

%gui qtmayavi3D
mayavipython3

```
import seaborn as sns
```

matplotlib

[31]

()

MNE

http://martinos.org/mne/stable/auto_tutorials/plot_artifacts_correction_filtering.html

()

-
- (psd)[32]
- notch filterlow pass filter
-

cell()[33]

- mne.io.read_raw_fif:
  preload=True
  preload
  (…)
  Reading raw data

  http://martinos.org/mne/stable/python_reference.html

- mne.read_selection:
- mne.pick_types:
- plot.psd:psd

jupyterspyderipython
tab
raw.tabplot

[32] 1

[33] jupyterjupyter
jupyterMNEjupyterjupyter

cellnotch filter

- notch_filter

  60Hz50Hz[34]
  np.arangenumpy
  6024160
  60Hz

low pass filter

- filter

  ERP
  0.1Hz
  ICA1Hz

- resample
  100Hz23

…MNE…

filter,resample()

python
()

```
raw=mne.io.Raw('hoge',preload=True)     #
raw.filter(1,100)     #0.1~100Hz
raw.notch_filter([60,100])     #60100Hz
raw.resample(sfreq=100)     #100Hz
raw.save('fuga')
```

[34] notchfilter

0
badchannnelinterpolationmaxfilter

- 1
  preloadTrue[35]
- 21Hz100Hz[36]
- 3[37]
- 4
  waveletwavelet23
  resample
- 5’fuga’

plot

…

-
-
-

()

[35] preloadpreloadFalseFalsepreloadFalse
[36] analyzing neural …
[37] notch

```
raw=mne.io.read_raw_edf(filename,preload=True,
       montage='biosemi64',
       eog=['eye-l','eye-r'],exclude=['X1','X2','X3','X4'])
```

…

- filename
- preload
- montage
- eog
- exclude

event

EDFevent
MNEpython
pyedflib

```
pip install pyedflib
```

```
import pyedflib
edf = pyedflib.EdfReader('hoge.edf')
annot = edf.read_annotation()
annot
```

annot(list)
annotannot
211

EDF
EDF+CEDF+DEDF+D
pyedflibEDF+D
open sourceedfbrowser

https://www.teuniz.net/edfbrowser/

windows
toolsEDF+DEDF+C

maclinux
mac

xcodeapp_store
homebrew
gitqt
brew install qt
brew install git

qmake
make

…montagemontage
10-20

MNEpython
10-20

MNEpython

montage
mne.io

raw

```
from mne.channels import read_montage
mont = read_montage('standard_1020')
raw.set_montage(mont)
```

…

raw.set_montage(mont)

```
raw.set_montage(mont, set_dig=True)
```

raw.inforaw.info[“dig”]
dig
set_montagemontage
megmontage
()

```
for n in raw.info['dig']:
    n['r']=n['r']/1000
```

…
MEGmne coreg
mne coreg

MNEpython

montage’Fp1’
’EEG-Fp1’

raw.rename_channels
mne.channels.read_montage

10-20

```
mont = mne.channels.read_montage('standard_1020')
print(mont.ch_names)
mont.plot()
```

```
print(raw.ch_names)
```

python
2

```
channel_list = {
    ”EEG Fp1-Ref”: ”Fp1”, ”EEG Fp2-Ref”: ”Fp2”,
    ”EEG F3-Ref”: ”F3”, ”EEG F4-Ref”: ”F4”,
    ”EEG C3-Ref”: ”C3”, ”EEG C4-Ref”: ”C4”,
    ”EEG P3-Ref”: ”P3”, ”EEG P4-Ref”: ”P4”,
    ”EEG O1-Ref”: ”O1”, ”EEG O2-Ref”: ”O2”,
    ”EEG F7-Ref”: ”F7”, ”EEG F8-Ref”: ”F8”,
    ”EEG T3-Ref”: ”T3”, ”EEG T4-Ref”: ”T4”,
    ”EEG T5-Ref”: ”T5”, ”EEG T6-Ref”: ”T6”,
    ”EEG Fz-Ref”: ”Fz”, ”EEG Cz-Ref”: ”Cz”,
    ”EEG Pz-Ref”: ”Pz”,”EEG A1-Ref”:”A1”,
    ”EEG A2-Ref”:”A2”}
```

```
raw.rename_channels(channel_list)
```

montage

```
mont=mne.channels.read_montage('standard_1020')
raw.set_montage(mont)
```

MNEpython

```
raw = mne.set_eeg_reference(
  raw, ref_channels=['LMASTOID'])[0]
```

```
raw2=mne.set_eeg_reference(raw)[0]
```

[0]list

http://martinos.org/mne/stable/python_reference.html

```
mne.find_events(raw)
```

raw

…pythonista

pandas

```
import pandas as pd
shigeki=pd.read_csv('hoge.csv')
```

```
raw.get_data()
```

numpy

bad channel

1
http://martinos.org/mne/stable/auto_tutorials/plot_artifacts_correction_rejection.html
2

1

raw.plot()
badchannel

```
raw.info['bads'] = ['MEG 2443']
```

badchannel…

2()

```
raw.plot()
```

rawbad

```
raw.save('hoge.fif')
```

python

plotpython

```
input()
```

interpolation

badchannel

```
raw.interpolate_bads()
```

badchannelICA

maxfilter

MNEpythonmaxfilter
MEG
https://mne-tools.github.io/stable/generated/mne.preprocessing.maxwell_filter.html

maxfilter2
2
calibrationdatcrosstalkfif
elekta

MNEmaxfilter
badchannel
elektabadchannel

```
from mne.preprocessing import maxwell_filter
cal = 'hoge.dat'
cross = 'fuga.fif'
raw = maxwell_filter(raw,calibration=cal,
                     cross_talk=cross, st_duration=10)
```

maxwell_filter
calibrationcross_talk
st_duration
MNEpythonst_durationNone

MEGNone
MEG

elekta maxfilter10

st_durationhighpass filter

1/st_duration

st_duration

ICA

2

ICA

[38]

ICA[39]

```
from mne.preprocessing import ICA
from mne.preprocessing import create_eog_epochs, create_ecg_epochs
```

ICA

```
picks_meg = mne.pick_types(raw.info, meg=True,
                           eeg=False, eog=False,
                           stim=False, exclude='bads')
```

ICA()

ICATruebadchannel

```
n_components = 25
method = 'fastica'
decim = 4
random_state = 9
```

n_componentsICA

ICA

25

methodica

API

decimICA

random_state

python

()

ICA

[38] DeepLearningDeepLearningCNNCNNICA

[39] PCA()

()

```
ica = ICA(n_components=n_components,
          method=method, random_state=random_state)
raw = raw.filter(1, 100)
ica.fit(raw, picks=picks_meg, decim=decim,reject = dict( grad=4000e-13))
```

rawICA

ica

jupyter%matplotlib qt
()

```
ica.plot_sources(raw)
```

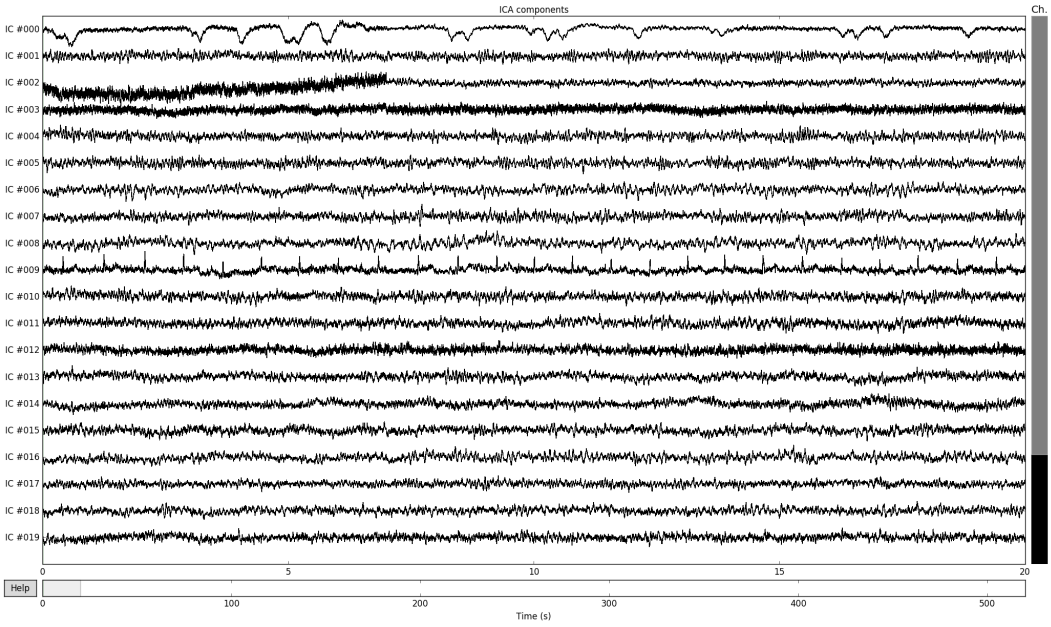


Figure 9: ica

topomap

```
ica.plot_properties(raw, picks=0)
```

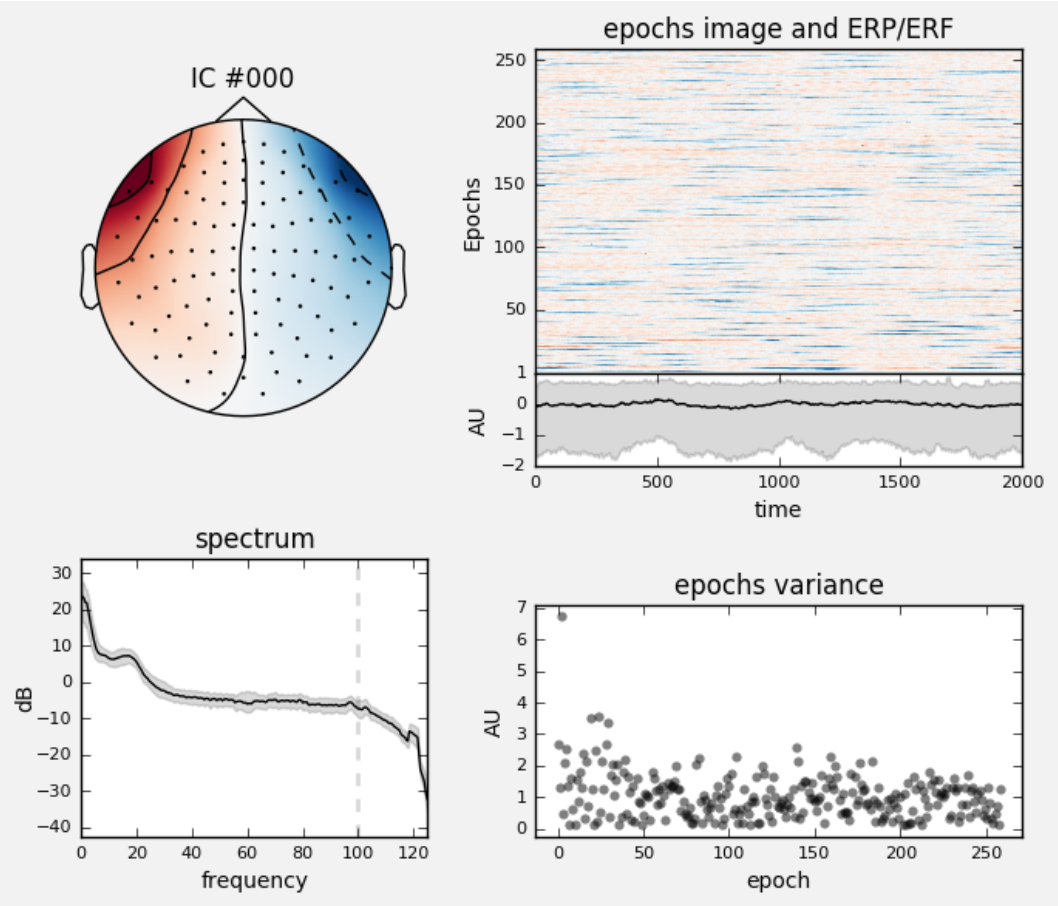


Figure 10: ica propertytopomap

010raw

```
filtered_raw=ica.apply(raw,exclude=[0,10])
```

rawraw…
ica
random_state
random_stateICA
()

ICA

()

2

MNE-python

epoch

```
from mne.preprocessing import create_eog_epochs

eog_epochs = create_eog_epochs(raw, reject=reject)
eog_inds, scores = ica.find_bads_eog(eog_epochs)
```

eog_inds
scores
plot

```
ica.plot_scores(scores, exclude=eog_inds)
```

plot

```
ica.plot_sources(eog_epochs.average(), exclude=eog_inds)
```

```
ica.plot_properties(eog_epochs, picks=eog_inds)
```

```
ica.exclude = eog_inds
ica.apply()
```

ecg

ICA
ICA.fit()

ICA.save

map()

```
from mne.preprocessing import read_ica
ica_paths = ['hoge.fif', 'fuga.fif', 'piyo.fif']
icas = list(map(read_ica, ica_paths))
```

ica
5ica3

```
template = (5, 3)
```

corrmap

```
from mne.preprocessing import corrmap
corrmap(icas, template, threshold='auto', label=None,
    ch_type='eeg', plot=True, show=True,
    verbose=None, outlines='head',
    layout=None, sensors=True, contours=6, cmap=None)
```

- icas:
- template:
- threshold:
  ’auto’’auto’
- label:
- ch_type: eegeegmegmaggrad

corrmapplot=True

labelica
ica.labels_label

```
{'eog': [1], 'ecg': [2]}
```

label’eog’’ecg’corrmap

corrmap

print(ica.labels_)
plot…
sources

```
raw = Raw('hoge.fif')  #
icas[0].plot_sources(raw)
```

label

ica.excludeList

```
from operator import add
from functools reduce

ica.exclude = list(set(reduce(add, ica.labels_.values())))
```

setreduce

python

```
for n in ica.labels_.values():
    if n not in ica.exclude:
        ica.exclude += n
```

plot_sources

ica

HighpassFilter

EpochEvoked

epoch
(raw)

evoked

(raw)

```
events=mne.find_events(raw)
```

events
epochevoked
events

```
221 events found
Events id: [1 2 4 7 8]
Out[205]:
array([[ 15628,      0,      2],
       [ 18053,      0,      2],
       [ 20666,      0,      4],
       [ 23131,      0,      1],
       [ 25597,      0,      8],
```

1, 2, 4, 8
1

```
epochs = mne.Epochs(raw, event_id=[1], events=events)
```

events
event_id[1, 2]
evoked

```
evoked = epochs.average()
```

plot

plot

```
epochs.plot()
```

```
2 evoked.plot()
```

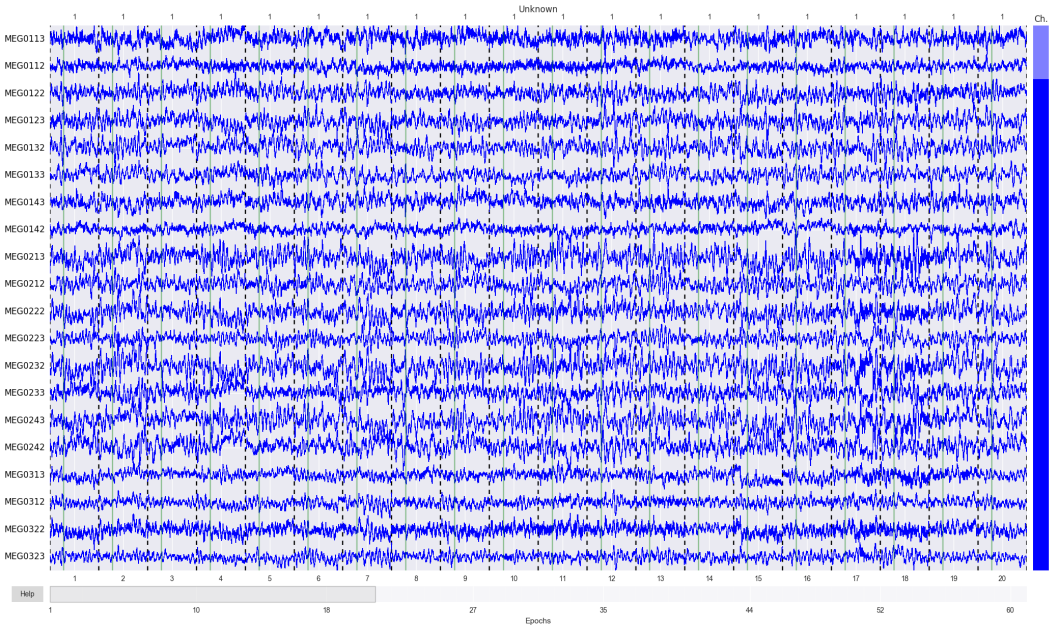


Figure 11: epochs

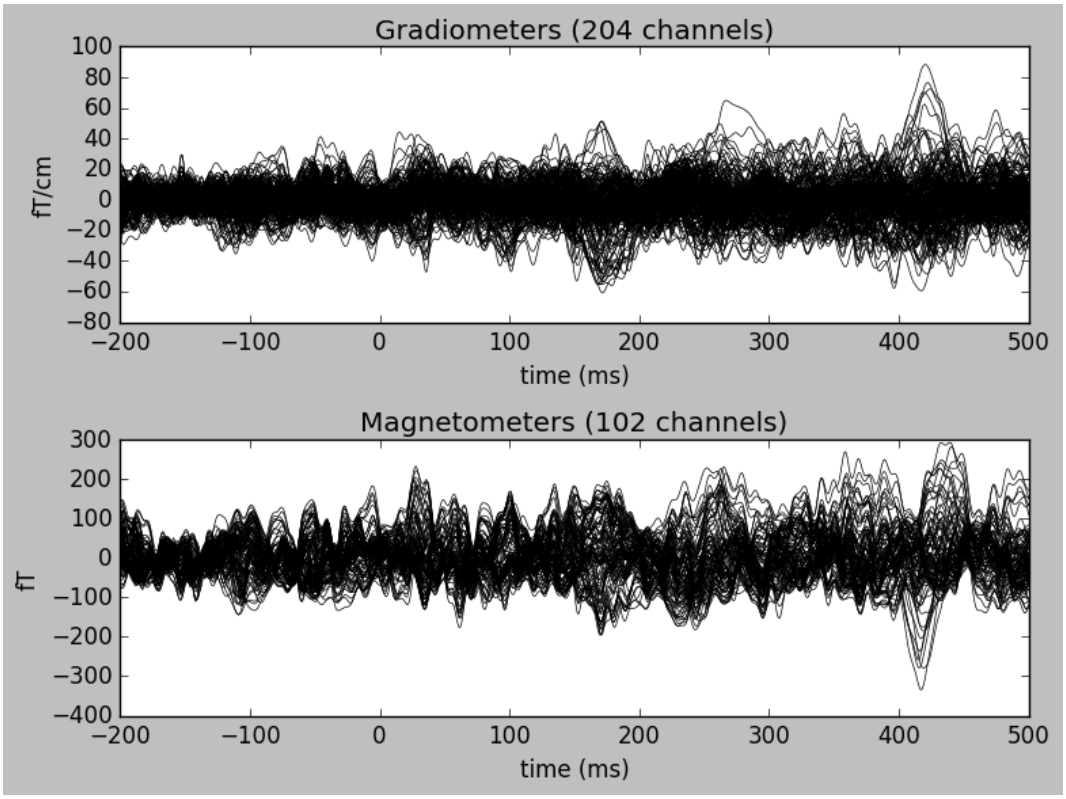


Figure 12: evoked

epochsraw

jupyter

jupyter

jupyterjupyter

```
%matolotlib inline
```

window

```
%matplotlib qt
```

3D

```
%gui qt
```

jupyterjupyter
rawepoch

jupyter
qiita

pysurfer

PySurfer
macubuntu
subjectsubjects_dirfreesurfer
jupyter

```
import surfer
%gui qt
```

```
brain = surfer.Brain(subject, ”lh”, ”inflated”,
subjects_dir=subjects_dir)
brain.add_label(”BA1.thresh”, color=”red”)
```

add_label

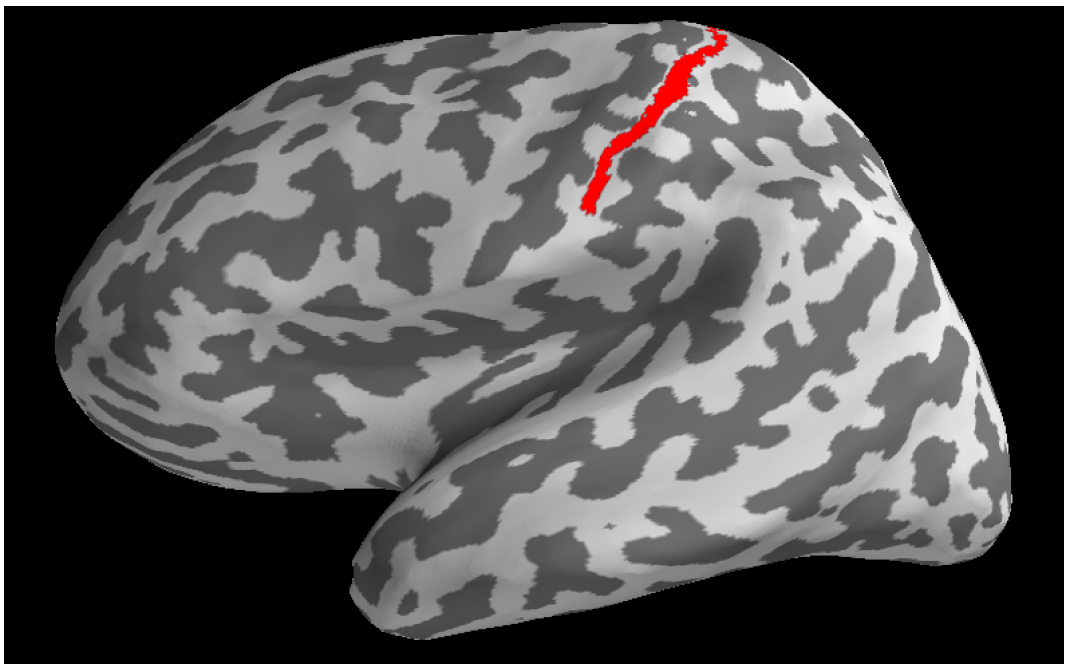


Figure 13: pysurferfreesurfer

labelsubjectlabel
label
annot

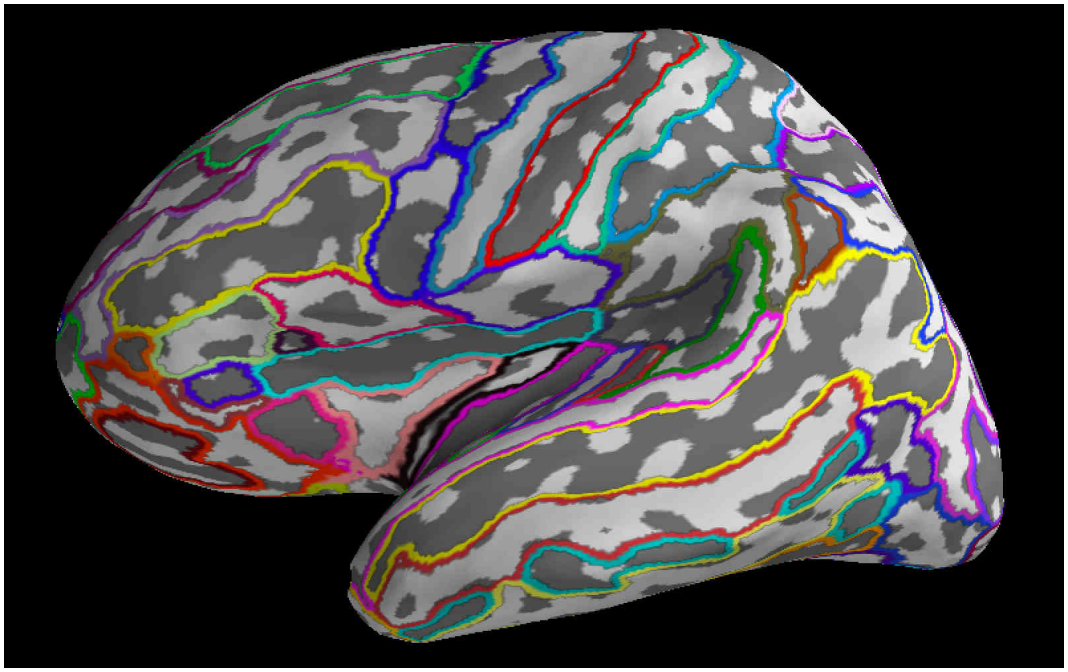


Figure 14: pysurferfreesurferannotation

```
brain = surfer.Brain(subject, ”lh”, ”inflated”,
subjects_dir = subjects_dir)
brain.add_annotation('aparc.a2009s')
```

```
labels = read_labels_from_annot(hoge, 'aparc')
labels = list(filter(lambda x: label_name in x.name, labels))
b.add_label(label)
```

hogeSubject

numpyplot

numpydata
wavelet

```
data_mean = data.mean(axis=0)
```

mne
axis=0

```
import matplotlib.pyplot as plt
def make_and_save_fig(data, fname)-> None:
    fig, ax = plt.addsubplot()
    ax = plt.imshow(data, vmax=0.25, cmap='rainbow')
    ax.set_yticks(np.arange(85, 0, -5))
    ax.set_yticklabels(np.arange(15, 100, 5))
    ax.set_xticks(np.arange(0, 1000, 100))
    ax.set_xticklabels(np.arange(-300, 700, 100))
    ax.invert_yaxis()
    plt.savefig(fname)
    plt.clf()
```

plot
set_yticks
set_yticklabels
15100Hz
5Hz
matplotlibplt
axplt

evoked
numpy
evoked

```
channels = ['Fz', 'FCz', 'FC1', 'FC2',
            'Cz', 'C1', 'C2', 'F1', 'F2']
```

python.index()

.data

1…'Fz'

```
evoked.data[evoked.info['ch_names'].index('Fz')]
```

'Fz'for

```
data = []
for channel in channels:
  wave = evoked.data[evoked.info['ch_names'].index(ch)]
  data.append(wave)
```

wavelet

wavelet

sin

sin

()

wavelet

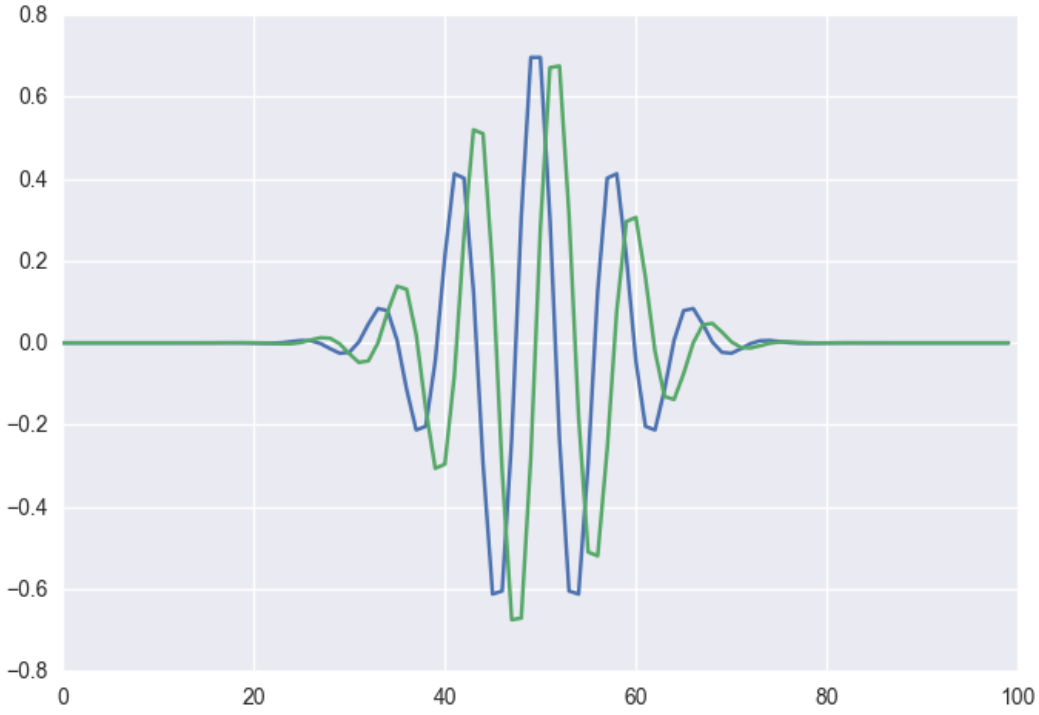


Figure 15: waveletmorlet waveletmorlet

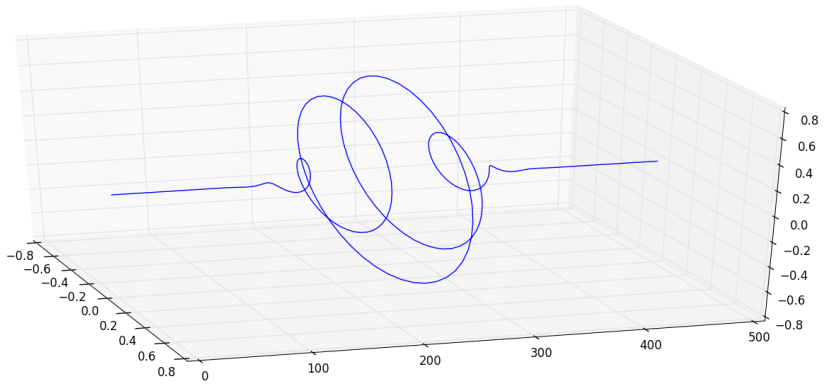


Figure 16: morlet wavelet3d plot

wavelet

()

total power	power
evoked power	power
induced power	evokedpower
phase locking factor	

evoked
induced
total

total powerwavelet

evoked power
induced power

phase locking factor inter-trial coherence(itc)
MNEpythonitc[40]

MNEpythoninduced poweritc[41]

evoked power,induced power,phase locking factor

2MNE

2

[40] phase locking value
[41] itc…

wavelet

morlet

```
freqs=np.arange(30,100,1)
n_cycles = 6
evoked_power=mne.time_frequency.tfr_morlet(evoked,n_jobs=4,
  freqs=freqs,n_cycles=n_cycles, use_fft=True,
  return_itc=False, decim=1)
```

- freqs :
  30Hz100Hz1Hz
- n_cycles : wavelet
  5~7
  MNE
- n_jobs : CPU
  n_jobsn_jobs1
  …
- use_fft : FFTwavelet

  True
- decim :

- return_itc : Truephaselocking factor

evokedepochs
return_itcTrueFalse

return_itc		1	2
False	evoked	evoked_power	
False	epochs	induced_power	
True	epochs	induced_power	phaselocking_factor

itc2

```
freqs=np.arange(30,100,1)
```

```
n_cycles = 6
induced_power,plf=mne.time_frequency.tfr_morlet(epochs,n_jobs=4,
  freqs=freqs,n_cycles=n_cycles, use_fft=True,
  return_itc=False, decim=1)
```

wavelet

wavelet
()

…
MNE
MNE
numpy

MNE(itc, power, evoked, epochs, raw)

data
get_data
powerpower.datarawraw.get_data()
numpy

numpyevoked

```
evoked.data.shape
```

	1	2	3
raw	raw.get_data()		
epochs	epochs.get_data()		
evoked	evoked.data		
itc	itc.data		

		1	2	3
power	power.data			

…
(evoked)

object.save(filename)

raw	mne.io.Raw()	API
epochs	mne.read_epochs()	
evoked	mne.read_evoked()	
itc	mne.time_frequency.read_tfrs()	
power	mne.time_frequency.read_tfrs()	

```
itc=mne.time_frequency.read_tfrs('/home/hoge/piyo')[0]
```

[0]

[0]

mne/python
objectinfopython
print(itc.info)print(itc.info[“ch_names”])
info

numpy

1. poweritc
2. numpy1

3.
4. R

hogefugaHzpiyoHz
foobar(×)

```
itc.data[hoge, huga:piyo, foo:bar]
```

waveletdecim
(×/waveletdecim)
APItime_frequency.tfr_morlet()

2numpymean
import numpy as np

```
np.mean(itc.data[hoge, huga:piyo, foo:bar])
```

3python
4
csv
pandas
numpylistcsv

```
from pandas import DataFrame
DataFrame(hoge).to_csv(filename)
```

jupyterRpadas

Rjupyter
jupyter

```
%load_ext rpy2.ipython
```

```
%%R -i input -o output
hogehoge
```

hogehogeR
pandas

```
from pandas import DataFrame
data = Dataframe(data
                 columns=('group',
                          'hemisphere',
                          'test', 'value'))
```

colums

to_csvjupyterR

```
%%R -i data
result <- aov(
  df$value ~ df$group * df$hemisphere * df$test,
  data=df))
cat(result)
```

RANOVA

pythonscipy

reject

ANOVAaovRANOVA

summary

cat

ANOVA

'+'

ANOVA

R

Connectivity

ConnectivityConnectivity

MRI

MNEpython

3

- multitaper
- fourier
- morlet wavelet

multitaperfourier
morlet waveletwavelet()

wavelet

- Coherence: Coherency
- Coherency:
- ImaginaryCoherence:
- Phase-Locking Value:
- Phase Lag Index:
- Weighted Phase Lag Index: PhaseLagIndex

…(´ω)
…

ImaginaryCoherencePhaseLagIndex

epoch
42

pick_channeldrop_channel

```
epochs.pick_channels(['hoge'])
epochs.drop_channels(['fuga'])
```

```
from mne.connectivity import spectral_connectivity
cons = sc(epochs, method'='coh, indices=None,
          sfreq=500, mode'='multitaper, fmin=35, fmax=45, fskip=0,
          faverage=False, tmin=0, tmax=0.5, mt_bandwidth=None,
          mt_adaptive=False, mt_low_bias=True,
          cwt_frequencies=None, cwt_n_cycles=7,
          block_size=1000, n_jobs=1)
```

…
…
sc…

42

- method: method
- indices: connectivity
- sfreq:
- fmin,fmax:
- fskip:
- faverage:
- tmin,tmax:
- cwt_frequencies: morlet wavelet(numpy)
- cwt_n_cycles: morlet wavelet
- block_size,n_jobs:

method
54

5

5

- con: connectivity numpy

- freqs:

  fouriermultitaper

  morlet waveletcwt_frewuencies
- times:
- n_epochs: epoch
- n_tapers: multitapernull
  DPSS

cons
cons[0]concons[2]times

con
con
0

$$A = \begin{pmatrix} 0 & 0 & 0 \\ 4 & 0 & 0 \\ 6 & 3 & 0 \end{pmatrix}$$

Figure 17:

fourier/multitaper

fouriermultitapermorlet wavelet
con[X X]
X

```
conmat=np.mean(con,axis=(2))
```

conmat

wavelet

morlet waveletfourier
[X X X]4

```
conmat=np.mean(con,axis=(2,3))
```

plot

2
plot

```
mne.viz.plot_connectivity_circle(conmat, epochs.ch_names)
```

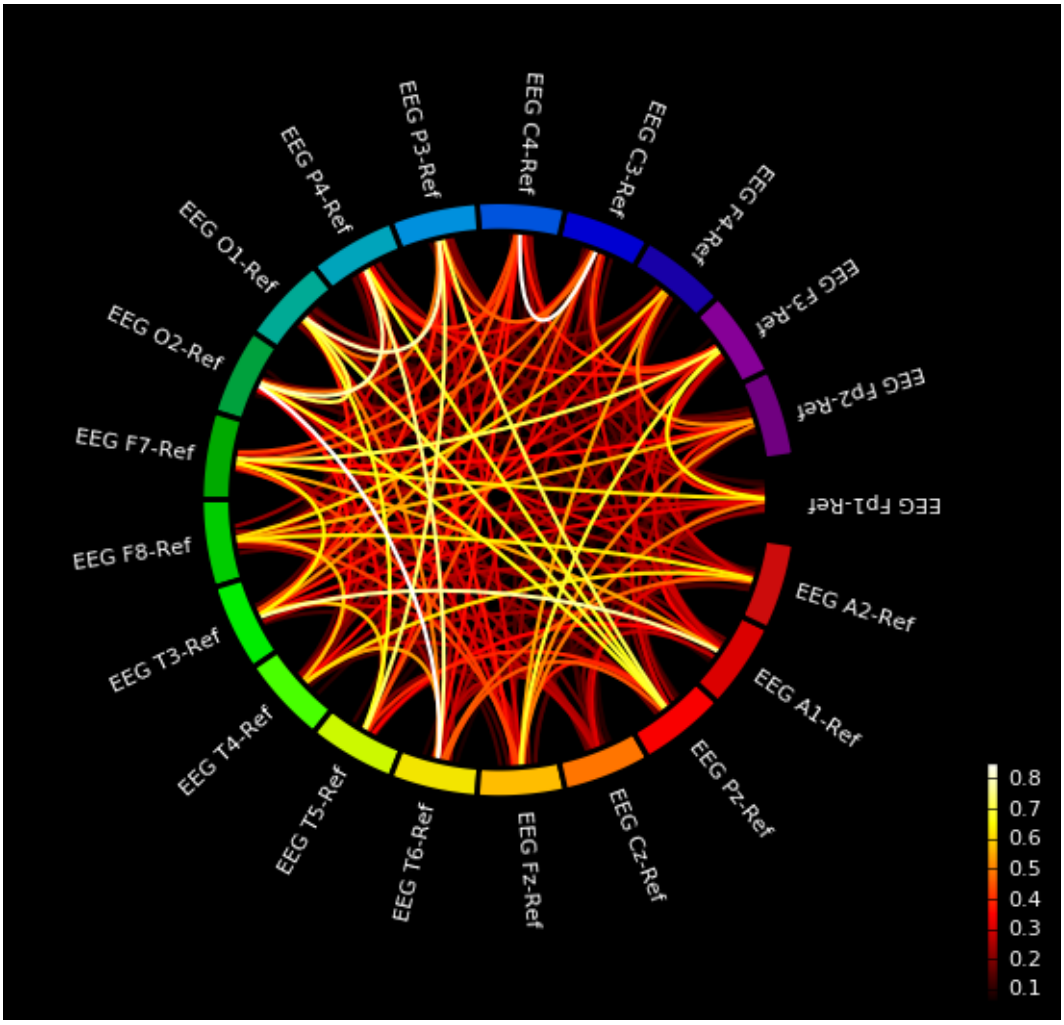


Figure 18:

indices

indicesconnectivity

```
indices = (np.array([0, 0, 0]),
           np.array([2, 3, 4]))
```

numpy1

2

0 → 2 , 0 → 3 , 0 → 4

indices
fourier/multitaper[X]
morlet wavelet[X X]

MEG

MNE/python

MRIMEG
(MRI)

- (MRI)
- (Montage)
-
- (BEM)

MRI
freesurferrecon-all

()

X
Y
$AX = Y$

A
AForwardSolution
$X = A^{-1}Y$X
InverseSolutionA^{-1}
InverseOperator
InverseOperator

1. MRI
   BEM
2.
   (source space)
   ()
3. EEG/MEG
   ()
   trans
4.

   (forward solution)

MNEsLORETAdSPM

1. covariance matrix()
2.
   …(inverse solution)

InverseOperator

3.

- wavelet
- PSDERP
-
-

1trans

GUI

python

```
from mne.gui import coregistration
coregistration()
```

bash

```
mne coreg
```

mne coreg

subjectmegpathGUI
0MRIsubject
subject

python

```
coregistration(subject = subject,
               subjects_dir = subjects_dir,
               inst = file_path)
```

instmeg…rawepoch

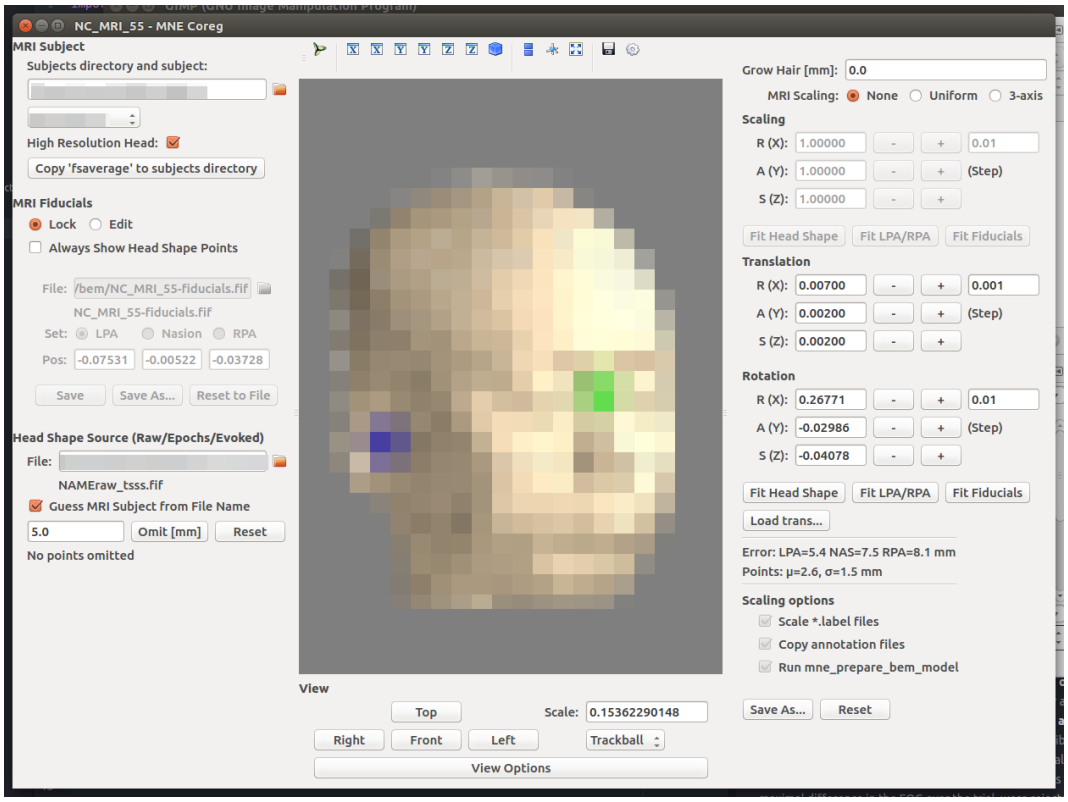


Figure 19: mne coregistration

1. MRIsubject
2. fif
3. set
   (MEG)
4. lock

5. Fit LPA/RPA
6. ±
7. fitsave as

trans

```
from mne import read_trans
trans = read_trans('/Users/hoge/fuga/trans.fif')
```

freesurfersubject

projection

2BEM

MRIBEM
BEM
BEM
3
(
BEMMethod)

freesurfer
freesurferSubject
SUBJECTSUBJECTS_DIR

```
mne watershed_bem -s subject -d subjects_dir
```

freesurferBEM
python

```
from mne.viz import plot_bem
plot_bem(subject=subject,
         subjects_dir=subjects_dir,
         brain_surfaces='white',
         orientation='coronal')
```

BEM

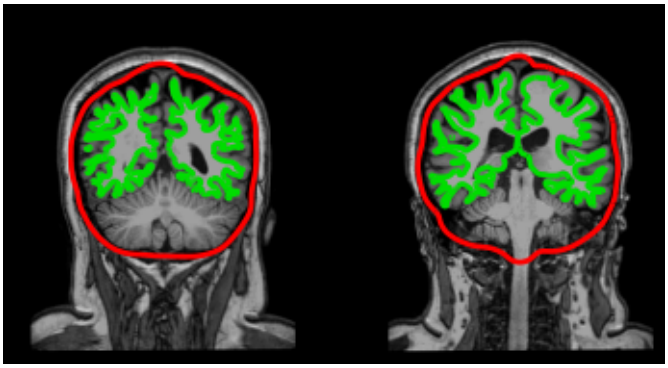


Figure 20: BEM

```
mne coreg
```

gui
’fsaverage→SUBJECTS_DIR’
freesurferfsaverage
subjectfsaverage

3

subjects_dir
bashrcbash_profile

```
from mne import setup_source_space
src = setup_source_space(subject=subject,
                         spacing='oct6',
                         subjects_dir=subjects_dir)
```

fsaverage

src

oct6

http://martinos.org/mne/stable/manual/cookbook.html#setting-up-source-space

’fsaverage’subject
2mne.gui.coregistration()

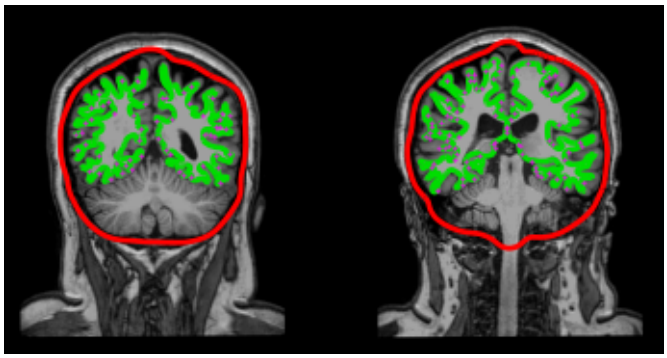


Figure 21:

4

BEM3
EEG3

BEM
MEG

BEM

```
from mne import make_bem_model, make_bem_solution
conductivity = (0.3,)
model = make_bem_model(subject='sample',
                       ico=4,
                       conductivity=conductivity,
                       subjects_dir=subjects_dir)
bem = make_bem_solution(model)
```

BEM
icoico
conductivity
EEG(0.3, 0.006, 0.3)

```
from mne import read_trans, make_forward_solution
trans = read_trans('/hoge/fuga')
mindist = 5
fwd = make_forward_solution(raw.info,
                            trans=trans,
                            src=src,
                            bem=bem,
                            meg=True,
                            eeg=False,
                            mindist=mindist,
                            n_jobs=4)
```

mindistmm
raw.infoepochs.info

5

MNEcovariance matrix

MEG

```
from mne import compute_covariance
cov = compute_raw_covariance(raw_empty_room,
                             tmin=0,
                             tmax=None)
```

```
from mne import compute_covariance
cov = compute_covariance(epochs,
                         tmax=0.,
                         method='auto')
```

method=autoMNE
tmax=0

epochscovariance…auto
auto

6

covariance matrix

```
inverse_operator = make_inverse_operator(epochs.info,
                                         fwd,
                                         cov,
                                         loose=0.2,
                                         depth=0.8)
```

inverse_operator
inverse_operator

epochs.infoinfo
rawevoked

loosedepth

loose

loose01loose1

loose0fixedTrue
fixedTrueMNEpython

depth
MNE

depth
depthNone

limit_depth_chs
True

```
write_inverse_operator('/home/hoge/fuga',
                       inverse_operator)
```

inverse_operator

7

```
from mne.minimum_norm import apply_inverse
source = apply_inverse(evoked, inverse_operator, 1 / 9)
```

evoked

epochsapply_inverse_epochs

rawapply_inverse_raw

```
from mne.minimum_norm import apply_inverse_epochs
source = apply_inverse_epochs(evoked, inverse_operator, 1 / 9)
```

```
from mne.minimum_norm import apply_inverse_raw
source = apply_inverse_raw(evoked, inverse_operator, 1 / 9)
```

epochslist

listSourceEstimate , VectorSourceEstimate , VolSourceEstimate

SourceEstimateBem

```
source[0].plot(time_viewer=True)
```

MNE

time_viewer=True

sourcedata

freesurfer

8

freesurfer

https://surfer.nmr.mgh.harvard.edu/fswiki/CorticalParcellation
desikan atlasDestrieux Atlas

```
ls $SUBJECT_DIR
```

freesurfer
MRI
label
freesurfer

annotlabel
annot
label
annot

```
mne.read_labels_from_annot(subject,
                           annot_fname='hoge')
```

(ry

label
label

```
mne.read_label(filename, subject = None)
```

label

8label

label

```
from mne import extract_label_time_course
source_label = extract_label_time_course(stcs,
                                         labels,
                                         src,
                                         mode='mean_flip')
```

stcsrc
mode
mean: …
mean_flip:
pca_flip: PCA
max:

wavelet

plot

mayavipysurfer
mayavi
pysurferfreesurfermayavi

```
from mne.minimum_norm import apply_inverse_epochs

hoge = 4
source = apply_inverse_epochs(evoked, inverse_operator, 1 / 9)
brain = source[0].plot(subjects_dir=subjects_dir, time_viewer=True)
labels = read_labels_from_annot('fsaverage', subjects_dir=subjects_dir)
brain.add_label(labels[hoge])
```

```
from mayavi import mlab
import surfer

hoge = 4
scene = mlab.figure()
source = apply_inverse(evoked, inverse_operator, 1 / 9)
labels = read_labels_from_annot('fsaverage',
                                subjects_dir=subjects_dir)
b = surfer.Brain('fsaverage',
                 'lh',
```

```
                  'inflated',
                  subjects_dir=subjects_dir,
                  figure=scene)
b.add_label(labels[hoge])
source.plot(subjects_dir=subjects_dir,
                time_viewer=True,
                figure=scene)
```

mayavicanvas

plot…
surfer.Brain
add_labels
plot

movie

scene

save_movie

```
surf = source_estimate.plot(subject['mri'],
                            surface='inflated',
                            hemi='both',
                            figure=scene)
surf.save_movie('hoge.gif')
```

gif

1wavelet

wavelet

induced powerinter trial coherence
label[43]

```
induced_power, itc=source_induced_power(epochs,
                                        inverse_operator,
                                        frequencies,
```

[43] label306MEG10000ROI××ROI×EPOCHwaveletpoweritc…label

```
                                                label,
                                                baseline=(-0.1, 0),
                                                baseline_mode='zscore',
                                                n_cycles=n_cycles,
                                                n_jobs=4)
```

wavelet
zscore
labelfreesurfer
baseline

waveletwavelet

2connectivity

```
from mne.connectivity import spectral_connectivity
con, freqs, times, n_epochs, n_tapers=spectral_connectivity(
             source_label, method='coh', mode='multitaper',
             sfreq=500, fmin=30,
             fmax=50, faverage=True, mt_adaptive=True)
```

5

3-markdown

```


**LaTexmarkdown**
LaTeX

macmactexpandoc
ubuntuwindowsTeXlive
mactexpandoc
brew install pandoc

ubuntu
```

```
sudo apt install texlive-lang-japanese
sudo apt install texlive-xetex
sudo apt install pandoc

pandocmarkdownpdf
Doujinshi.md

pandoc Doujinshi.md -o out.pdf \
-V documentclass=ltjarticle --toc --latex-engine=lualatex\
-V geometry:margin=1in -f markdown+hard_line_breaks --listings


```{frame=single}

PDF
```

[44]

()

…αβγ

-
-

[44]
```

- ()
-
-

3

-
- Wavelet
-

sincos
sin,cos

$Acosx + Bsinx$

$Acosx + Bisinx$
(!?)

ShortTime

sincos

ShortTime

(Taper)

Wavelet

sincos

[45]

Wavelet

wavelet
wavelet

$1/x$

$$f(x) = a_0 + \sum_{k=1}^{\infty}(a_n \cos\frac{2\pi nt}{T} + b_n \sin\frac{2\pi nt}{T})$$

…

- $f(x)$:
- a_0:
- t:
- n:

[45]

- T:()
- :

$\sum$

nab
ab

$$r(cos\theta + isin\theta)$$

()

$$e^{i\theta} = cos\theta + isin\theta$$

[46]

sincosei

$$cos\theta = \frac{e^{i\theta} + e^{-i\theta}}{2}$$

[46] θ1

sincos

$$f(x) = \sum_{n=-\infty}^{\infty} C_n e^{i\pi t/T}$$

Cna,b

$f(x)e^{i\pi t/T}$...1

Cn
Cn

$$C_n = \frac{1}{T}\int_{-T/2}^{T/2} x(t)e^{-2\pi nt/T}$$

$f(x)$
1

plot
i
…
python3e^i

python3

47

FFT
wavelet

47

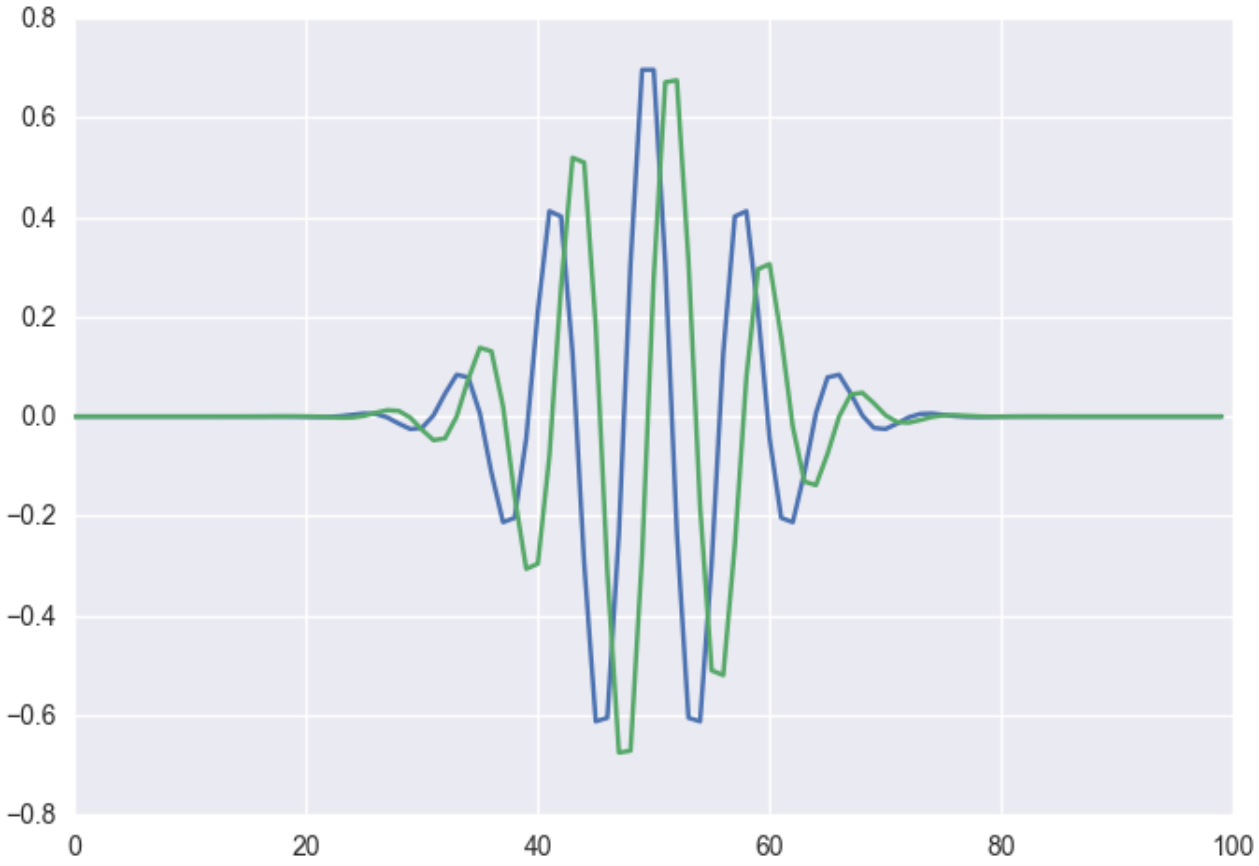


Figure 22: Morlet Wavelet2D

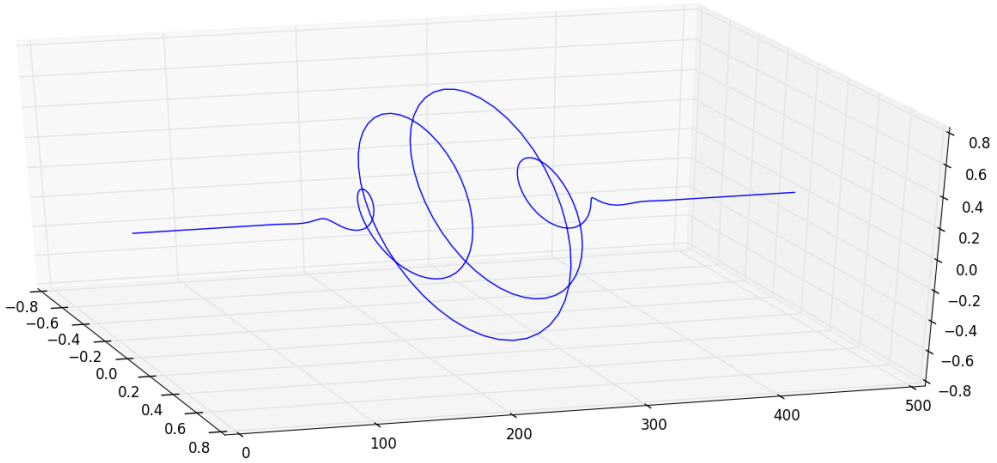


Figure 23: 3D

$= 1 + 2 + 3...$

$= *$

$A + Bi \ (r, \theta)$

()

()
()

$f(\omega)$()

(PSD)

PhaseLockingFactorInterTrialCoherence
PLFITC()

PhaseLockingValue
PLV(PLV)

$A + iB$
$ (A + iB)(A - iB) $

0

Sxx (xx)
Sxy (xy)

wavelet

Power

Power
sincos

wavelet

Gabor Wavelet

$$c\sigma\pi^{\frac{-1}{4}}e\frac{-1}{2}t^2e^{i\sigma t}$$

Gabor Wavelet

1

(0)
Wavelet

MorletWavelet

$$c\sigma\pi^{\frac{-1}{4}}e\frac{-1}{2}t^2(e^{i\sigma t}-\kappa\sigma)$$

$\kappa\sigma$

Wavelet
Power

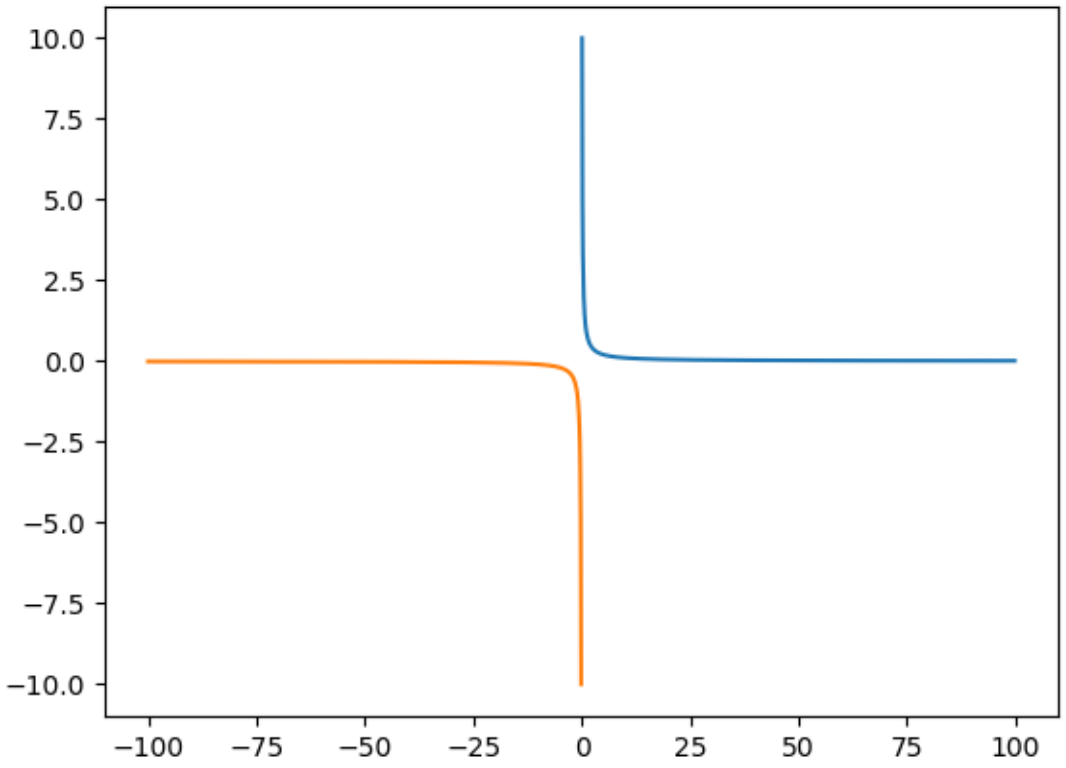
waveletbandpass filter

wavelet
bandpass filter
Wavelet
Wavelet
GaborMorlet
Wavelet
Waveletbandpass filter

bandpass filter

wavelet1

Wavelet



wavelet

…

$f(t)\hat{f}(w)$tw

$$\hat{f}(w) = \int_{-\infty}^{\infty} f(t) e^{-iwt} dt$$

$-\infty$ ~ ∞

```
1
2   * → *
```

$$f(t) = \int_{-\infty}^{\infty} \hat{f}(w) e^{iwt} dw$$

```
1
2   * → *
```

$$f(t) = \sum_{n=-\infty}^{\infty} C_n e^{iwt}$$

$\int \Sigma f(\hat{w}) C_n$
n$-\infty$ ~ ∞
C_n

C_n

$f(\hat{w}) w - \infty$ ~ ∞()
$\hat{f}(w) \hat{f}(-w)$

$$\hat{f}(w) = \overline{\hat{f}(-w)}$$

$\widehat{f}(w)a(\cos\theta + i\sin\theta)$

$$\widehat{f}(w) + \overline{\widehat{f}(-w)} = a(\cos\theta + i\sin\theta) + a(cos\theta - isin\theta)$$

$$\widehat{f}(w) + \overline{\widehat{f}(-w)} = 2a\cos\theta$$

cos

sin

$$\widehat{f}(w) - \overline{\widehat{f}(-w)} = 2ai\sin\theta$$

sinsgn
sgnsgn(x)x1-1sin

$$sgn(w)\widehat{f}(w)$$

$\widehat{f}(w)$
-i
$\ldots H(t)$

$$H(t) = \int_{-\infty}^{\infty} -isgn(w)\hat{f}(w)e^{iwt}dw$$

sgn$-i\pi/t$
()

F

$$F(a * b) = F(a)F(b)$$

a*b

$$F(a * b) = \int_{-\infty}^{\infty} a(x)b(t-x)dx$$

$$F(H(t)) = sgn(w)\hat{f}(w) = -isgn(w)F(f(t))$$

sgnG

$$= F(G)F(f(t)) = F(G * f())$$

$$H(t) = G * f(t)$$

G1/t

$$H(t) = 1/t * f(t)$$

method

method

γ

PLVCoherence

PLV

$$PLV = |\frac{\overline{Sxy}}{|Sxy|}|$$

2()

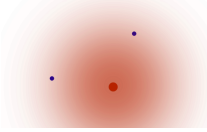


Figure 24: PLV

PLVCoherence

PLV

$$Coherence = \frac{\overline{|Sxy|}}{\sqrt{\overline{|Sxx|} * \overline{|Syy|}}}$$

CoherenceCoherency

$$Coherence = \frac{\overline{Sxy}}{\sqrt{\overline{|Sxx|} * \overline{|Syy|}}}$$

…

PLVCoherence

2

-
-

…
MNEsLORETAdSPM

CurrentSourceDensity

PLV
MNEpython

PLV

MNEpythonPLIWPLI

PLI PhaseLagIndex

MNEspectral_connectivity

$$PLI = \overline{|sign(Im(Sxy))|}$$

sign1001
Im
x
0

…
ConnectivityPlot

WPLI 11
WeightedPhaseLagIndex
$\pi/2$
$-\pi/2$
…
PLI1-1

$$WPLI = \frac{|\overline{Sxy}|}{\overline{|Sxy|}}$$

…
…

Coherence

PLI

ImaginaryCoherence

Coherence

$\pi/2$

$$Coherence = \frac{\overline{Im(Sxy)}}{\sqrt{\overline{|Sxx|} * \overline{|Syy|}}}$$

……

MNE

https://qiita.com/uesseu/items/750c236bfa706c361b3b

MNE

MNE

(…)

…

…

…

yx

$$y = ax$$

11

y,a,x

$$Y = y_1, y_2, y_3.....$$

$$X = x_1, x_2, x_3.....$$

A

$$Y = AX$$

…

MinimumNormEstimation(MNE)
(beamformer)
…

$Y = AXX$[48]
X

$$||X||^2$$

[49]

$f(x, y)$x,y

$$L(x, y, \lambda) = f(x, y) - \lambda g(x, y)$$

$$\frac{\partial L}{\partial \lambda} = \frac{\partial L}{\partial y} = \frac{\partial L}{\partial x} = 0$$

$$\frac{\partial g}{\partial x} = \frac{\partial g}{\partial y}$$

…

[48]
[49]

$$\frac{\partial a^t x}{\partial x} = a$$

$$\frac{\partial x^t a}{\partial x} = a$$

$$L = ||X||^2 - \lambda||Y - AX||^2$$

$$L = X^T X - \lambda(Y - AX)^T(Y - AX)$$

$$= X^T X - \lambda(Y^T - X^T A^T)(Y - AX)$$

$$= X^T X - \lambda(Y^T Y - X^T A^T Y - Y^T AX + X^T A^T AX)$$

$$\frac{\partial L}{\partial X} = 2X - \lambda(-A^T Y - A^T Y + (A^T A + A^T A)X)$$

$$= 2\lambda(A^T Y - A^T AX + \frac{X}{\lambda})$$

0

$$(A^T A - \frac{I}{\lambda})X = A^T Y$$

$$X = (A^T A - \frac{I}{\lambda})^{-1} A^T Y$$

$\frac{I}{\lambda}$C

$$X = (A^T A - CI)^{-1} A^T Y$$

XAY

0

0

covariance matrix

$$||X||^2$$

C

$$X^T C X$$

C0

I

$$L = X^T C X - \lambda ||Y - AX||^2$$

$$L = X^T C X - \lambda (Y - AX)^T (Y - AX)$$

$$= X^T C X - \lambda (Y^T - X^T A^T)(Y - AX)$$

$$= X^T C X - \lambda (Y^T Y - X^T A^T Y - Y^T A X + X^T A^T A X)$$

$$\frac{\partial L}{\partial X} = (C + C^T)X - \lambda(-A^T Y - A^T Y + (A^T A + A^T A)X)$$

$$= 2\lambda(A^T Y - A^T A X + \frac{(C + C^T)X}{2\lambda})$$

$$= 2\lambda(A^T Y - A^T A X + \frac{CX}{\lambda})$$

$$= 2\lambda(A^T Y - (A^T A + \frac{C}{\lambda})X)$$

0

$$(A^T A + \frac{C}{\lambda})X = A^T Y$$

$$(\lambda A^T A + C)X = \lambda A^T Y$$

$$X = \lambda(\lambda A^T A + C)^{-1} A^T Y$$

MNE

MAP

MAP

dSPMsLORETA

...MNE

$$Y = AX$$

MNE

$$X = A^{\dagger} Y$$

$A^{\dagger}$1
$A^{\dagger}$1

$A^{\dagger}$1

$$X' = \frac{A^\dagger Y}{||A^\dagger||}$$

$$X' = \frac{A^\dagger Y}{\sqrt{A^\dagger C {A^\dagger}^T}}$$

1
MNEdSPM
dSPM

1

sLORETAdSPM

$$X' = \frac{A^\dagger Y}{\sqrt{A^\dagger}}$$

(´ω)

> ab
>

xy

$2x + 4y = a$
$x + y = b$

2
()

$$\begin{pmatrix} 2 & 4 \\ 1 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} a \\ b \end{pmatrix}$$

numpy

$$A = \begin{pmatrix} 2 & 4 \\ 1 & 1 \end{pmatrix}$$

$$X = \begin{pmatrix} x \\ y \end{pmatrix}$$

$$Y = \begin{pmatrix} a \\ b \end{pmatrix}$$

$$AX = Y$$

$$X = A^{-1}Y$$

X

!numpy

pythonimport

()

```
from numpy import linalg, array
A = [[2, 4], [1, 1]]  #
At = linalg.inv(A) #
Y = array([10, 3]) # 103
```

```
At @ Y  #
>array([1., 2.])
```

12

```
linalg.solve(A, Y)
```

()

$$\begin{pmatrix} 2 & 4 & 6 \\ 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} a \\ b \end{pmatrix}$$

yxz
(´ω)

…
()

```
from numpy import linalg, array
A = array([[2, 4, 6], [1, 1, 1], [0, 2, 4]])
At = linalg.inv(A)
> LinAlgError: Singular matrix
```

7
3

```
from numpy import linalg, array
A = array([[2, 4, 6], [1, 1, 1], [0, 0, 7]])
At = linalg.inv(A)
Y = array([10, 3, 7])
At @ Y

>array([ 2., -0.,  1.])
```

()
X()

```
from numpy import linalg, array
A = [[2, 4, 6], [1, 1, 1]]  #
At = linalg.pinv(A)  #
Y = array([10, 3])  # 103
At @ Y  #

>array([1.5, 1. , 0.5])
```

/

python

MNEpythonGPGPU
numpy

formap

pythonforfor…
MNE

python

```
n = [i + 4 for i in range(5)]
```

[4, 5, 6, 7, 8]

map
map

```
def plus4(num: int) -> int:
    return num + 4

n = list(map(plus4, range(5))
```

…

deflambda

```
n = list(map(lambda x: x + 4, range(5))
```

numpy()

numpy
mapnumpy

()

python
Pool

```
from multiprocessing import Pool
```

pythonmap

(poolmaplambda)

```
def test(i):
    return i * 8
```

withPool

```
with Pool(4) as p:
  result = p.map(test, [1, 2, 3, 4])
print(result)
```

test

()

map_async
map_asyncmap
mapmap_async

```
with Pool(4) as p:
  result = p.map(test, [1, 2, 3, 4]).get()
print(result)
```

mapp.map_async(hoge).get()
get

mapmap_async1
starmap
starmapstarmap_asyncasync

```
from multiprocessing import Pool

def test(x, y): return x + y

```

```
with Pool(4) as p:
    result=p.map_async(test, [(1, 2), (4, 6)]).get()
print(result)
```

graph

graph

```
pip install bctpy
```

bctpy

```
import bct
```

conmatnumpy

()

```
dcon = conmat + conmat.T
```

global efficiency

```
bct.efficiency_wei(dcon)
```

- Analyzing Neural Time Series Data:Theory and Practice

  amazon
  MNE-Python

- —
-
-
  MNE

  ()
-

- Electromagnetic Brain Imaging: A Bayesian Perspective 2015

  MNE, beamformer, dSPM, sLORETA

- DeepLearning
  4

  chainertensorflow

- ()

http://mathtrain.jp

https://www.slideshare.net/ryosuketachibana12/ss-42388444

SNS

qiita http://qiita.com
SNS…

twitter http://twitter.com
twitter

github https://github.com
SNS
qiitagithub
gitweb
octocat

- git

git

- source tree
  git
  gitGUI
  gitgit
  github desktopgit kraken
- pandoc
  markdown
  markdown
  wordLaTeXPDFHTML
  markdown
  (LaTeX…)
  JupyterGithubmarkdown

(…)

- Gramfort, M. Luessi, E. Larson, D. Engemann, D. Strohmeier, C. Brodbeck, R. Goj, M. Jas, T. Brooks, L. Parkkonen, M. Hämäläinen, MEG and EEG data analysis with MNE-Python, Frontiers in Neuroscience, Volume 7, 2013, ISSN 1662-453X
- Margherita Lai, Matteo Demuru, Arjan Hillebrand, Matteo Fraschini, A Comparison Between Scalp- And Source-Reconstructed EEG Networks
- Gramfort, M. Luessi, E. Larson, D. Engemann, D. Strohmeier, C. Brodbeck, L. Parkkonen, M. Hämäläinen, MNE software for processing MEG and EEG data, NeuroImage, Volume 86, 1 February 2014, Pages 446-460, ISSN 1053-8119
- https://surfer.nmr.mgh.harvard.edu/fswiki/FreeSurferWiki

MNEpython

object

MNEpythonraw

```
from mne.io import Raw
Raw('hoge.fif').filter(1,100).notch_filter(60).save('fuga.fif')
```

2

rawraw.filterraw

rawraw

raw.copy

```
raw2 = raw.copy()
```

rawcopy
raw2, raw3, raw4raw∞

```
filtered = raw.copy().filter(1,100).notch_filter(60)
```

raw2

MNEAPI

MNEmethod

python

```
from functools import partial
```

epoch
event_id123456

```
from mne.io import Raw
from mne.epochs import Epochs
from mne import find_events

raw = Raw('hoge.fif', preload=True)
events = find_events(raw)
make_my_epochs = partial(Epochs, raw, events)
```

make_my_epochs

```
make_my_epochs(4)
```

event_id4epoch

epoching

```
from mne.io import Raw
from mne import Epochs
raw = Raw('hoge').interpolate_bads().filter(1, 100).notch_filter(60)
make_epochs = partial(Epochs,
                      raw, mne.find_events(raw),
                      tmin=-0.2, tmax=5.0)
epochs = [make_epochs(n) for n in range(1,7)]
```

ICA

filter

epochsraw
()
for
os.pathexists[50]
filterlambda[51]

filterlisttuple

filter(, list)
raw

```
from os.path import exists

file_list = ['hoge', 'fuga', 'piyo']
fnames = list(filter(lambda fname: exists(fname), file_list))
```

epochsfilename

mapreduce
MNE

mapfilter
list

file

```
from pathlib import Path
path = Path(epochs.filename).parent
dirname = str(path)
```

…
…

[50] bool
[51]