

Who's who?

Benchmarking offline BCI pipelines in BCI with MOABB

Sylvain Chevallier
Inria TAU team, LISN, Université Paris-Saclay, France
sylvain.chevallier@universite-paris-saclay.fr

W5: Offline and online tools for real-world BCI applications



7 June 2023

Reproducible research in BCI built on a rich Python ecosystem
to design FAIR benchmarks with the help of a community

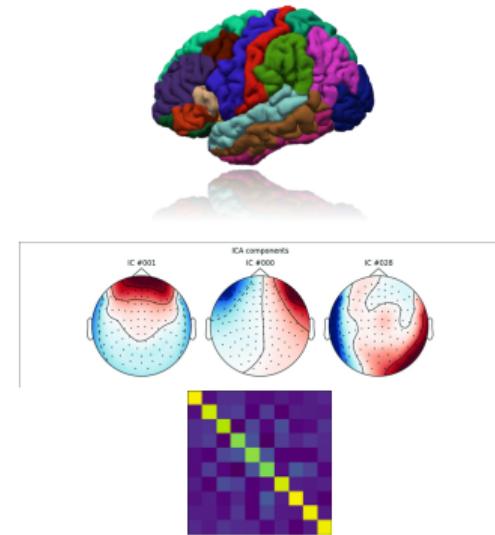
Why open source matters

Reproducibility issues

Freesurfer Popular software for extracting features from MRI
→ Software variation lead to different conclusions

ICA Popular matrix factorization problem
→ Different results with different machines

eigs/eigsh Popular solver for eigenvalues decomposition
→ Solvers can lead to different outcome



Neurophysiological analysis is complex, require advanced processing
⇒ **Need for collective efforts to build open science**

Why do we need MOABB?

Reproducible research in BCI has a long way to go...

- Unavailable code
- Exotic data format/language/toolboxes
- Preprocessed data (including errors)

No comprehensive benchmark of BCI algorithms

Huge waste of time for everyone

⇒ **MOABB aims to be the standard benchmark for any new paper**

- Comprehensive benchmark of popular BCI algorithms
- Extensive list of freely available EEG datasets
- Ranking algorithms with fair evaluations

Reproducible research in BCI **built on a rich Python ecosystem**
to design FAIR benchmarks with the help of a community

MNE

<https://github.com/mne-tools/mne-python>

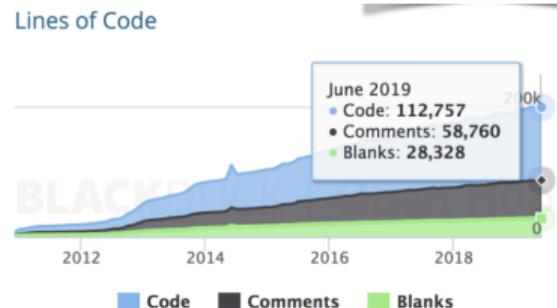
History

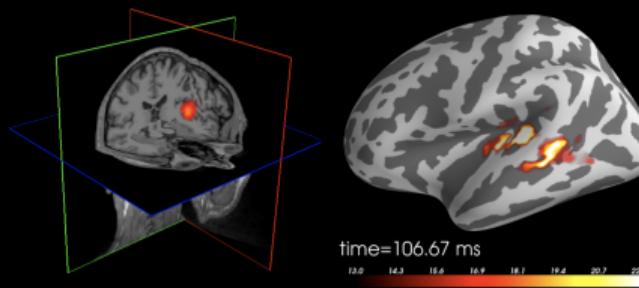
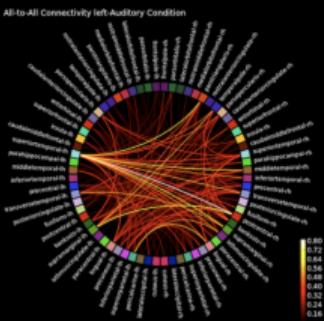
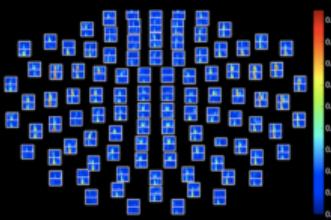
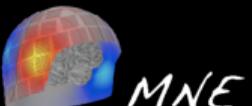
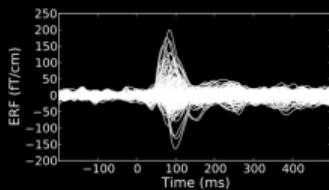
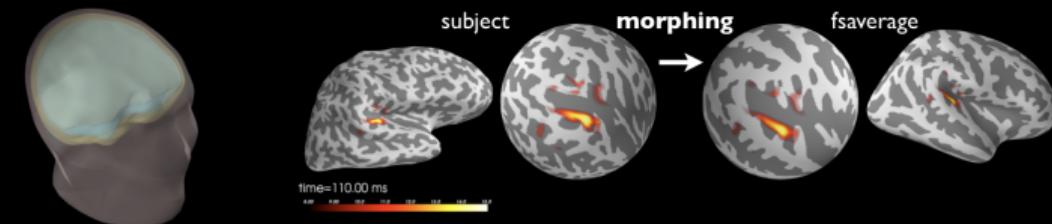
- based on C code developed for 18 years by Matti Hämäläinen
- Python started in 2010 at MGH, Boston

In a nutshell

- 236 contributors, 100k LOC
- mature codebase, large dev team
- ~ 29 years of efforts (COCOMO)

⇒ BSD licensed (commercial use ok)
⇒ Mac / Linux / Windows





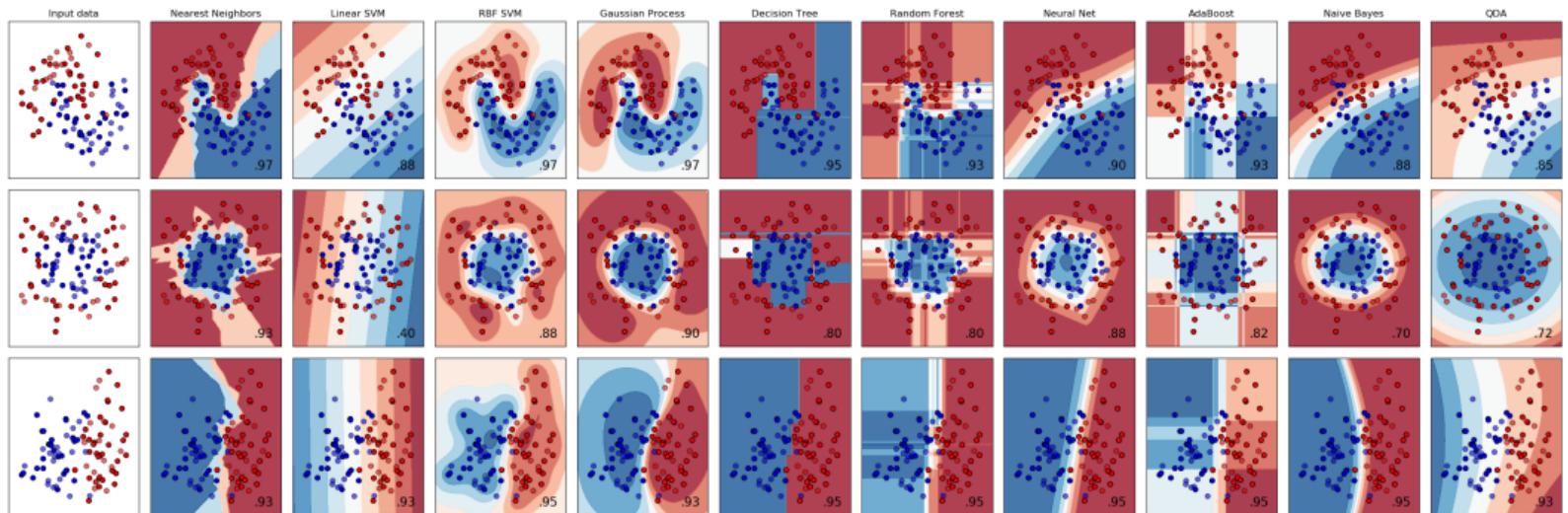
Scikit-learn – accessible machine learning

<http://scikit-learn.org>

- **Machine learning for all**
⇒ No specific application domain
⇒ No requirements in machine learning
- **High-quality Pythonic software library**
⇒ Interfaces designed for users
- **Community-driven development**
⇒ BSD licensed, very diverse contributors

Easy as py:

```
from sklearn import svm
classifier = svm.SVC()
classifier.fit(X_train, Y_train)
Y_test = classifier.predict(X_test)
```



PyRiemann – Riemannian ML for All !

<https://pyriemann.readthedocs.io>

- **Scikit-learn compatible**

⇒ High-level interface

⇒ Wide machine learning models

- **Multivariate time series**

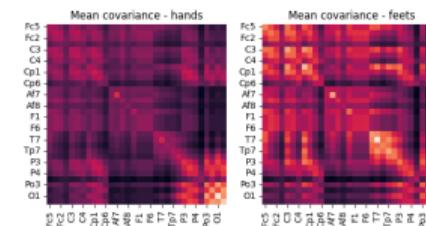
⇒ Biosignals: MEG, EEG, EMG

⇒ Radar, sensor networks, ...

- **Batteries included**

⇒ Preprocessing, transfer learning

⇒ Documentation, examples

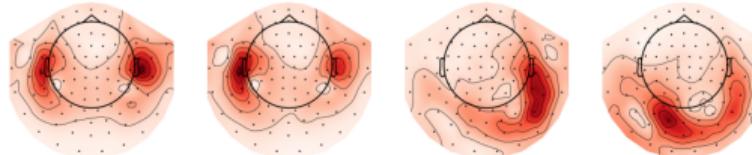


Pattern 0

Pattern 3

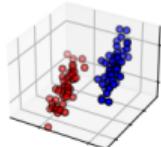
Pattern 6

Pattern 9

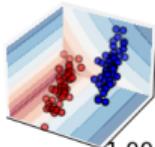


Compare classifiers with metric='riemann'

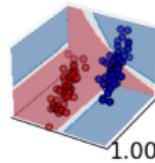
Input data



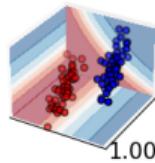
MDM



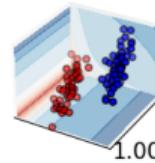
k-NN



SVC



MeanField

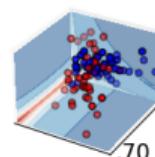
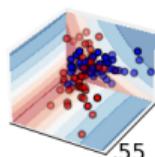
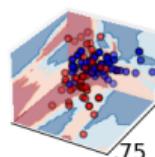
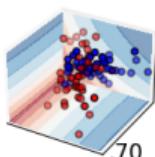
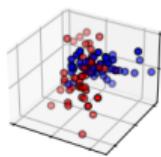


1.00

1.00

1.00

1.00

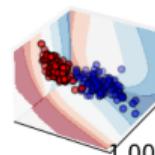
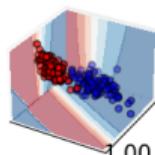
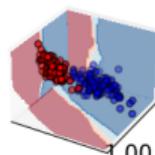
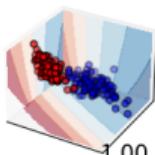
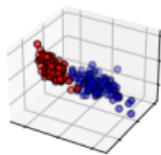


.70

.75

.55

.70

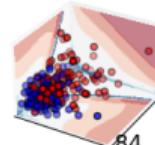
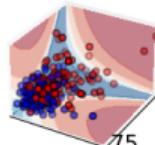
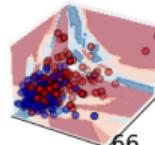
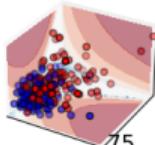
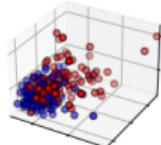


1.00

1.00

1.00

1.00



.75

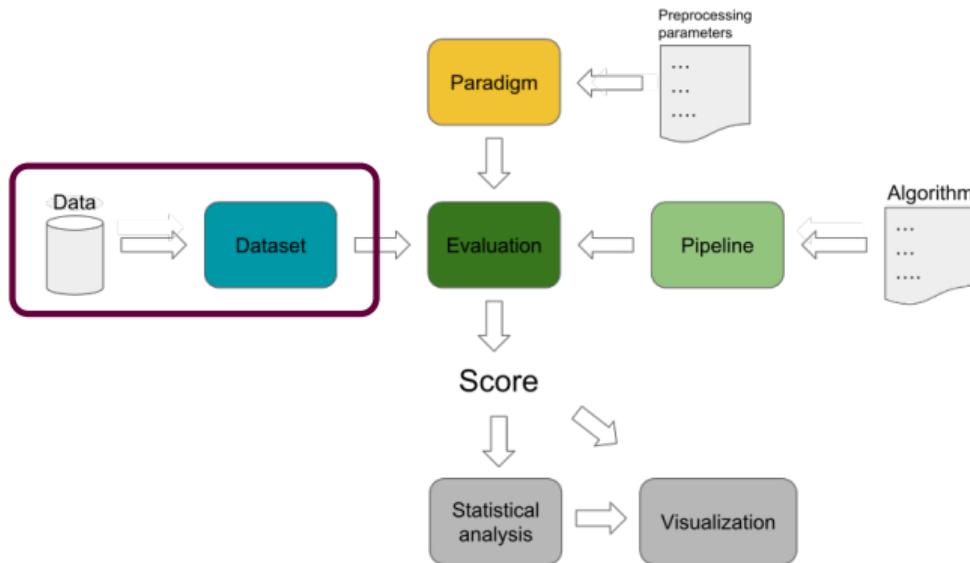
.66

.75

.84

Reproducible research in BCI built on a rich Python ecosystem
to design FAIR benchmarks with the help of a community

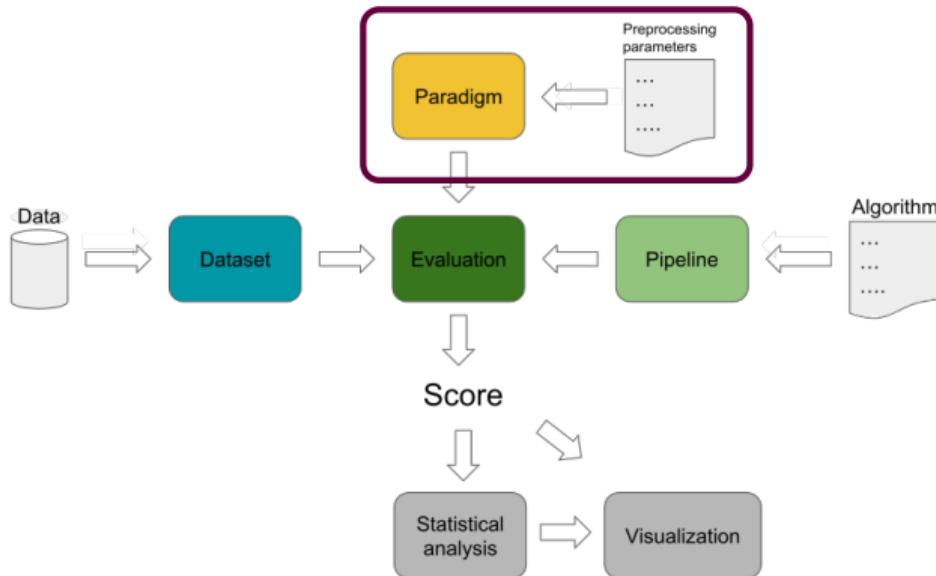
MOABB Architecture: Datasets



Dataset

- Stored locally, converted in MNE format
- Pick only subjects/sessions you need

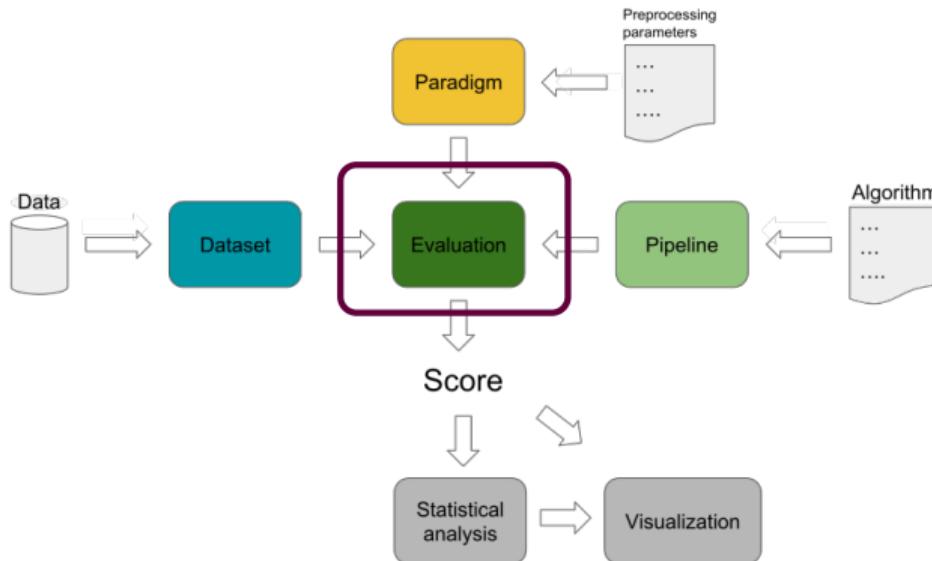
MOABB Architecture: Paradigm



Paradigm

- Motor Imagery, P300, SSVEP
- Preprocessing

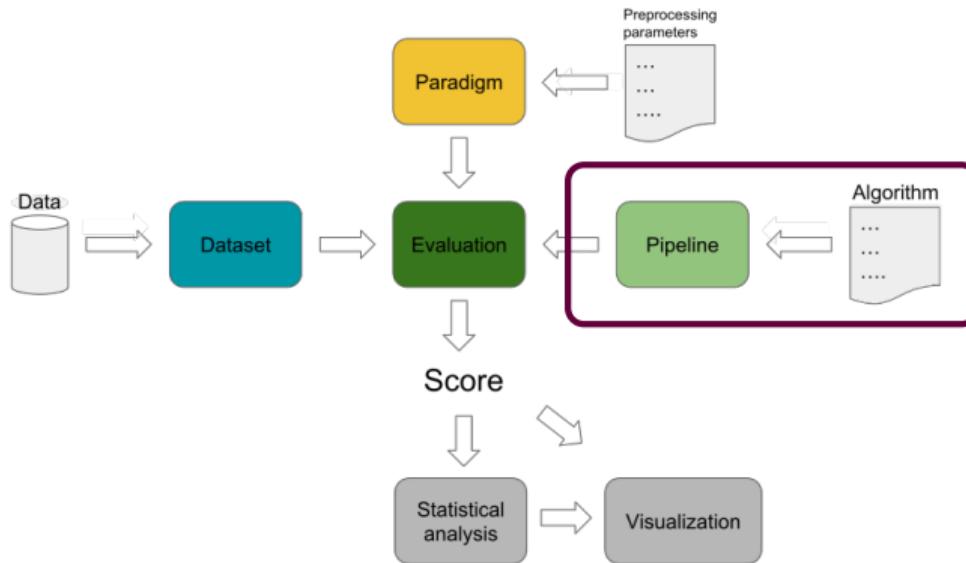
MOABB Architecture: Evaluations



Evaluations

- Defines a scoring method (AUC, accuracy, ...)
- within or across session, across-subject, ...

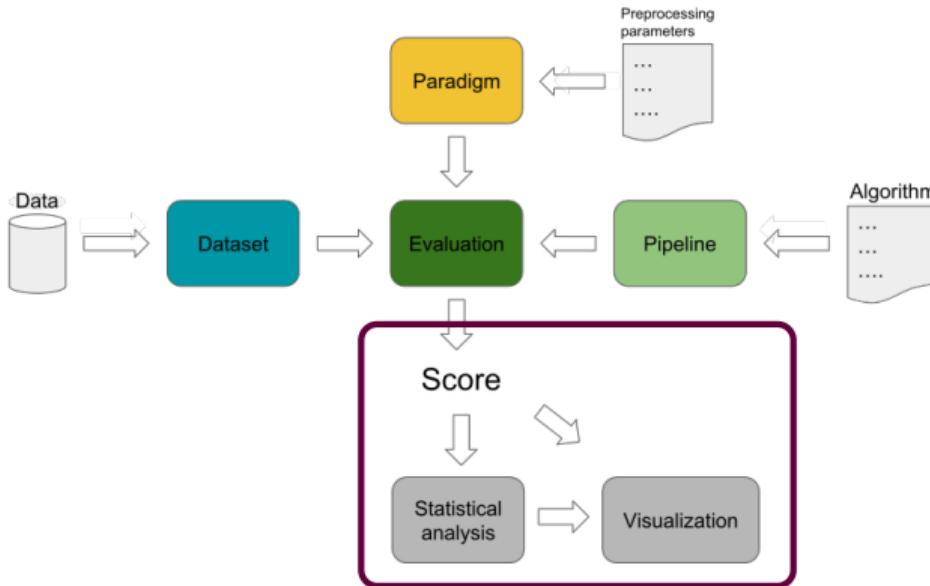
MOABB Architecture: Pipelines



Pipelines

- All steps required for obtaining a prediction
- Scikit-learn style

MOABB Architecture: Results

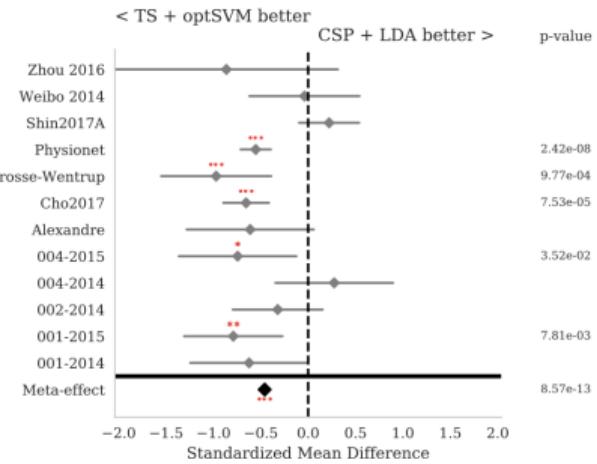


Results

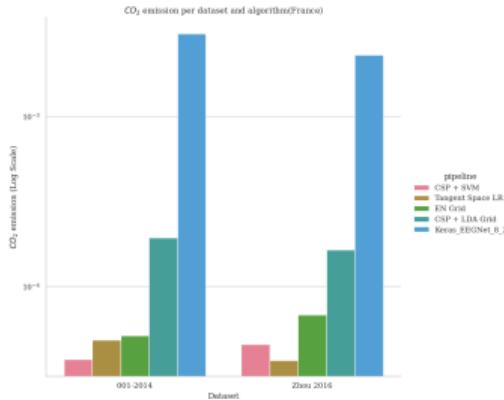
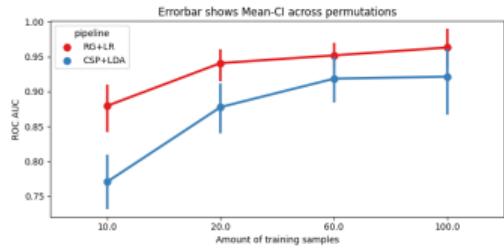
- Statistics & visualization
- Results are stored in a DataFrame

Fair and Reproducible Benchmarks

- ➊ Load multiple datasets
- ➋ Apply pipelines
- ➌ Run meta-analysis and plot



What's new?



New version 0.5 is out !

- Support latest python, MNE and sklearn version
- Support for learning curves
- New documentation pages
- New datasets: 6 for SSVEP, 2 ERP, 1 MI
- Deep learning pipelines (Pytorch/Tensorflow)
- Carbon footprint evaluation

⇒ “MOABB reloaded” paper available soon

Reproducible research in BCI built on a rich Python ecosystem
to design FAIR benchmarks **with the help of a community**

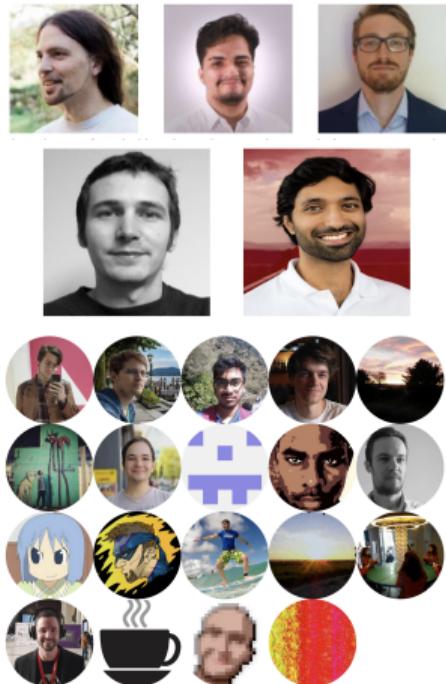
A Community Project

Maintainers: Sylvain Chevallier, Bruno Aristimunha, Igor Carrara

Founders: Alexandre Barachant, Vinay Jayaram

Contributors:

- Pedro Rodrigues
- Jan Sosulski
- Erik Bjäreholt
- Divyesh Narayanan
- Pierre Guetschel
- Quentin Barthelemy
- Vladislav Goncharenko
- Ali Abdul Hussain
- Ramiro Gatti
- Lucas Custódio
- Robin Schirrmeyer
- Mohammad Mostafa Farzan
- Yannick Roy, Morgan Hough & a vibrant community



How to contribute

Check the github and the documentation

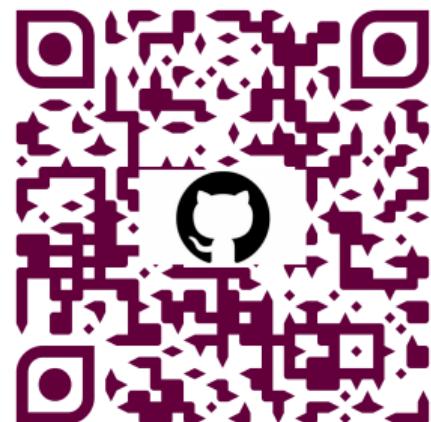
- <https://github.com/NeuroTechX/moabb>
- <https://neurotechx.github.io/moabb/>

Discuss during Office Hours or on Gitter

- <https://github.com/NeuroTechX/moabb/issues/191>
- https://gitter.im/moabb_dev/community

Possible contributions:

- Migrate to BIDS format
- Evaluation closer to online setup
- Add new datasets and pipelines



Thank you !