BrainFlow Documentation

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Nov 13, 2020

CONTENTS

BrainFlow is a library intended to obtain, parse and analyze EEG, EMG, ECG and other kinds of data from biosensors.

It provides a **uniform data acquisition API for all supported boards**, it means that you can switch boards without any changes in code and applications on top of BrainFlow are board agnostic. Also there is **powerful API to perform signal processing** which you can use even without BCI headset. Both of these two APIs are the same across bindings.

CHAPTER

ONE

SUPPORTED BOARDS

To create an instance of BoardShim class for your board check required inputs in the table below:

Table 1: Required inputs

Board	Board Id	BrainFlowInputParams.serial_port	BrainFlowInputParams.mac_address	BrainFlowInputParams.ip_address	BrainFlowInputParams.ip_port	BrainFlowInputParams.ip_protocol	BrainFlowInputParams.other_info	BrainFlowInputParams.timeout	BrainFlowInputParams.serial_number	BrainFlowInputParams.file
Playback Board	BoardIds.PLAYBACK_FILE_BOARD (-3)	•	•	•	•	•	Board Id of master board	•	•	path to file for playback
Streaming Board	BoardIds.STREAMING_BOARD (-2)	•	•	multicast IP address	port	•	Board Id of master board	•	•	•
Synthetic Board	BoardIds.SYNTHETIC_BOARD (-1)	•	•	•	•	•	•	•	•	•
Cyton	BoardIds.CYTON_BOARD (0)	dongle serial port(COM3, /dev/ttyUSB0, /dev/cu.usbserial-xxxxxx…)	•	•	•	•	•	•	•	•
Ganglion	BoardIds.GANGLION_BOARD (1)	dongle serial port(COM3, /dev/ttyUSB0…)	Optional: Ganglion's MAC address	•	•	•	•	Timeout for device discovery(default 15sec)	•	•
Cyton Daisy	BoardIds.CYTON_DAISY_BOARD (2)	dongle serial port(COM3, /dev/ttyUSB0, /dev/cu.usbserial-xxxxxx…)	•	•	•	•	•	•	•	•
Ganglion WIFI	BoardIds.GANGLION_WIFI_BOARD (4)	•	•	WIFI Shield IP(default 192.168.4.1)	any local port which is free	•	•	Timeout for HTTP response(default 10sec)	•	•
Cyton WIFI	BoardIds.CYTON_WIFI_BOARD (5)	•	•	WIFI Shield IP(default 192.168.4.1)	any local port which is free	•	•	Timeout for HTTP response(default 10sec)	•	•
Cyton Daisy WIFI	BoardIds.CYTON_DAISY_WIFI_BOARD (6)	•	•	WIFI Shield IP(default 192.168.4.1)	any local port which is free	•	•	Timeout for HTTP response(default 10sec)	•	•
BrainBit	BoardIds.BRAINBIT_BOARD (7)	•	•	•	•	•	•	Timeout for device discovery(default 15sec)	Optional: Serial Number of BrainBit device	•
Unicorn	BoardIds.UNICORN_BOARD (8)	•	•	•	•	•	•	•	Optional: Serial Num-	•

1.1 Playback File Board

This board playbacks file recorded using another BrainFlow board.

It can be extremely useful during development.

To choose this board in BoardShim constructor please specify:

- board_id: -3
- other_info field of BrainFlowInputParams structure, write there board_id for a board which acts like data provider(master board)
- file field of BrainFlowInputParams structure

Supported platforms:

- Windows >= 8.1
- Linux
- MacOS

In methods like:

```
get_eeg_channels (board_id)
get_emg_channels (board_id)
get_ecg_channels (board_id)
# .......
```

You need to use master board id instead Playback Board Id, because exact data format for streaming board is controlled by master board as well as sampling rate

Board Specs:

- num eeg(emg,...) channels: like in master board
- num acceleration channels: like in master board
- sampling rate: like in master board
- communication: UDP multicast socket to read data from master board

1.2 Streaming Board

BrainFlow's boards can stream data to different destinations like file, socket and so on. This board acts like a consumer for data streamed from the main process.

To use it in the first process you should call:

```
# choose any valid multicast address(from "224.0.0.0" to "239.255.255.255") and port
start_stream (450000, 'streaming_board://225.1.1.1:6677')
```

In the second process please specify:

- board_id: -2
- ip_address field of BrainFlowInputParams structure, for example above it's 225.1.1.1
- ip_port field of BrainFlowInputParams structure, for example above it's 6677
- other_info field of BrainFlowInputParams structure, write there board_id for a board which acts like data provider(master board)

Supported platforms:

- Windows >= 8.1
- Linux
- MacOS

In methods like:

```
get_eeg_channels (board_id)
get_emg_channels (board_id)
get_ecg_channels (board_id)
# .......
```

You need to use master board id instead Streaming Board Id, because exact data format for streaming board is controlled by master board as well as sampling rate.

Board Specs:

- num eeg(emg,...) channels: like in master board
- num acceleration channels: like in master board
- sampling rate: like in master board
- communication: UDP multicast socket to read data from master board

1.3 Synthetic Board

This board generates synthetic data and you dont need real hardware to use it.

It can be extremely useful during development.

To choose this board in BoardShim constructor please specify:

- board_id: -1
- you dont need to set any fields in BrainFlowInputParams structure

Supported platforms:

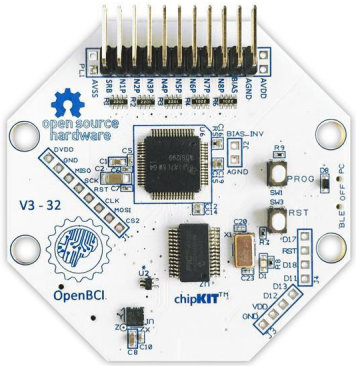
- Windows >= 8.1
- Linux
- MacOS
- Android

Board Specs:

- num eeg(emg,...) channels: 8
- num acceleration channels: 3
- sampling rate: 256
- communication: None

1.4 OpenBCI

1.4.1 Cyton



Cyton Getting Started Guide from OpenBCI

To choose this board in BoardShim constructor please specify:

- board_id: 0
- serial_port field of BrainFlowInputParams structure

Supported platforms:

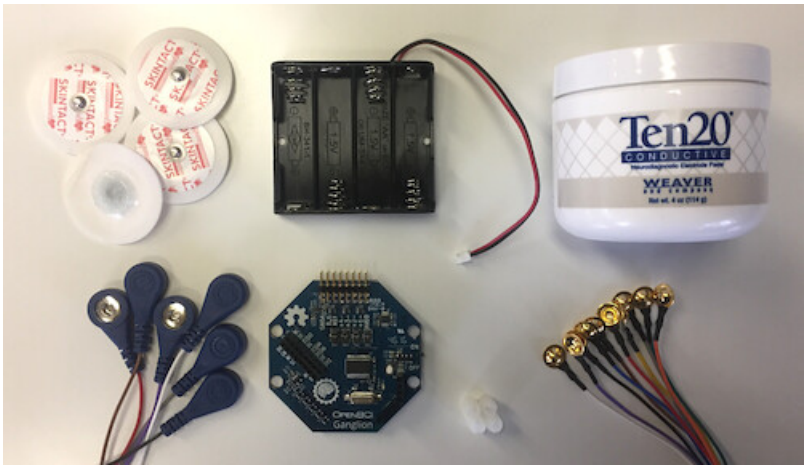
- Windows >= 8.1
- Linux
- MacOS

On MacOS there are two serial ports for each device: /dev/tty.... and /dev/cu.... You HAVE to specify /dev/cu....

Board Spec:

- num eeg(emg,...) channels: 8
- num acceleration channels: 3
- sampling rate: 250
- communication: serial port
- signal gain: 24

1.4.2 Ganglion



Ganglion Getting Started Guide from OpenBCI

To use Ganglion board you need a dongle

To choose this board in BoardShim constructor please specify:

- board_id: 1
- serial_port field of BrainFlowInputParams structure
- mac_address field of BrainFlowInputParams structure, if its empty BrainFlow will try to autodiscover Ganglion
- optional: timeout field of BrainFlowInputParams structure, default is 15sec

To get Ganglion's MAC address you can use:

- Windows: Bluetooth LE Explorer App
- Linux: hcitool command

Supported platforms:

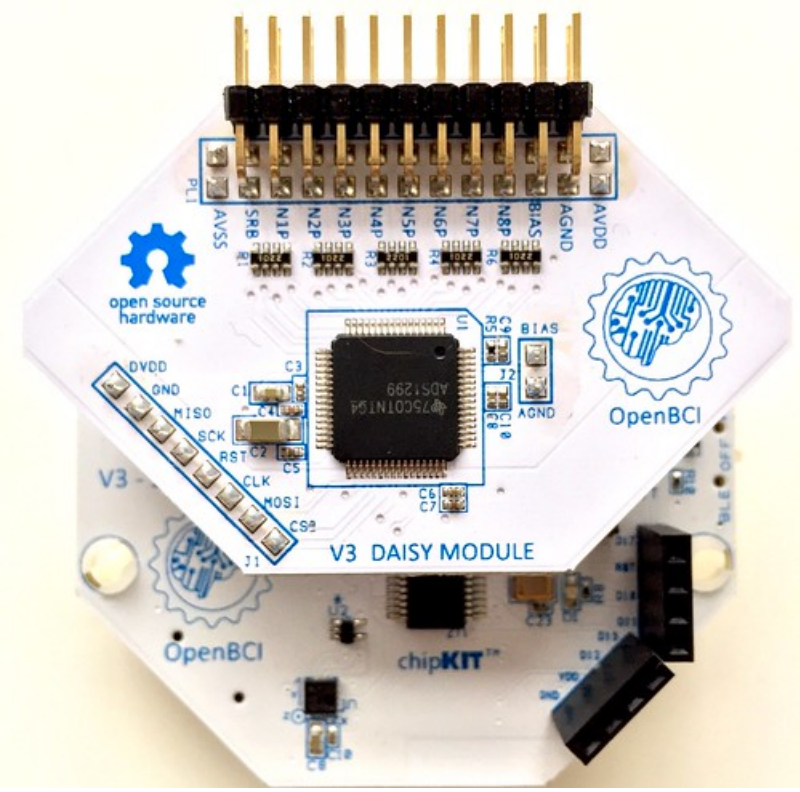
- Windows >= 8.1
- Linux
- MacOS

On MacOS there are two serial ports for each device: /dev/tty.... and /dev/cu.... You HAVE to specify /dev/cu....

Board Spec:

- num eeg(emg,...) channels: 4
- num acceleration channels: 3
- sampling rate: 200
- communication: Bluetooth Low Energy behind serial port from the dongle

1.4.3 Cyton Daisy



CytonDaisy Getting Started Guide from OpenBCI

To choose this board in BoardShim constructor please specify:

- board_id: 2
- serial_port field of BrainFlowInputParams structure

Supported platforms:

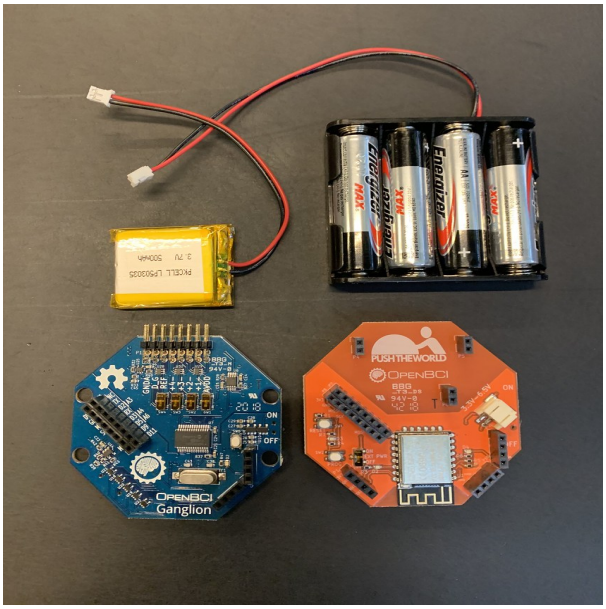
- Windows >= 8.1
- Linux
- MacOS

On MacOS there are two serial ports for each device: /dev/tty..... and /dev/cu..... You HAVE to specify /dev/cu.....

Board Spec:

- num eeg(emg,...) channels: 16
- num acceleration channels: 3
- sampling rate: 125
- communication: serial port
- signal gain: 24

1.4.4 Ganglion with WIFI Shield



WIFI Shield Getting Started Guide from OpenBCI

WIFI Shield Programming Guide from OpenBCI

To choose this board in BoardShim constructor please specify:

- board_id: 4
- ip_address field of BrainFlowInputParams structure should contain WiFi Shield Ip address(in direct mode its 192.168.4.1), if it's empty BrainFlow will try to autodiscover WIFI Shield and in case of failure will try to use 192.168.4.1
- ip_port field of BrainFlowInputParams structure should be any local port which is free right now
- optional: timeout field of BrainFlowInputParams structure, default is 10sec

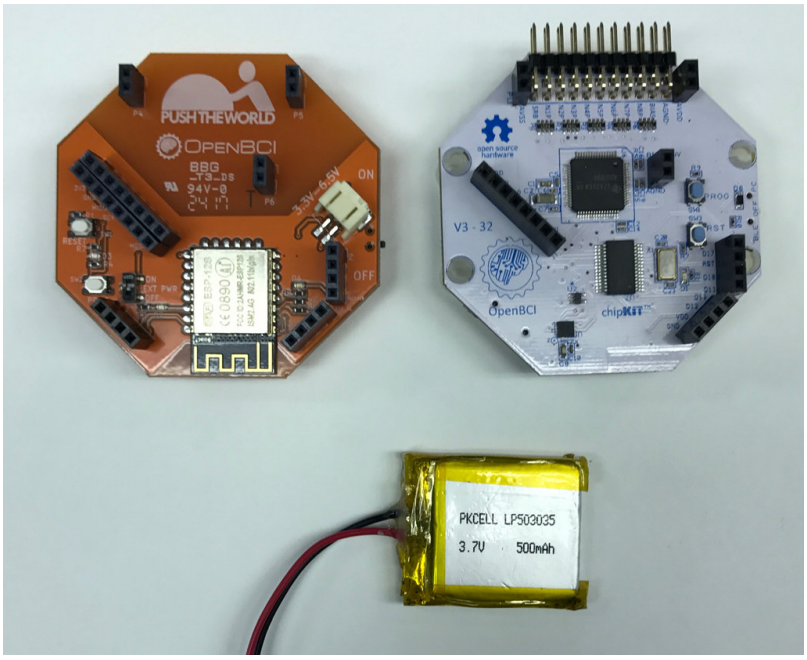
Supported platforms:

- Windows >= 8.1
- Linux
- MacOS
- Android

Board Spec:

- num eeg(emg,...) channels: 4
- num acceleration channels: 3
- sampling rate: 1600
- communication: TCP socket to read data and HTTP to send commands

1.4.5 Cyton with WIFI Shield



WIFI shield Getting Started Guide from OpenBCI

WIFI shield Programming Guide from OpenBCI

To choose this board in BoardShim constructor please specify:

- board_id: 5
- ip_address field of BrainFlowInputParams structure should contain WiFi Shield Ip address(in direct mode its 192.168.4.1), if it's empty BrainFlow will try to autodiscover WIFI Shield and in case of failure will try to use 192.168.4.1
- ip_port field of BrainFlowInputParams structure should be any local port which is free right now
- optional: timeout field of BrainFlowInputParams structure, default is 10sec

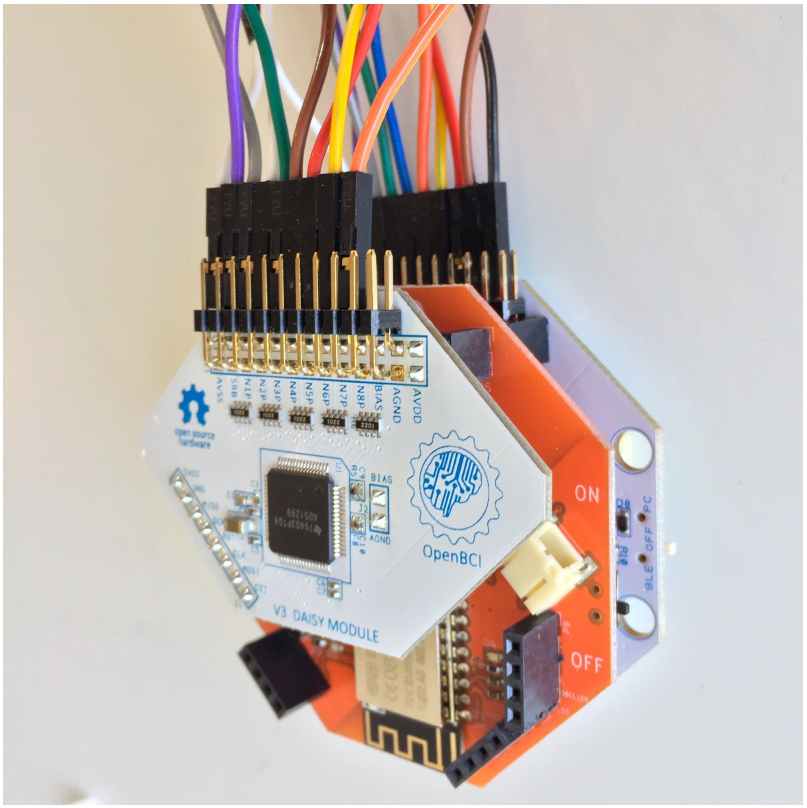
Supported platforms:

- Windows >= 8.1
- Linux
- MacOS
- Android

Board Spec:

- num eeg(emg,. . .) channels: 8
- num acceleration channels: 3
- sampling rate: 1000
- communication: TCP socket to read data and HTTP to send commands
- signal gain: 24

1.4.6 CytonDaisy with WIFI Shield



WIFI Shield Getting Started Guide from OpenBCI

WIFI Shield Programming Guide from OpenBCI

To choose this board in BoardShim constructor please specify:

- board_id: 6
- ip_address field of BrainFlowInputParams structure should contain WiFi Shield Ip address(in direct mode its 192.168.4.1), if it's empty BrainFlow will try to autodiscover WIFI Shield and in case of failure will try to use 192.168.4.1
- ip_port field of BrainFlowInputParams structure should be any local port which is free right now
- optional: timeout field of BrainFlowInputParams structure, default is 10sec

Supported platforms:

- Windows >= 8.1
- Linux
- MacOS
- Android

Board Spec:

- num eeg(emg,...) channels: 16
- num acceleration channels: 3
- sampling rate: 1000

- communication: TCP socket to read data and HTTP to send commands
- signal gain: 24

1.5 NeuroMD

1.5.1 BrainBit

BrainBit website

To choose this board in BoardShim constructor please specify:

- board_id: 7
- optional: serial_number field of BrainFlowInputParams structure should contain Serial Number of BrainBit device, use it if you have multiple devices
- optional: timeout field of BrainFlowInputParams structure, default is 15sec

Supported platforms:

- Windows >= 10
- MacOS

Board Spec:

- num eeg channels: 4
- num acceleration channels: None
- sampling rate: 250

- communication: Bluetooth Low Energy

1.5.2 Callibri(Yellow)

Callibri website

Callibri can be used to record EMG, ECG and EEG, but based on signal type you need to apply different settings for device.

BrainFlow does it for you, so there are:

- CALLIBRI_EEG_BOARD (board_id 9)
- CALLIBRI_EMG_BOARD (board_id 10)
- CALLIBRI_ECG_BOARD (board_id 11)

To choose this board in BoardShim constructor please specify:

- board_id: 9, 10 or 11 based on data type
- optional: to use electrodes connected vis USB write "ExternalSwitchInputMioUSB" to other_info field of BrainFlowInputParams structure
- optional: timeout field of BrainFlowInputParams structure, default is 15sec

Supported platforms:

- Windows >= 10
- MacOS

Board Spec:

- num exg channels: 1
- num acceleration channels: None
- communication: Bluetooth Low Energy

1.6 G.TEC

1.6.1 Unicorn

Unicorn website

To choose this board in BoardShim constructor please specify:

- board_id: 8
- optional: serial_number field of BrainFlowInputParams structure should contain Serial Number of BrainBit device, use it if you have multiple devices

Supported platforms:

- Ubuntu 18.04, may work on other Linux OSes, it depends on dynamic library provided by Unicorn
- May also work on Raspberry PI, if you replace libunicorn.so by library provided by Unicorn for Raspberry PI

Board Spec:

- num eeg channels: 8

- num acceleration channels: 3
- sampling rate: 250
- communication: Bluetooth Low Energy

1.7 Neurosity

1.7.1 Notion 1

Notion website

Link to Neurosity Tutorial

To choose this board in BoardShim constructor please specify:

- board_id: 13
- optional: Serial Number field of BrainFlowInputParams structure, important if you have multiple devices in the same place

Supported platforms:

- Windows
- Linux
- MacOS

Board Spec:

- num eeg channels: 8
- sampling rate: 250
- communication: UDP BroadCast

1.7.2 Notion 2

Notion website

Link to Neurosity Tutorial

To choose this board in BoardShim constructor please specify:

- board_id: 14
- optional: Serial Number field of BrainFlowInputParams structure, important if you have multiple devices in the same place

Supported platforms:

- Windows
- Linux
- MacOS

Board Spec:

- num eeg channels: 8
- sampling rate: 250
- communication: UDP BroadCast

CHAPTER

TWO

INSTALLATION INSTRUCTIONS

2.1 Python

Please, make sure to use Python 3+. Next, install the latest release from PYPI with the following command in terminal

```
python -m pip install brainflow
```

If you want to install it from source files or build unreleased version from Github, you should compile core module first and run

```
cd python-package
python -m pip install -e .
```

2.2 C#

For C#, only Windows is currently supported.

You are able to install the latest release from Nuget or build it yourself:

- Compile BrainFlow's core module
- open Visual Studio Solution
- install required nuget packages
- build it using Visual Studio
- **make sure that unmanaged(C++) libraries exist in search path** - set PATH env variable or copy them to correct folder

2.3 R

R binding is based on reticulate package and calls Python code, so you need to install Python binding first, make sure that reticulate uses correct virtual environment, after that you will be able to build R package from command line or using R Studio, install it and run samples.

2.4 Java

You are able to download jar files directly from release page

If you want to install it from source files or build unreleased version from github you should compile core module first and run

```
cd java-package
cd brainflow
mvn package
```

2.5 Matlab

Steps to setup Matlab binding for BrainFlow:

- Compile Core Module, using instructions below
- Open Matlab IDE and open brainflow/matlab-package/brainflow folder there
- Add folders lib and inc to Matlab path
- If you want to run Matlab scripts from folders different than brainflow/matlab-package/brainflow you need to add it to your Matlab path too

2.6 Julia

Steps to setup Julia binding for BrainFlow:

- Compile Core Module, using instructions below
- Set PATH(on Windows) or LD_LIBRARY_PATH(on Unix) env variables to ensure that compiled libraries are in search path
- Install BrainFlow package locally

Example

```
# compile core module first
# set env variable
export LD_LIBRARY_PATH=/home/andreyparfenov/brainflow/installed_linux/lib/:$LD_
↪LIBRARY_PATH
cd julia-package/brainflow
julia
# type ']' to switch to pkg terminal
activate . # activate BrainFlow's env
```

2.7 Compilation of Core Module and C++ Binding

2.7.1 Windows

- Install Cmake>=3.13 you can install it from PYPI via pip
- Install Visual Studio 2017, you can use another version but you will need to change cmake generator in batch files or run cmake commands manually. Also in CI we test only VS2017
- Build it as a cmake project manually or use cmd files from tools directory

Compilation using cmd files

```
python -m pip install cmake==3.13.3
# need to run these files from project dir
.\tools\build_win32.cmd
.\tools\build_win64.cmd
```

2.7.2 Linux

- Install Cmake>=3.13 you can install it from PYPI via pip
- If you wanna distribute compiled Linux libraries you HAVE to build it inside manylinux Docker container
- Build it as a cmake project manually or use bash file from tools directory
- You can use any compiler but for Linux we test only GCC, also we test only 64bit libraries for Linux

Compilation using bash file

```
python -m pip install cmake==3.13.3
# you may need to change line endings using dos2unix or text editor for file below
# need to run this file from project dir
bash ./tools/build_linux.sh
```

2.7.3 MacOS

- Install Cmake>=3.13 you can install it from PYPI via pip
- Build it as a cmake project manually or use bash file from tools directory
- You can use any compiler but for MacOS we test only Clang

Compilation using bash file

```
python -m pip install cmake==3.13.3
# you may need to change line endings using dos2unix or text editor for file below
# need to run this file from project dir
bash ./tools/build_mac.sh
```

2.8 Android

To check supported boards for Android visit *Supported Boards*

2.8.1 Installation instructions

- Create Java project in Android Studio, Kotlin is not supported
- Download *jniLibs.zip* from Release page
- Unpack *jniLibs.zip* and copy it's content to *project/app/src/main/jniLibs*
- Download *brainflow-jar-with-dependencies.jar* from Release page or from Github package
- Copy *brainflow-jar-with-dependencies.jar* to *project/app/libs folder*

Now you can use BrainFlow SDK in your Android application!

Note: Android Studio inline compiler may show red errors but it should be compiled fine with Gradle. To fix inline compiler you can use *File > Sync Project with Gradle Files* or click at *File > Invalidate Cache/Restart > Invalidate and Restart*

For some API calls you need to provide additional permissions via manifest file of your application

```
<uses-permission android:name="android.permission.INTERNET"></uses-permission>
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE"></uses-
↪permission>
<uses-permission android:name="android.permission.READ_EXTERNAL_STORAGE"></uses-
↪permission>
<uses-permission android:name="android.permission.WRITE_EXTERNAL_STORAGE"></uses-
↪permission>
```

2.8.2 Compilation using Android NDK

For BrainFlow developers

To test your changes in BrainFlow on Android you need to build it using Android NDK manually.

Compilation instructions:

- Download Android NDK
- Download Ninja, for Windows there is exe file in tools folder, make sure that ninja.exe in search path
- You can also try *MinGW Makefiles* instead Ninja, but it's not tested and may not work
- Build C++ code using cmake and Ninja for **all ABIs**
- Compiled libraries will be in tools/jniLibs folder

Command line examples

```
# to prepare project
# for arm64-v8a
cmake -G Ninja -DCMAKE_TOOLCHAIN_FILE=E:\android-ndk-r21d-windows-x86_64\android-ndk-
↪r21d\build\cmake\android.toolchain.cmake -DANDROID_NATIVE_API_LEVEL=android-19 -
↪DANDROID_ABI=arm64-v8a ..
# for armeabi-v7a
cmake -G Ninja -DCMAKE_TOOLCHAIN_FILE=E:\android-ndk-r21d-windows-x86_64\android-ndk-
↪r21d\build\cmake\android.toolchain.cmake -DANDROID_NATIVE_API_LEVEL=android-19 -
↪DANDROID_ABI=armeabi-v7a ..
```

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```
# for x86_64
cmake -G Ninja -DCMAKE_TOOLCHAIN_FILE=E:\android-ndk-r21d-windows-x86_64\android-ndk-
↪r21d\build\cmake\android.toolchain.cmake -DANDROID_NATIVE_API_LEVEL=android-19 -
↪DANDROID_ABI=x86_64 ..
# for x86
cmake -G Ninja -DCMAKE_TOOLCHAIN_FILE=E:\android-ndk-r21d-windows-x86_64\android-ndk-
↪r21d\build\cmake\android.toolchain.cmake -DANDROID_NATIVE_API_LEVEL=android-19 -
↪DANDROID_ABI=x86 ..

# to build
cmake --build . --target install --config Release -j 2 --parallel 2
```

CHAPTER

THREE

USER API

BrainFlow User API has three main modules:

- BoardShim to read data from a board, it calls methods from underlying BoardController library
- DataFilter to perform signal processing, it calls methods from underlying DataHandler library
- MLModel to calculate derivative metrics, it calls methods from underlying MLModule library

These classes are independent, so if you want, you can use BrainFlow API only for data streaming and perform signal processing by yourself and vice versa.

BrainFlow data acqusition API is board agnostic, so **to select a specific board you need to pass BrainFlow's board id to BoardShim's constructor and an instance of BrainFlowInputParams structure** which should hold information for your specific board, check *Supported Boards*. for details. This abstraction allows you to switch boards without any changes in code.

In BoardShim, all board data is returned as a 2d array. Rows in this array may contain timestamps, EEG and EMG data and so on. To see instructions how to query specific kind of data check *Data Format Description* and *Code Samples*.

3.1 Python API Reference

3.1.1 brainflow.board_shim

class brainflow.board_shim.**BoardIds**(*value*)

Bases: enum.Enum

Enum to store all supported Board Ids

PLAYBACK_FILE_BOARD = -3

STREAMING_BOARD = -2

SYNTHETIC_BOARD = -1

CYTON_BOARD = 0

GANGLION_BOARD = 1

CYTON_DAISY_BOARD = 2

GALEA_BOARD = 3

GANGLION_WIFI_BOARD = 4

CYTON_WIFI_BOARD = 5

CYTON_DAISY_WIFI_BOARD = 6

BRAINBIT_BOARD = 7

UNICORN_BOARD = 8

CALLIBRI_EEG_BOARD = 9

CALLIBRI_EMG_BOARD = 10

CALLIBRI_ECG_BOARD = 11

FASCIA_BOARD = 12

NOTION_OSC_BOARD = 13

NOTION_1_BOARD = 13

NOTION_2_BOARD = 14

IRONBCI_BOARD = 15

FREEEEG32_BOARD = 17

class brainflow.board_shim.**LogLevels**(*value*)
Bases: enum.Enum

Enum to store all log levels supported by BrainFlow

LEVEL_TRACE = 0

LEVEL_DEBUG = 1

LEVEL_INFO = 2

LEVEL_WARN = 3

LEVEL_ERROR = 4

LEVEL_CRITICAL = 5

LEVEL_OFF = 6

class brainflow.board_shim.**IpProtocolType**(*value*)
Bases: enum.Enum

Enum to store Ip Protocol types

NONE = 0

UDP = 1

TCP = 2

class brainflow.board_shim.**BrainFlowInputParams**
Bases: object

inputs parameters for prepare_session method

Parameters

- **serial_port** (*str*) – serial port name is used for boards which reads data from serial port
- **mac_address** (*str*) – mac address for example its used for bluetooth based boards
- **ip_address** (*str*) – ip address is used for boards which reads data from socket connection
- **ip_port** (*int*) – ip port for socket connection, for some boards where we know it in front you dont need this parameter

- **ip_protocol** (*int*) – ip protocol type from IpProtocolType enum
- **other_info** (*str*) – other info
- **serial_number** (*str*) – serial number
- **file** (*str*) – file

exception brainflow.board_shim.**BrainFlowError**(*message: str*, *exit_code: int*)

Bases: Exception

This exception is raised if non-zero exit code is returned from C code

Parameters

- **message** (*str*) – exception message
- **exit_code** (*int*) – exit code flow low level API

class brainflow.board_shim.**BoardShim**(*board_id: int*, *input_params: brainflow.board_shim.BrainFlowInputParams*)

Bases: object

BoardShim class is a primary interface to all boards

Parameters

- **board_id** (*int*) – Id of your board
- **input_params** (*BrainFlowInputParams*) – board specific structure to pass required arguments

classmethod set_log_level(*log_level: int*) → None

set BrainFlow log level, use it only if you want to write your own messages to BrainFlow logger, otherwise use enable_board_logger, enable_dev_board_logger or disable_board_logger

Parameters **log_level** (*int*) – log level, to specify it you should use values from LogLevels enum

classmethod enable_board_logger() → None

enable BrainFlow Logger with level INFO, uses stderr for log messages by default

classmethod disable_board_logger() → None

disable BrainFlow Logger

classmethod enable_dev_board_logger() → None

enable BrainFlow Logger with level TRACE, uses stderr for log messages by default

classmethod log_message(*log_level: int*, *message: str*) → None

write your own log message to BrainFlow logger, use it if you wanna have single logger for your own code and BrainFlow's code

Parameters

- **log_level** – log level
- **message** (*str*) – message

classmethod set_log_file(*log_file: str*) → None

redirect logger from stderr to file, can be called any time

Parameters **log_file** (*str*) – log file name

classmethod get_sampling_rate(*board_id: int*) → int

get sampling rate for a board

Parameters **board_id** (*int*) – Board Id

Returns sampling rate for this board id

Return type int

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_package_num_channel(*board_id: int*) → int
get package num channel for a board

Parameters **board_id** (*int*) – Board Id

Returns number of package num channel

Return type int

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_battery_channel(*board_id: int*) → int
get battery channel for a board

Parameters **board_id** (*int*) – Board Id

Returns number of batter channel

Return type int

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_num_rows(*board_id: int*) → int
get number of rows in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns number of rows in returned numpy array

Return type int

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_timestamp_channel(*board_id: int*) → int
get timestamp channel in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns number of timestamp channel in returned numpy array

Return type int

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_eeg_names(*board_id: int*) → List[str]
get names of EEG channels in 10-20 system if their location is fixed

Parameters **board_id** (*int*) – Board Id

Returns EEG channels names

Return type List[str]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_eeg_channels(*board_id: int*) → List[int]
get list of eeg channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of eeg channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_exg_channels(*board_id: int*) → List[int]
get list of exg channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of eeg channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_emg_channels(*board_id: int*) → List[int]
get list of emg channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of eeg channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_ecg_channels(*board_id: int*) → List[int]
get list of ecg channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of ecg channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_eog_channels(*board_id: int*) → List[int]
get list of eog channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of eog channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_eda_channels(*board_id: int*) → List[int]
get list of eda channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of eda channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_ppg_channels(*board_id: int*) → List[int]
get list of ppg channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of ppg channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_accel_channels(*board_id: int*) → List[int]
get list of accel channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of accel channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_analog_channels(*board_id: int*) → List[int]
get list of analog channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of analog channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_gyro_channels(*board_id: int*) → List[int]
get list of gyro channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of gyro channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_other_channels(*board_id: int*) → List[int]
get list of other channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of other channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_temperature_channels(*board_id: int*) → List[int]
get list of temperature channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of temperature channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

classmethod get_resistance_channels(*board_id: int*) → List[int]
get list of resistance channels in resulting data table for a board

Parameters **board_id** (*int*) – Board Id

Returns list of resistance channels in returned numpy array

Return type List[int]

Raises **BrainFlowError** – If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

prepare_session() → None
prepare streaming sesssion, init resources, you need to call it before any other BoardShim object methods

start_stream(*num_samples: int = 450000*, *streamer_params: str = None*) → None
Start streaming data, this methods stores data in ringbuffer

Parameters

- **num_samples** (*int*) – size of ring buffer to keep data
- **parameter to stream data from brainflow, supported vals** (*streamer_params*) – “file://%file_name%:w”, “file://%file_name%:a”, “streaming_board://%multicast_group_ip%:%port%”. Range for multicast addresses is from “224.0.0.0” to “239.255.255.255”

stop_stream() → None
Stop streaming data

release_session() → None
release all resources

get_current_board_data()
Get specified amount of data or less if there is not enough data, doesnt remove data from ringbuffer

Parameters **num_samples** (*int*) – max number of samples

Returns latest data from a board

Return type NDArray[Float64]

get_board_data_count() → int
Get num of elements in ringbuffer

Returns number of elements in ring buffer

Return type int

get_board_id() → int
Get’s the actual board id, can be different than provided

Returns board id

Return type int

is_prepared() → bool
Check if session is ready or not

Returns session status

Return type bool

get_board_data()
Get all board data and remove them from ringbuffer

Returns all data from a board

Return type NDArray[Float64]

config_board(*config*) → None
Use this method carefully and only if you understand what you are doing, do NOT use it to start or stop streaming

Parameters **config** (*str*) – string to send to a board

Returns response string if any

Return type str

3.1.2 brainflow.exit_codes

class brainflow.exit_codes.**BrainflowExitCodes**(*value*)
Bases: enum.Enum

Enum to store all possible exit codes

STATUS_OK = 0

PORT_ALREADY_OPEN_ERROR = 1

UNABLE_TO_OPEN_PORT_ERROR = 2

SER_PORT_ERROR = 3

BOARD_WRITE_ERROR = 4

INCOMMING_MSG_ERROR = 5

INITIAL_MSG_ERROR = 6

BOARD_NOT_READY_ERROR = 7

STREAM_ALREADY_RUN_ERROR = 8

INVALID_BUFFER_SIZE_ERROR = 9

STREAM_THREAD_ERROR = 10

STREAM_THREAD_IS_NOT_RUNNING = 11

EMPTY_BUFFER_ERROR = 12

INVALID_ARGUMENTS_ERROR = 13

UNSUPPORTED_BOARD_ERROR = 14

BOARD_NOT_CREATED_ERROR = 15

ANOTHER_BOARD_IS_CREATED_ERROR = 16

GENERAL_ERROR = 17

SYNC_TIMEOUT_ERROR = 18

JSON_NOT_FOUND_ERROR = 19

NO_SUCH_DATA_IN_JSON_ERROR = 20

CLASSIFIER_IS_NOT_PREPARED_ERROR = 21

ANOTHER_CLASSIFIER_IS_PREPARED_ERROR = 22

UNSUPPORTED_CLASSIFIER_AND_METRIC_COMBINATION_ERROR = 23

3.1.3 brainflow.data_filter

class brainflow.data_filter.**FilterTypes**(*value*)
Bases: enum.Enum

Enum to store all supported Filter Types

BUTTERWORTH = 0

CHEBYSHEV_TYPE_1 = 1

BESSEL = 2

class brainflow.data_filter.**AggOperations**(*value*)
Bases: enum.Enum

Enum to store all supported aggregation operations

MEAN = 0

MEDIAN = 1

EACH = 2

class brainflow.data_filter.**WindowFunctions**(*value*)
Bases: enum.Enum

Enum to store all supported window functions

NO_WINDOW = 0

HANNING = 1

HAMMING = 2

BLACKMAN_HARRIS = 3

class brainflow.data_filter.**DetrendOperations**(*value*)
Bases: enum.Enum

Enum to store all supported detrend options

NONE = 0

CONSTANT = 1

LINEAR = 2

class brainflow.data_filter.**DataFilter**
Bases: object

DataFilter class contains methods for signal processig

classmethod enable_data_logger() → None
enable Data Logger with level INFO, uses stderr for log messages by default

classmethod disable_data_logger() → None
disable Data Logger

classmethod enable_dev_data_logger() → None
enable Data Logger with level TRACE, uses stderr for log messages by default

classmethod set_log_file(*log_file: str*) → None
redirect logger from stderr to file, can be called any time

Parameters **log_file** (*str*) – log file name

classmethod perform_lowpass()
apply low pass filter to provided data

Parameters

- **data** (*NDArray[Float64]*) – data to filter, filter works in-place
- **sampling_rate** (*int*) – board's sampling rate
- **cutoff** (*float*) – cutoff frequency
- **order** (*int*) – filter order
- **filter_type** (*int*) – filter type from special enum
- **ripple** (*float*) – ripple value for Chebyshev filter

classmethod perform_highpass()
apply high pass filter to provided data

Parameters

- **data** (*NDArray[Float64]*) – data to filter, filter works in-place
- **sampling_rate** (*int*) – board's sampling rate
- **cutoff** (*float*) – cutoff frequency
- **order** (*int*) – filter order
- **filter_type** (*int*) – filter type from special enum
- **ripple** (*float*) – ripple value for Chebyshev filter

classmethod perform_bandpass()
apply band pass filter to provided data

Parameters

- **data** (*NDArray[Float64]*) – data to filter, filter works in-place
- **sampling_rate** (*int*) – board's sampling rate
- **center_freq** (*float*) – center frequency
- **band_width** (*float*) – band width
- **order** (*int*) – filter order
- **filter_type** (*int*) – filter type from special enum
- **ripple** (*float*) – ripple value for Chebyshev filter

classmethod perform_bandstop()
apply band stop filter to provided data

Parameters

- **data** (*NDArray[Float64]*) – data to filter, filter works in-place
- **sampling_rate** (*int*) – board's sampling rate
- **center_freq** (*float*) – center frequency
- **band_width** (*float*) – band width

- **order** (*int*) – filter order
- **filter_type** (*int*) – filter type from special enum
- **ripple** (*float*) – ripple value for Chebyshev filter

classmethod perform_rolling_filter()
smooth data using moving average or median

Parameters

- **data** (*NDArray[Float64]*) – data to smooth, it works in-place
- **period** (*int*) – window size
- **operation** (*int*) – int value from AggOperation enum

classmethod perform_downsampling()
perform data downsampling, it doesnt apply lowpass filter for you, it just aggregates several data points

Parameters

- **data** (*NDArray[Float64]*) – initial data
- **period** (*int*) – downsampling period
- **operation** (*int*) – int value from AggOperation enum

Returns downsampled data

Return type NDArray[Float64]

classmethod perform_wavelet_transform()
perform wavelet transform

Parameters

- **data** (*NDArray[Float64]*) – initial data
- **wavelet** (*str*) – supported vals: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2
  ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- **decomposition_level** (*int*) – level of decomposition

Returns tuple of wavelet coeffs in format [A(J) D(J) D(J-1) . . . .. D(1)] where J is decomposition level, A - app coeffs, D - detailed coeffs, and array with lengths for each block

Return type tuple

classmethod perform_inverse_wavelet_transform()
perform wavelet transform

Parameters

- **wavelet_output** – tuple of wavelet_coeffs and array with lengths
- **original_data_len** (*int*) – len of signal before wavelet transform
- **wavelet** (*str*) – supported vals: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2
  ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- **decomposition_level** (*int*) – level of decomposition

Returns restored data

Return type NDArray[Float64]

classmethod perform_wavelet_denoising()
perform wavelet denoising

Parameters

- **data** (*NDArray[Float64]*) – data to denoise
- **wavelet** (*str*) – supported vals: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2
,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- **decomposition_level** (*int*) – decomposition level

classmethod perform_fft()
perform direct fft

Parameters

- **data** (*NDArray[Float64]*) – data for fft, len of data must be a power of 2
- **window** (*int*) – window function

Returns numpy array of complex values, len of this array is N / 2 + 1

Return type NDArray[Complex128]

classmethod get_psd()
calculate PSD

Parameters

- **data** (*NDArray[Float64]*) – data to calc psd, len of data must be a power of 2
- **sampling_rate** (*int*) – sampling rate
- **window** (*int*) – window function

Returns amplitude and frequency arrays of len N / 2 + 1

Return type tuple

classmethod get_psd_welch()
calculate PSD using Welch method

Parameters

- **data** (*NDArray[Float64]*) – data to calc psd
- **nfft** (*int*) – FFT Window size, must be power of 2
- **overlap** (*int*) – overlap of FFT Windows, must be between 0 and nfft
- **sampling_rate** (*int*) – sampling rate
- **window** (*int*) – window function

Returns amplitude and frequency arrays of len N / 2 + 1

Return type tuple

classmethod detrend()
detrend data

Parameters

- **data** (*NDArray[Float64]*) – data to calc psd
- **detrend_operation** (*int*) – Type of detrend operation

classmethod get_band_power(*psd: Tuple*, *freq_start: float*, *freq_end: float*) → float
calculate band power

Parameters

- **psd** (*typle*) – psd from get_psd
- **freq_start** (*int*) – start freq
- **freq_end** (*int*) – end freq

Returns band power

Return type float

classmethod get_avg_band_powers(*data: nptyping.types._ndarray.NDArray*, *channels: List*, *sampling_rate: int*, *apply_filter: bool*) → Tuple
calculate avg and stddev of BandPowers across all channels

Parameters

- **data** (*NDArray*) – 2d array for calculation
- **channels** (*List*) – channels - rows of data array which should be used for calculation
- **sampling_rate** (*int*) – sampling rate
- **apply_filter** (*bool*) – apply bandpass and bandstop filtrers or not

Returns avg and stddev arrays for bandpowers

Return type tuple

classmethod perform_ifft()
perform inverse fft

Parameters **data** (*NDArray[Complex128]*) – data from fft

Returns restored data

Return type NDArray[Float64]

classmethod get_nearest_power_of_two(*value: int*) → int
calc nearest power of two

Parameters **value** (*int*) – input value

Returns nearest power of two

Return type int

classmethod write_file(*data*, *file_name: str*, *file_mode: str*) → None
write data to file, in file data will be transposed

Parameters

- **data** (*2d numpy array*) – data to store in a file
- **file_name** (*str*) – file name to store data
- **file_mode** (*str*) – 'w' to rewrite file or 'a' to append data to file

classmethod read_file(*file_name: str*)
read data from file

Parameters **file_name** (*str*) – file name to read

Returns 2d numpy array with data from this file, data will be transposed to original dimensions

Return type 2d numpy array

3.1.4 brainflow.ml_model

class brainflow.ml_model.**BrainFlowMetrics**(*value*)
Bases: enum.Enum

Enum to store all supported metrics

RELAXATION = 0

CONCENTRATION = 1

class brainflow.ml_model.**BrainFlowClassifiers**(*value*)
Bases: enum.Enum

Enum to store all supported classifiers

REGRESSION = 0

KNN = 1

SVM = 2

LDA = 3

class brainflow.ml_model.**BrainFlowModelParams**(*metric*, *classifier*)
Bases: object

inputs parameters for prepare_session method

Parameters

- **metric** (*int*) – metric to calculate
- **classifier** (*int*) – classifier to use
- **file** (*str*) – file to load model
- **other_info** (*int*) – additional information

class brainflow.ml_model.**MLModel**(*model_params: brainflow.ml_model.BrainFlowModelParams*)
Bases: object

MLModel class used to calc derivative metrics from raw data

Parameters **model_params** (*BrainFlowModelParams*) – Model Params

classmethod enable_ml_logger() → None
enable ML Logger with level INFO, uses stderr for log messages by default

classmethod disable_ml_logger() → None
disable BrainFlow Logger

classmethod enable_dev_ml_logger() → None
enable ML Logger with level TRACE, uses stderr for log messages by default

classmethod set_log_file(*log_file: str*) → None
redirect logger from stderr to file, can be called any time

Parameters **log_file** (*str*) – log file name

prepare() → None
prepare classifier

release() → None
release classifier

predict (*data: nptyping.types._ndarray.NDArray*) → float
calculate metric from data

Parameters **data** (*NDArray*) – input array

Returns metric value

Return type float

3.2 C++ API Reference

3.2.1 BoardShim class

class BoardShim
BoardShim class to communicate with a board.

Public Functions

BoardShim(int *board_id*, **struct** BrainFlowInputParams *params*)

~BoardShim()

void **prepare_session**()
prepare BrainFlow's streaming session, should be called first

void **start_stream**(int *buffer_size* = 450000, char **streamer_params* = NULL)
start streaming thread and store data in ringbuffer

Parameters

- `buffer_size`: size of internal ring buffer
- `streamer_params`: use it to pass data packages further or store them directly during streaming, supported values: "file://%file_name%:w", "file://%file_name%:a", "streaming_board://%multicast_group_ip%:%port%"".

  Range for multicast addresses is from "224.0.0.0" to "239.255.255.255"

bool **is_prepared**()
check if session is ready or not

void **stop_stream**()
stop streaming thread, doesnt release other resources

void **release_session**()
release streaming session

double ****get_current_board_data**(int *num_samples*, int **num_data_points*)
get latest collected data, doesnt remove it from ringbuffer

int **get_board_id**()
Get board id, for some boards can be different than provided (playback, streaming)

int **get_board_data_count**()
get number of packages in ringbuffer

double ****get_board_data**(int **num_data_points*)
get all collected data and flush it from internal buffer

std::string **config_board**(char *_config_)
send string to a board, use it carefully and only if you understand what you are doing

Public Members

int **board_id**

Public Static Functions

void **disable_board_logger**()
disable BrainFlow loggers

void **enable_board_logger**()
enable BrainFlow logger with LEVEL_INFO

void **enable_dev_board_logger**()
enable BrainFlow logger with LEVEL_TRACE

void **set_log_file**(char *_log_file_)
redirect BrainFlow logger from stderr to file

void **set_log_level**(int _log_level_)
use set_log_level only if you want to write your own log messages to BrainFlow logger

void **log_message**(int _log_level_, **const** char *_format_, ...)
write user defined string to BrainFlow logger

int **get_sampling_rate**(int _board_id_)
get sampling rate for this board

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_package_num_channel**(int _board_id_)
get row index which holds package nums

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_timestamp_channel**(int _board_id_)
get row index which holds timestamps

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_battery_channel** (int *board_id*)
get row index which holds battery level info

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_num_rows** (int *board_id*)
get number of rows in returned from *get_board_data()* 2d array

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

std::string ***get_eeg_names** (int *board_id*, int **len*)
get eeg channel names in 10-20 system for devices with fixed electrode locations

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_eeg_channels** (int *board_id*, int **len*)
get row indices which hold EEG data, for some board we can not split EEG...

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_emg_channels** (int *board_id*, int **len*)
get row indices which hold EMG data, for some board we can not split EEG...

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_ecg_channels** (int *board_id*, int **len*)
get row indices which hold ECG data, for some board we can not split EEG...

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int *__get_eog_channels__(int *board_id*, int **len*)
get row indices which hold EOG data, for some board we can not split EEG...

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int *__get_exg_channels__(int *board_id*, int **len*)
get row indices which hold EXG data

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int *__get_ppg_channels__(int *board_id*, int **len*)
get row indices which hold PPG data

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int *__get_eda_channels__(int *board_id*, int **len*)
get row indices which hold EDA data

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int *__get_accel_channels__(int *board_id*, int **len*)
get row indices which hold accel data

Parameters

- board_id: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int *__get_analog_channels__(int *board_id*, int **len*)
get row indices which hold analog data

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_gyro_channels*** (int *board_id*, int **len*)
get row indices which hold gyro data

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_other_channels*** (int *board_id*, int **len*)
get row indices which hold other information

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_temperature_channels*** (int *board_id*, int **len*)
get row indices which hold temperature data

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int ***get_resistance_channels*** (int *board_id*, int **len*)
get row indices which hold resistance data

Parameters

- `board_id`: board id of your device

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

3.2.2 DataFilter class

class DataFilter

DataFilter class to perform signal processing.

Public Static Functions

void **enable_data_logger**()
enable Data logger with LEVEL_INFO

void **disable_data_logger**()
disable Data loggers

void **enable_dev_data_logger**()
enable Data logger with LEVEL_TRACE

void **set_log_file**(char **log_file*)

void **perform_lowpass**(double **data*, int *data_len*, int *sampling_rate*, double *cutoff*, int *order*, int *filter_type*, double *ripple*)
perform low pass filter in-place

void **perform_highpass**(double **data*, int *data_len*, int *sampling_rate*, double *cutoff*, int *order*, int *filter_type*, double *ripple*)
perform high pass filter in-place

void **perform_bandpass**(double **data*, int *data_len*, int *sampling_rate*, double *center_freq*, double *band_width*, int *order*, int *filter_type*, double *ripple*)
perform bandpass filter in-place

void **perform_bandstop**(double **data*, int *data_len*, int *sampling_rate*, double *center_freq*, double *band_width*, int *order*, int *filter_type*, double *ripple*)
perform bandstop filter in-place

void **perform_rolling_filter**(double **data*, int *data_len*, int *period*, int *agg_operation*)
perform moving average or moving median filter in-place

double ***perform_downsampling**(double **data*, int *data_len*, int *period*, int *agg_operation*, int **filtered_size*)
perform data downsampling, it just aggregates several data points

std::pair<double*, int*> **perform_wavelet_transform**(double **data*, int *data_len*, char **wavelet*, int *decomposition_level*)
perform wavelet transform

Return std::pair of wavelet coeffs array in format [A(J) D(J) D(J-1) . . . .. D(1)] where J is decomposition level A - app coeffs, D - detailed coeffs, and array of lengths for each block in wavelet coeffs array, length of this array is decomposition_level + 1

Parameters

- `data`: input array, any size
- `data_len`: length of input array
- `wavelet`: supported vals: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2.4,bior2.6 ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- `decomposition_level`: level of decomposition in wavelet transform

double *__perform_inverse_wavelet_transform__(std::pair<double*, int*> *wavelet_output*, int *original_data_len*, char **wavelet*, int *decomposition_level*)

performs inverse wavelet transform

void __perform_wavelet_denoising__(double **data*, int *data_len*, char **wavelet*, int *decomposition_level*)

perform wavelet denoising

std::complex<double> *__perform_fft__(double **data*, int *data_len*, int *window*)

perform direct fft

Return complex array with size data_len / 2 + 1, it holds only positive im values

Parameters

- `data`: input array
- `data_len`: must be power of 2
- `window`: window function

double *__perform_ifft__(std::complex<double> **data*, int *data_len*)

perform inverse fft

Return restored data

Parameters

- `data`: complex array from perform_fft
- `data_len`: len of original array, must be power of 2

int __get_nearest_power_of_two__(int *value*)

calculate nearest power of 2

Return nearest power of 2

Parameters

- `value`: input value

std::pair<double*, double*> __get_psd__(double **data*, int *data_len*, int *sampling_rate*, int *window*)

calculate PSD

Return pair of amplitude and freq arrays of size data_len / 2 + 1

Parameters

- `data`: input array
- `data_len`: must be power of 2
- `sampling_rate`: sampling rate
- `window`: window function

void __detrend__(double **data*, int *data_len*, int *detrend_operation*)

subtract trend from data

Parameters

- `data`: input array
- `data_len`:
- `detrend_operation`: use DetrendOperations enum

std::pair<double*, double*> **get_psd_welch**(double **data*, int *data_len*, int *nfft*, int *overlap*, int *sampling_rate*, int *window*)

double **get_band_power**(std::pair<double*, double*> *psd*, int *data_len*, double *freq_start*, double *freq_end*)

calculate band power

Return band power

Parameters

- `psd`: psd calculated using get_psd
- `data_len`: len of ampl and freq arrays: N / 2 + 1 where N is FFT size
- `freq_start`: lowest frequency
- `freq_end`: highest frequency

std::pair<double*, double*> **get_avg_band_powers**(double ***data*, int *cols*, int **channels*, int *channels_len*, int *sampling_rate*, bool *apply_filters*)

calculate avg and stddev of BandPowers across all channels

Return pair of double arrays of size 5, first of them - avg band powers, second stddev

Parameters

- `data`: input 2d array
- `cols`: number of cols in 2d array - number of datapoints
- `channels`: array of rows - eeg channels which should be used
- `channels_len`: - len of channels array
- `sampling_rate`: sampling rate
- `apply_filters`: set to true to apply filters before band power calculations

void **write_file**(double ***data*, int *num_rows*, int *num_cols*, char **file_name*, char **file_mode*)

write file, in file data will be transposed

double ****read_file**(int **num_rows*, int **num_cols*, char **file_name*)

read data from file, data will be transposed to original format

3.2.3 BrainFlowException class

class BrainFlowException : **public** exception

BrainFlowException class to notify about errors.

Public Functions

BrainFlowException(**const** char **msg*, int *exit_code*)

~BrainFlowException()

const char ***what**() **const**

Public Members

int **exit_code**
exit code returned from low level API

3.2.4 BrainFlowModelParams class

Warning: doxygenclass: Cannot find class "BrainFlowModelParams" in doxygen xml output for project "BrainFlowCpp" from directory: build-cpp/xml

3.2.5 MLModel class

class MLModel
Calculates different metrics from raw data.

Public Functions

MLModel(**struct** BrainFlowModelParams *params*)

~MLModel()

void **prepare**()
initialize classifier, should be called first

double **predict**(double **data*, int *data_len*)
calculate metric from data

void **release**()
release classifier

Public Static Functions

void **set_log_file**(char **log_file*)
redirect logger to a file

void **enable_ml_logger**()
enable ML logger with LEVEL_INFO

void **disable_ml_logger**()
disable ML loggers

void **enable_dev_ml_logger**()
enable ML logger with LEVEL_TRACE

3.2.6 BrainFlow constants

```
#pragma once

enum class BrainFlowExitCodes : int
{
    STATUS_OK = 0,
    PORT_ALREADY_OPEN_ERROR = 1,
    UNABLE_TO_OPEN_PORT_ERROR = 2,
    SET_PORT_ERROR = 3,
    BOARD_WRITE_ERROR = 4,
    INCOMMING_MSG_ERROR = 5,
    INITIAL_MSG_ERROR = 6,
    BOARD_NOT_READY_ERROR = 7,
    STREAM_ALREADY_RUN_ERROR = 8,
    INVALID_BUFFER_SIZE_ERROR = 9,
    STREAM_THREAD_ERROR = 10,
    STREAM_THREAD_IS_NOT_RUNNING = 11,
    EMPTY_BUFFER_ERROR = 12,
    INVALID_ARGUMENTS_ERROR = 13,
    UNSUPPORTED_BOARD_ERROR = 14,
    BOARD_NOT_CREATED_ERROR = 15,
    ANOTHER_BOARD_IS_CREATED_ERROR = 16,
    GENERAL_ERROR = 17,
    SYNC_TIMEOUT_ERROR = 18,
    JSON_NOT_FOUND_ERROR = 19,
    NO_SUCH_DATA_IN_JSON_ERROR = 20,
    CLASSIFIER_IS_NOT_PREPARED_ERROR = 21,
    ANOTHER_CLASSIFIER_IS_PREPARED_ERROR = 22,
    UNSUPPORTED_CLASSIFIER_AND_METRIC_COMBINATION_ERROR = 23,
};

enum class BoardIds : int
{
    PLAYBACK_FILE_BOARD = -3,
    STREAMING_BOARD = -2,
    SYNTHETIC_BOARD = -1,
    CYTON_BOARD = 0,
    GANGLION_BOARD = 1,
    CYTON_DAISY_BOARD = 2,
    GALEA_BOARD = 3,
    GANGLION_WIFI_BOARD = 4,
    CYTON_WIFI_BOARD = 5,
    CYTON_DAISY_WIFI_BOARD = 6,
    BRAINBIT_BOARD = 7,
    UNICORN_BOARD = 8,
    CALLIBRI_EEG_BOARD = 9,
    CALLIBRI_EMG_BOARD = 10,
    CALLIBRI_ECG_BOARD = 11,
    FASCIA_BOARD = 12,
    NOTION_1_BOARD = 13,
    NOTION_2_BOARD = 14,
    IRONBCI_BOARD = 15,
    FREEEEG32_BOARD = 17
};

enum class FilterTypes : int
```

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```
{
    BUTTERWORTH = 0,
    CHEBYSHEV_TYPE_1 = 1,
    BESSEL = 2
};

enum class AggOperations : int
{
    MEAN = 0,
    MEDIAN = 1,
    EACH = 2
};

enum class WindowFunctions : int
{
    NO_WINDOW = 0,
    HANNING = 1,
    HAMMING = 2,
    BLACKMAN_HARRIS = 3
};

enum class DetrendOperations : int
{
    NONE = 0,
    CONSTANT = 1,
    LINEAR = 2
};

enum class BrainFlowMetrics : int
{
    RELAXATION = 0,
    CONCENTRATION = 1
};

enum class BrainFlowClassifiers : int
{
    REGRESSION = 0,
    KNN = 1,
    SVM = 2,
    LDA = 3
};
/// LogLevels enum to store all possible log levels
enum class LogLevels : int
{
    LEVEL_TRACE = 0,     /// TRACE
    LEVEL_DEBUG = 1,     /// DEBUG
    LEVEL_INFO = 2,      /// INFO
    LEVEL_WARN = 3,      /// WARN
    LEVEL_ERROR = 4,     /// ERROR
    LEVEL_CRITICAL = 5, /// CRITICAL
    LEVEL_OFF = 6        // OFF
};
```

3.3 Java API Reference

Content of Brainflow Package:

enum AggOperations
enum to store all supported aggregation operations

Public Functions

int **get_code** ( )

brainflow::AggOperations (final int code)

Public Members

brainflow::MEAN =(0)

brainflow::MEDIAN =(1)

brainflow::EACH =(2)

Public Static Functions

String brainflow::string_from_code (final int code)

AggOperations brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::agg_operation

Private Static Attributes

final Map< Integer, AggOperations > brainflow::ao_map = new HashMap<Integer, AggOper

enum BoardIds
enum to store all supported boards

Public Functions

int **get_code** ( )

brainflow::BoardIds (final int code)

Public Members

brainflow::PLAYBACK_FILE_BOARD =(-3)

brainflow::STREAMING_BOARD =(-2)

brainflow::SYNTHETIC_BOARD =(-1)

brainflow::CYTON_BOARD =(0)

brainflow::GANGLION_BOARD =(1)

brainflow::CYTON_DAISY_BOARD =(2)

brainflow::GALEA_BOARD =(3)

brainflow::GANGLION_WIFI_BOARD =(4)

brainflow::CYTON_WIFI_BOARD =(5)

brainflow::CYTON_DAISY_WIFI_BOARD =(6)

brainflow::BRAINBIT_BOARD =(7)

brainflow::UNICORN_BOARD =(8)

brainflow::CALLIBRI_EEG_BOARD =(9)

brainflow::CALLIBRI_EMG_BOARD =(10)

brainflow::CALLIBRI_ECG_BOARD =(11)

brainflow::FASCIA_BOARD =(12)

brainflow::NOTION_1_BOARD =(13)

brainflow::NOTION_2_BOARD =(14)

brainflow::IRONBCI_BOARD =(15)

brainflow::FREEEEG32_BOARD =(17)

Public Static Functions

String brainflow::string_from_code (final int code)

BoardIds brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::board_id

Private Static Attributes

```
final Map< Integer, BoardIds > brainflow::bi_map   = new HashMap<Integer, BoardIds> ()
```

class brainflow::brainflow::**BoardShim**

BoardShim class to communicate with a board

Public Functions

BoardShim(int *board_id*, *BrainFlowInputParams* *params*)

Create BoardShim object

void **prepare_session**()

prepare steaming session, allocate resources

int **get_board_id**()

Get Board Id, can be different than provided (playback or streaming board)

String **config_board**(String *config*)

send string to a board, use this method carefully and only if you understand what you are doing

void **start_stream**(int *buffer_size*, String *streamer_params*)

start streaming thread, store data in internal ringbuffer and stream them from brainflow at the same time

Parameters

- `buffer_size`: size of internal ringbuffer
- `streamer_params`: supported vals: "file://%file_name%:w", "file://%file_name%:a", "streaming_board://%multicast_group_ip%:%port%". Range for multicast addresses is from "224.0.0.0" to "239.255.255.255"

void **start_stream**()

start streaming thread, store data in internal ringbuffer

void **start_stream**(int *buffer_size*)

start streaming thread, store data in internal ringbuffer

void **stop_stream**()

stop streaming thread

void **release_session**()

release all resources

int **get_board_data_count**()

get number of packages in ringbuffer

boolean **is_prepared**()

check session status

double [][] get_current_board_data (int num_samples)

get latest collected data, can return less than "num_samples", doesnt flush it from ringbuffer

double [][] get_board_data ()

get all data from ringbuffer and flush it

Public Members

int **board_id**
BrainFlow's board id

Public Static Functions

void **enable_board_logger**()
enable BrainFlow logger with level INFO

void **enable_dev_board_logger**()
enable BrainFlow logger with level TRACE

void **disable_board_logger**()
disable BrainFlow logger

void **set_log_file**(String *log_file*)
redirect logger from stderr to a file

void **set_log_level**(int *log_level*)
set log level

void **log_message**(int *log_level*, String *message*)
send user defined strings to BrainFlow logger

int **get_sampling_rate**(int *board_id*)
get sampling rate for this board

int **get_timestamp_channel**(int *board_id*)
get row index in returned by *get_board_data()* 2d array which contains timestamps

int **get_num_rows**(int *board_id*)
get number of rows in returned by *get_board_data()* 2d array

int **get_package_num_channel**(int *board_id*)
get row index in returned by *get_board_data()* 2d array which contains package nums

int **get_battery_channel**(int *board_id*)
get row index in returned by *get_board_data()* 2d array which contains battery level

String [] get_eeg_names (int board_id)
Get names of EEG electrodes in 10-20 system. Only if electrodes have freezed locations

int [] get_eeg_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain EEG data, for some boards we can not split EEG... and return the same array

int [] get_emg_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain EMG data, for some boards we can not split EEG... and return the same array

int [] get_ecg_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain ECG data, for some boards we can not split EEG... and return the same array

int [] get_temperature_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain temperature data

int [] get_resistance_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain resistance data

int [] get_eog_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain EOG data, for some boards we can not split EEG... and return the same array

int [] get_exg_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain EXG data

int [] get_eda_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain EDA data, for some boards we can not split EEG... and return the same array

int [] get_ppg_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain PPG data, for some boards we can not split EEG... and return the same array

int [] get_accel_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain accel data

int [] get_analog_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain analog data

int [] get_gyro_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain gyro data

int [] get_other_channels (int board_id)
get row indices in returned by *get_board_data()* 2d array which contain other data

enum BrainFlowClassifiers

Public Functions

int **get_code** ( )

brainflow::BrainFlowClassifiers (final int code)

Public Members

brainflow::REGRESSION =(0)

brainflow::KNN =(1)

brainflow::SVM =(2)

brainflow::LDA =(3)

Public Static Functions

String brainflow::string_from_code (final int code)

BrainFlowClassifiers brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::protocol

Private Static Attributes

final Map< Integer, BrainFlowClassifiers > brainflow::cl_map = new HashMap<Integer,

class brainflow::brainflow::**BrainFlowError** : **public** Exception

BrainFlowError exception to notify about errors

Public Functions

BrainFlowError(String *message*, int *ec*)

Public Members

String **msg**

int **exit_code**

exit code returned from low level API

class brainflow::brainflow::**BrainFlowInputParams**

to get fields which are required for your board check SupportedBoards section

Public Functions

BrainFlowInputParams()

String **to_json**()

String **get_ip_address**()

void **set_ip_address**(String *ip_address*)

String **get_mac_address**()

void **set_mac_address**(String *mac_address*)

String **get_serial_port**()

void **set_serial_port**(String *serial_port*)

int **get_ip_port**()

void **set_ip_port**(int *ip_port*)

int **get_ip_protocol**()

void **set_ip_protocol**(int *ip_protocol*)

String **get_other_info**()

void **set_other_info**(String *other_info*)

void **set_timeout**(int *timeout*)

int **get_timeout**()

String **get_serial_number**()

void **set_serial_number** (String *serial_number*)

String **get_file** ()

void **set_file** (String *file*)

Public Members

String **ip_address**

String **mac_address**

String **serial_port**

int **ip_port**

int **ip_protocol**

String **other_info**

int **timeout**

String **serial_number**

String **file**

enum BrainFlowMetrics

Public Functions

int **get_code** ()

brainflow::BrainFlowMetrics (final int code)

Public Members

brainflow::RELAXATION =(0)

brainflow::CONCENTRATION =(1)

Public Static Functions

String brainflow::string_from_code (final int code)

BrainFlowMetrics brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::protocol

Private Static Attributes

final Map< Integer, BrainFlowMetrics > brainflow::metr_map = new HashMap<Integer, Br

class brainflow::brainflow::**BrainFlowModelParams**
describe model parameters

Public Functions

BrainFlowModelParams (int *metric*, int *classifier*)

int **get_metric** ()

void **set_metric** (int *metric*)

int **get_classifier** ()

void **set_classifier** (int *classifier*)

String **get_file** ()

void **set_file** (String *file*)

String **get_other_info** ()

void **set_other_info** (String *other_info*)

String **to_json** ()

Public Members

int **metric**

int **classifier**

String **file**

String **other_info**

class brainflow::brainflow::**DataFilter**
DataFilter class to perform signal processing

Public Static Functions

void **enable_data_logger** ()
enable Data logger with level INFO

void **enable_dev_data_logger** ()
enable Data logger with level TRACE

void **disable_data_logger** ()
disable Data logger

void **set_log_file** (String *log_file*)
redirect logger from stderr to a file

void perform_lowpass (double[] data, int sampling_rate, double cutoff, int order, int
perform lowpass filter in-place

void perform_highpass (double[] data, int sampling_rate, double cutoff, int order, int
perform highpass filter in-place

void perform_bandpass (double[] data, int sampling_rate, double center_freq, double ba
perform bandpass filter in-place

void perform_bandstop (double[] data, int sampling_rate, double center_freq, double ba
perform bandstop filter in-place

void perform_rolling_filter (double[] data, int period, int operation)
perform moving average or moving median filter in-place

void detrend (double[] data, int operation)
subtract trend from data in-place

double [] perform_downsampling (double[] data, int period, int operation)
perform data downsampling, it doesnt apply lowpass filter for you, it just aggregates several data points

void perform_wavelet_denoising (double[] data, String wavelet, int decomposition_level
perform wavelet based denoising in-place

Parameters

- `wavelet`: supported vals: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2.4,bior2.6 ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- `decomposition_level`: level of decomposition of wavelet transform

Pair< double[], int[]> perform_wavelet_transform (double[] data, String wavelet, int d
perform wavelet transform

Parameters

- `wavelet`: supported vals: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2.4,bior2.6 ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8

double [] perform_inverse_wavelet_transform (Pair< double[], int[]> wavelet_output, in
perform inverse wavelet transform

Complex [] perform_fft (double[] data, int start_pos, int end_pos, int window)
perform direct fft

Return array of complex values with size N / 2 + 1

Parameters

- `data`: data for fft transform
- `start_pos`: starting position to calc fft
- `end_pos`: end position to calc fft, total_len must be a power of two
- `window`: window function

double [] perform_ifft (Complex[] data)
perform inverse fft

Return restored data

Parameters

- `data`: data from fft transform(array of complex values)

Pair< double[], double[]> get_avg_band_powers (double[][] data, int[] channels, int sa
calc average and stddev of band powers across all channels

Return pair of avgs and stddevs for bandpowers

Parameters

- `data`: data to process
- `channels`: rows of data arrays which should be used in calculation
- `sampling_rate`: sampling rate
- `apply_filters`: apply bandpass and bandstop filters before calculation

Pair< double[], double[]> get_psd (double[] data, int start_pos, int end_pos, int samp
get PSD

Return pair of ampl and freq arrays with len N / 2 + 1

Parameters

- `data`: data to process
- `start_pos`: starting position to calc PSD
- `end_pos`: end position to calc PSD, total_len must be a power of two
- `sampling_rate`: sampling rate
- `window`: window function

Pair< double[], double[]> get_psd_welch (double[] data, int nfft, int overlap, int sam
get PSD using Welch Method

Return pair of ampl and freq arrays

Parameters

- `data`: data to process
- `nfft`: size of FFT, must be power of two
- `overlap`: overlap between FFT Windows, must be between 0 and nfft
- `sampling_rate`: sampling rate
- `window`: window function

double **get_band_power** (Pair<double[], double[]> *psd*, double *freq_start*, double *freq_end*)
get band power

Return band power

Parameters

- `psd`: PSD from get_psd or get_log_psd
- `freq_start`: lowest frequency of band
- `freq_end`: highest frequency of band

int **get_nearest_power_of_two** (int *value*)
calculate nearest power of two

void write_file (double[][] data, String file_name, String file_mode)
write data to csv file, in file data will be transposed

double [][] read_file (String file_name)
read data from file, transpose it back to original format

enum DetrendOperations
enum to store all supported detrend operations

Public Functions

int **get_code** ( )

brainflow::DetrendOperations (final int code)

Public Members

brainflow::NONE =(0)

brainflow::CONSTANT =(1)

brainflow::LINEAR =(2)

Public Static Functions

String brainflow::string_from_code (final int code)

DetrendOperations brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::detrend_operation

Private Static Attributes

final Map< Integer, DetrendOperations > brainflow::dt_map = new HashMap<Integer, Det

enum ExitCode

Public Functions

int **get_code** ( )

brainflow::ExitCode (final int code)

Public Members

brainflow::STATUS_OK =(0)

brainflow::PORT_ALREADY_OPEN_ERROR =(1)

brainflow::UNABLE_TO_OPEN_PORT_ERROR =(2)

brainflow::SET_PORT_ERROR =(3)

brainflow::BOARD_WRITE_ERROR =(4)

brainflow::INCOMMING_MSG_ERROR =(5)

brainflow::INITIAL_MSG_ERROR =(6)

brainflow::BOARD_NOT_READY_ERROR =(7)

brainflow::STREAM_ALREADY_RUN_ERROR =(8)

brainflow::INVALID_BUFFER_SIZE_ERROR =(9)

brainflow::STREAM_THREAD_ERROR =(10)

brainflow::STREAM_THREAD_IS_NOT_RUNNING =(11)

brainflow::EMPTY_BUFFER_ERROR =(12)

brainflow::INVALID_ARGUMENTS_ERROR =(13)

brainflow::UNSUPPORTED_BOARD_ERROR =(14)

brainflow::BOARD_NOT_CREATED_ERROR =(15)

brainflow::ANOTHER_BOARD_IS_CREATED_ERROR =(16)

brainflow::GENERAL_ERROR =(17)

brainflow::SYNC_TIMEOUT_ERROR =(18)

brainflow::JSON_NOT_FOUND_ERROR =(19)

brainflow::NO_SUCH_DATA_IN_JSON_ERROR =(20)

brainflow::CLASSIFIER_IS_NOT_PREPARED_ERROR =(21)

brainflow::ANOTHER_CLASSIFIER_IS_PREPARED_ERROR =(22)

brainflow::UNSUPPORTED_CLASSIFIER_AND_METRIC_COMBINATION_ERROR =(23)

Public Static Functions

String brainflow::string_from_code (final int code)

ExitCode brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::exit_code

Private Static Attributes

final Map< Integer, ExitCode > brainflow::ec_map = new HashMap<Integer, ExitCode> ()

enum FilterTypes

enum to store all possible filter types

Public Functions

int **get_code** ( )

brainflow::FilterTypes (final int code)

Public Members

brainflow::BUTTERWORTH =(0)

brainflow::CHEBYSHEV_TYPE_1 =(1)

brainflow::BESSEL =(2)

Public Static Functions

String brainflow::string_from_code (final int code)

FilterTypes brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::filter_type

Private Static Attributes

final Map< Integer, FilterTypes > brainflow::ft_map = new HashMap<Integer, FilterTyp

enum IpProtocolType

Public Functions

int **get_code** ( )

brainflow::IpProtocolType (final int code)

Public Members

brainflow::NONE =(0)

brainflow::UDP =(1)

brainflow::TCP =(2)

Public Static Functions

String brainflow::string_from_code (final int code)

IpProtocolType brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::protocol

Private Static Attributes

final Map< Integer, IpProtocolType > brainflow::ip_map = new HashMap<Integer, IpProt

enum LogLevels

Public Functions

int get_code ( )

brainflow::LogLevels (final int code)

Public Members

brainflow::LEVEL_TRACE =(0)

brainflow::LEVEL_DEBUG =(1)

brainflow::LEVEL_INFO =(2)

brainflow::LEVEL_WARN =(3)

brainflow::LEVEL_ERROR =(4)

brainflow::LEVEL_CRITICAL =(5)

brainflow::LEVEL_OFF =(6)

Public Static Functions

String brainflow::string_from_code (final int code)

LogLevels brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::log_level

Private Static Attributes

final Map< Integer, LogLevels > brainflow::ll_map = new HashMap<Integer, LogLevels>

class brainflow::brainflow::**MLModel**

Public Functions

MLModel(*BrainFlowModelParams params*)
Create MLModel object

void **prepare**()
Prepare classifier

Exceptions

- *BrainFlowError*:

void **release**()
Release classifier

Exceptions

- *BrainFlowError*:

double predict (double[] data)
Get score of classifier

Exceptions

- *BrainFlowError*:

Public Static Functions

void **enable_ml_logger**()
enable ML logger with level INFO

void **enable_dev_ml_logger**()
enable ML logger with level TRACE

void **disable_ml_logger**()
disable BrainFlow logger

void **set_log_file**(String *log_file*)
redirect logger from stderr to a file

enum WindowFunctions

Public Functions

int **get_code**()

brainflow::WindowFunctions (final int code)

Public Members

brainflow::NO_WINDOW =(0)

brainflow::HANNING =(1)

brainflow::HAMMING =(2)

brainflow::BLACKMAN_HARRIS =(3)

Public Static Functions

String brainflow::string_from_code (final int code)

WindowFunctions brainflow::from_code (final int code)

brainflow::[static initializer]

Private Members

final int brainflow::window

Private Static Attributes

final Map< Integer, WindowFunctions > brainflow::window_map = new HashMap<Integer, W

3.4 C# API Reference

To simplify 2D array manipulation we use Accord Library.

Content of brainflow namespace:

enum brainflow::**LogLevels**

Values:

enumerator LEVEL_TRACE = 0

enumerator LEVEL_DEBUG = 1

enumerator LEVEL_INFO = 2

enumerator LEVEL_WARN = 3

enumerator LEVEL_ERROR = 4

enumerator LEVEL_CRITICAL = 5

enumerator LEVEL_OFF = 6

enum brainflow::**CustomExitCodes**

Values:

enumerator **STATUS_OK** = 0

enumerator **PORT_ALREADY_OPEN_ERROR** = 1

enumerator **UNABLE_TO_OPEN_PORT_ERROR** = 2

enumerator **SET_PORT_ERROR** = 3

enumerator **BOARD_WRITE_ERROR** = 4

enumerator **INCOMMING_MSG_ERROR** = 5

enumerator **INITIAL_MSG_ERROR** = 6

enumerator **BOARD_NOT_READY_ERROR** = 7

enumerator **STREAM_ALREADY_RUN_ERROR** = 8

enumerator **INVALID_BUFFER_SIZE_ERROR** = 9

enumerator **STREAM_THREAD_ERROR** = 10

enumerator **STREAM_THREAD_IS_NOT_RUNNING** = 11

enumerator **EMPTY_BUFFER_ERROR** = 12

enumerator **INVALID_ARGUMENTS_ERROR** = 13

enumerator **UNSUPPORTED_BOARD_ERROR** = 14

enumerator **BOARD_NOT_CREATED_ERROR** = 15

enumerator **ANOTHER_BOARD_IS_CREATED_ERROR** = 16

enumerator **GENERAL_ERROR** = 17

enumerator **SYNC_TIMEOUT_ERROR** = 18

enumerator **JSON_NOT_FOUND_ERROR** = 19

enumerator **NO_SUCH_DATA_IN_JSON_ERROR** = 20

enumerator **CLASSIFIER_IS_NOT_PREPARED_ERROR** = 21

enumerator **ANOTHER_CLASSIFIER_IS_PREPARED_ERROR** = 22

enumerator **UNSUPPORTED_CLASSIFIER_AND_METRIC_COMBINATION_ERROR** = 23

enum brainflow::**BoardIds**

Values:

enumerator **PLAYBACK_FILE_BOARD** = -3

enumerator **STREAMING_BOARD** = -2

enumerator **SYNTHETIC_BOARD** = -1

enumerator **CYTON_BOARD** = 0

enumerator **GANGLION_BOARD** = 1

enumerator **CYTON_DAISY_BOARD** = 2

enumerator **GALEA_BOARD** = 3

enumerator **GANGLION_WIFI_BOARD** = 4

enumerator **CYTON_WIFI_BOARD** = 5

enumerator **CYTON_DAISY_WIFI_BOARD** = 6

enumerator BRAINBIT_BOARD = 7

enumerator UNICORN_BOARD = 8

enumerator CALLIBRI_EEG_BOARD = 9

enumerator CALLIBRI_EMG_BOARD = 10

enumerator CALLIBRI_ECG_BOARD = 11

enumerator FASCIA_BOARD = 12

enumerator NOTION_1_BOARD = 13

enumerator NOTION_2_BOARD = 14

enumerator IRONBCI_BOARD = 15

enumerator FREEEEG32_BOARD = 17

enum brainflow::**IpProtocolType**

Values:

enumerator NONE = 0

enumerator UDP = 1

enumerator TCP = 2

enum brainflow::**FilterTypes**

Values:

enumerator BUTTERWORTH = 0

enumerator CHEBYSHEV_TYPE_1 = 1

enumerator BESSEL = 2

enum brainflow::**AggOperations**

Values:

enumerator MEAN = 0

enumerator MEDIAN = 1

enumerator EACH = 2

enum brainflow::**WindowFunctions**

Values:

enumerator NO_WINDOW = 0

enumerator HANNING = 1

enumerator HAMMING = 2

enumerator BLACKMAN_HARRIS = 3

enum brainflow::**DetrendOperations**

Values:

enumerator NONE = 0

enumerator CONSTANT = 1

enumerator LINEAR = 2

enum brainflow::**BrainFlowMetrics**

Values:

enumerator RELAXATION = 0

enumerator CONCENTRATION = 1

enum brainflow::**BrainFlowClassifiers**
Values:

enumerator REGRESSION = 0

enumerator KNN = 1

enumerator SVM = 2

enumerator LDA = 3

class brainflow::brainflow::**BoardShim**
BoardShim class to communicate with a board

Public Functions

BoardShim(int *board_id*, *BrainFlowInputParams* *input_params*)
Create an instance of BoardShim class

Parameters

- board_id
- input_params

void **prepare_session**()
prepare BrainFlow's streaming session, allocate required resources

string **config_board**(string *config*)
send string to a board, use this method carefully and only if you understand what you are doing

Parameters

- config

void **start_stream**(int *buffer_size* = 3600 * 250, string *streamer_params* = "")
start streaming thread, store data in internal ringbuffer

Parameters

- buffer_size: size of internal ringbuffer
- streamer_params: supported values: file://%file_name%:w, file://%file_name%:a, streaming_board://multicast_group_ip%:port%

void **stop_stream**()
stop streaming thread, doesnt release other resources

void **release_session**()
release BrainFlow's session

bool **is_prepared**()
check session status

summary> Get Board Id, for some boards can be different than provided /summary>

Return session status

Return Master board id

int **get_board_id**()

int **get_board_data_count**()
get number of packages in ringbuffer

Return number of packages

double [,] get_current_board_data (int num_samples)
get latest collected data, doesnt remove it from ringbuffer

Return latest collected data, can be less than "num_samples"

Parameters

- num_samples

double [,] get_board_data ()
get all collected data and remove it from ringbuffer

Return all collected data

Public Members

int **board_id**
BrainFlow's board id

Public Static Functions

int **get_sampling_rate**(int *board_id*)
get sampling rate for this board id

Return sampling rate

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_package_num_channel**(int *board_id*)
get row index in returned by *get_board_data()* 2d array which hold package nums

Return row num in 2d array

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_timestamp_channel**(int *board_id*)
get row index which hold timestamps

Return row num in 2d array

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_battery_channel** (int *board_id*)
get row undex which holds battery level

Return row num in 2d array

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int **get_num_rows** (int *board_id*)
get number of rows in returned by *get_board_data()* 2d array

Return number of rows in 2d array

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

string [] get_eeg_names (int board_id)
get names of EEG channels in 10-20 system. Only if electrodes have fixed locations

Return array of 10-20 locations

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_eeg_channels (int board_id)
get row indices of EEG channels for this board, for some board we can not split EMG.. data and return the same array for all of them

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_emg_channels (int board_id)

get row indices of EMG channels for this board, for some board we can not split EMG.. data and return the same array for all of them

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_ecg_channels (int board_id)

get row indices of ECG channels for this board, for some board we can not split EMG.. data and return the same array for all of them

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_eog_channels (int board_id)

get row indices of EOG channels for this board, for some board we can not split EMG.. data and return the same array for all of them

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_exg_channels (int board_id)

get row indices of EXG channels for this board

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_eda_channels (int board_id)
get row indices of EDA channels for this board, for some board we can not split EMG.. data and return the same array for all of them

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_ppg_channels (int board_id)
get row indeces which hold ppg data

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_accel_channels (int board_id)
get row indices which hold accel data

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_analog_channels (int board_id)
get row indices which hold analog data

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_gyro_channels (int board_id)
get row indices which hold gyro data

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_other_channels (int board_id)
get other channels for this board

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_temperature_channels (int board_id)
get temperature channels for this board

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

int [] get_resistance_channels (int board_id)
get resistance channels for this board

Return array of row nums

Parameters

- board_id

Exceptions

- *BrainFlowException*: If this board has no such data exit code is UNSUPPORTED_BOARD_ERROR

void **set_log_level** (int *log_level*)
set log level, logger is disabled by default

Parameters

- log_level

void **enable_board_logger**()
enable BrainFlow's logger with level INFO

void **disable_board_logger**()
disable BrainFlow's logger

void **enable_dev_board_logger**()
enable BrainFLow's logger with level TRACE

void **set_log_file**(string *log_file*)
redirect BrainFlow's logger from stderr to file

Parameters

- `log_file`

void **log_message**(int *log_level*, string *message*)
send your own log message to BrainFlow's logger

Parameters

- `log_level`
- `message`

class `brainflow::brainflow::`**BrainFlowException** : **public** Exception
BrainFlowException class to notify about errors

Public Functions

BrainFlowException(int *code*)

Public Members

int **exit_code**
exit code returned from low level API

class `brainflow::brainflow::`**BrainFlowInputParams**
Check SuportedBoards to get information about fields which are required for specific board

Public Functions

BrainFlowInputParams()

string **to_json**()

Public Members

string **serial_port**
serial port name

string **mac_address**
MAC address

string **ip_address**
IP address

int **ip_port**
PORT

int **ip_protocol**
IP protocol, use IpProtocolType

string **other_info**
you can provide additional info to low level API using this field

int **timeout**
timeout for device discovery or connection

string **serial_number**
serial number

string **file**
file

class brainflow::brainflow::**BrainFlowModelParams**
Describe model

Public Functions

BrainFlowModelParams(int *metric*, int *classifier*)

string **to_json**()

Public Members

int **metric**
metric to caclulate

int **classifier**
classifier to use

string **file**
path to model file

string **other_info**
other info

class brainflow::brainflow::**DataFilter**
DataFilter class to perform signal processing

Public Static Functions

void **enable_data_logger**()
enable Data logger with level INFO

void **disable_data_logger**()
disable Data logger

void **enable_dev_data_logger**()
enable Data logger with level TRACE

void **set_log_file**(string *log_file*)
redirect BrainFlow's logger from stderr to file

Parameters

- log_file

double [] perform_lowpass (double[] data, int sampling_rate, double cutoff, int order,
perform lowpass filter, unlike other bindings instead in-place calculation it returns new array

Return filtered data

Parameters

- data
- sampling_rate
- cutoff
- order
- filter_type
- ripple

double [] perform_highpass (double[] data, int sampling_rate, double cutoff, int order
perform highpass filter, unlike other bindings instead in-place calculation it returns new array

Return filtered data

Parameters

- data
- sampling_rate
- cutoff
- order
- filter_type
- ripple

double [] perform_bandpass (double[] data, int sampling_rate, double center_freq, doub
perform bandpass filter, unlike other bindings instead in-place calculation it returns new array

Return filtered data

Parameters

- data
- sampling_rate
- center_freq
- band_width
- order
- filter_type
- ripple

double [] perform_bandstop (double[] data, int sampling_rate, double center_freq, doub
perform bandstop filter, unlike other bindings instead in-place calculation it returns new array

Return filtered data

Parameters

- data
- sampling_rate
- center_freq
- band_width
- order

- filter_type
- ripple

double [] perform_rolling_filter (double[] data, int period, int operation)
perform moving average or moving median filter, unlike other bindings instead in-place calculation it returns new array

Return filered data

Parameters

- data
- period
- operation

double [] detrend (double[] data, int operation)
detrend, unlike other bindings instead in-place calculation it returns new array

Return data with removed trend

Parameters

- data
- operation

double [] perform_downsampling (double[] data, int period, int operation)
perform data downsampling, it just aggregates data without applying lowpass filter

Return data after downsampling

Parameters

- data
- period
- operation

Tuple< double[], int[]> perform_wavelet_transform (double[] data, string wavelet, int
perform wavelet transform

Return tuple of wavelet coeffs in format [A(J) D(J) D(J-1) ….. D(1)] where J is decomposition level, A - app coeffs, D - detailed coeffs, and array with lengths for each block

Parameters

- data: data for wavelet transform
- wavelet: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2.4,bior2.6,bior2.8,bior3.1 ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- decomposition_level: decomposition level

double [] perform_inverse_wavelet_transform (Tuple< double[], int[]> wavelet_data, int
perform inverse wavelet transorm

Return restored data

Parameters

- wavelet_data: tuple returned by perform_wavelet_transform

- `original_data_len`: size of original data before direct wavelet transform
- `wavelet`: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2.4,bior2.6,bior2.8,bior3.1 ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- `decomposition_level`: level of decomposition

double [] perform_wavelet_denoising (double[] data, string wavelet, int decomposition_
perform wavelet based denoising

Return denoised data

Parameters

- `data`: data for denoising
- `wavelet`: db1..db15,haar,sym2..sym10,coif1..coif5,bior1.1,bior1.3,bior1.5,bior2.2,bior2.4,bior2.6,bior2.8,bior3.1 ,bior3.7,bior3.9,bior4.4,bior5.5,bior6.8
- `decomposition_level`: level of decomposition in wavelet transform

Complex [] perform_fft (double[] data, int start_pos, int end_pos, int window)
perform direct fft

Return complex array of size N / 2 + 1 of fft data

Parameters

- `data`: data for fft
- `start_pos`: start pos
- `end_pos`: end pos, end_pos - start_pos must be a power of 2
- `window`: window function

double [] perform_ifft (Complex[] data)
perform inverse fft

Return restored data

Parameters

- `data`: data from perform_fft

void write_file (double[,] data, string file_name, string file_mode)
write data to csv file, data will be transposed

Parameters

- `data`
- `file_name`
- `file_mode`

double [,] read_file (string file_name)
read data from file, data will be transposed back to original format

Return

Parameters

- `file_name`

int **get_nearest_power_of_two** (int *value*)
calculate nearest power of two

Return nearest power of two

Parameters

- value

Tuple< double[], double[]> get_avg_band_powers (double[,] data, int[] channels, int sa
calculate avg and stddev bandpowers across channels

Return Tuple of avgs and stddev arrays

Parameters

- data: 2d array with values
- channels: rows of data array which should be used for calculation
- sampling_rate: sampling rate
- apply_filters: apply bandpass and bandstop filters before calculation

Tuple< double[], double[]> get_psd (double[] data, int start_pos, int end_pos, int samp
calculate PSD

Return Tuple of ampls and freqs arrays of size N / 2 + 1

Parameters

- data: data for PSD
- start_pos: start pos
- end_pos: end pos, end_pos - start_pos must be a power of 2
- sampling_rate: sampling rate
- window: window function

Tuple< double[], double[]> get_psd_welch (double[] data, int nfft, int overlap, int sa
calculate PSD using Welch method

Return Tuple of ampls and freqs arrays

Parameters

- data: data for log PSD
- nfft: FFT Size
- overlap: FFT Window overlap, must be between 0 and nfft
- sampling_rate: sampling rate
- window: window function

double **get_band_power** (Tuple<double[], double[]> *psd*, double *start_freq*, double *stop_freq*)
calculate band power

Return band power

Parameters

- psd: psd data returned by get_psd or get_psd_welch

- `start_freq`: lowest frequency of band
- `stop_freq`: highest frequency of band

class brainflow::brainflow::**MLModel**

Public Functions

MLModel (*BrainFlowModelParams input_params*)
Create an instance of MLModel class

Parameters

- `input_params`

void **prepare** ()
Prepare classifier

void **release** ()
Release classifier

double predict (double[] data)
Get score of classifier

Public Static Functions

void **enable_ml_logger** ()
enable ML logger with level INFO

void **disable_ml_logger** ()
disable ML logger

void **enable_dev_ml_logger** ()
enable ML logger with level TRACE

void **set_log_file** (string *log_file*)
redirect BrainFlow's logger from stderr to file

Parameters

- `log_file`

3.5 R API Reference

R binding is a wrapper on top of Python binding. It is implemented using reticulate.

Check R samples to see how to use it.

Full code for R binding:

```
#' @import reticulate
NULL

#' @export
brainflow_python <- NULL
#' @export
```

(continues on next page)

(continued from previous page)

```
np <- NULL
#' @export
pandas <- NULL
sys <- NULL
type_map <- NULL

.onLoad <- function (libname, pkgname)
{
    brainflow_python <<- import ('brainflow', delay_load = TRUE)
    np <<- import ('numpy', delay_load = TRUE)
    pandas <<- import ('pandas', delay_load = TRUE)
    sys <<- import ('sys', delay_load = TRUE)
    type_map <<- function (type)
    {
        if (is.character (type))
        {
            return (list (
                'float32' = np$float32,
                'float64' = np$float64,
                'auto' = NULL
            )[[type]])
        }
        type
    }
}
```

3.6 Matlab API Reference

Matlab binding calls CC++ code as any other binding, it's not compatible with Octave. Use Matlab examples and API reference for other languaes as a starting point.

A few general rules to keep in mind:

- Use char arrays instead strings to work with BrainFlow API, it means 'my_string' instead "my_string", otherwise you will get calllib error
- Use int32 values intead enums, it means int32 (BoardIDs.SYNTHETIC_BOARD) instead BoardIDs.SYNTHETIC_BOARD, the same is true for all enums in BrainFlow API

Like here:

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (2)
board_shim.stop_stream ()
data = board_shim.get_current_board_data (20);
board_shim.release_session ();

DataFilter.write_file (data, 'data.csv', 'w');
restored_data = DataFilter.read_file ('data.csv');
```

3.7 Julia API Reference

Julia binding calls CC++ code as any other binding. Use Julia examples and API reference for other languaes as a starting point.

Since Julia is not Object-Oriented language, there is no DataFilter class. BoardShim class exists but all BoardShim class methods were moved to BrainFlow package and you need to pass BoardShim object to them.

Like here:

```
import brainflow


# specify logging library to use
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_current_board_data(32, board_shim)
brainflow.release_session(board_shim)

brainflow.write_file(data, "test.csv", "w")
restored_data = brainflow.read_file("test.csv")

println("Original Data")
println(data)
println("Restored Data")
println(restored_data)
```

CHAPTER

FOUR

DATA FORMAT DESCRIPTION

4.1 Units of Measure

For EEG, EMG, etc BrainFlow returns uV.

For timestamps BrainFlow uses UNIX timestamp, this count starts at the Unix Epoch on January 1st, 1970 at UTC. Precision is microsecond, but for some boards timestamps are generated on PC side as soon as package was received.

You can compare BrainFlow's timestamp with time returned by code like this:

```
import time
print (time.time ())
```

4.2 Generic Format Description

Methods like:

```
get_board_data ()
get_current_board_data (max_num_packages)
```

Return 2d double array [num_channels x num_data_points], rows of this array represent different channels like EEG channels, EMG channels, Accel channels, Timesteps and so on, while columns in this array represent actual packages from a board.

Exact format for this array is board specific. To keep the API uniform, we have methods like:

```
# these methods return an array of rows in this 2d array containing eeg\emg\ecg\accel␣
↪data
get_eeg_channels (board_id)
get_emg_channels (board_id)
get_ecg_channels (board_id)
get_accel_channels (board_id)
# and so on, check docs for full list
# also we have methods to get sampling rate from board id, get number of timestamp␣
↪channel and others
get_sampling_rate (board_id)
get_timestamp_channel (board_id)
# and so on
```

For some boards like OpenBCI Cyton, OpenBCI Ganglion, etc we cannot separate EMG, EEG, EDA and ECG and in this case we return exactly the same array for all these methods but for some devices EMG and EEG channels will differ.

If board has no such data these methods throw an exception with UNSUPPORTED_BOARD_ERROR exit code.

Using the methods above, you can write completely board agnostic code and switch boards using a single parameter! Even if you have only one board using these methods you can easily switch to Synthetic Board or Streaming Board.

4.3 OpenBCI Specific Data

4.3.1 Special Channels for OpenBCI Cyton Based Boards

Cyton-based boards from OpenBCI support different output formats, described here.

For Cyton based boards, we add Cyton End byte to a first channel from:

```
get_other_channels (board_id)
```

If Cyton End byte is equal to 0xC0 we add accel data. To get rows which contain accel data use:

```
get_accel_channels (board_id)
```

If Cyton End byte is equal to 0xC1 we add analog data. To get rows which contain analog data use:

```
get_analog_channels (board_id)
```

For analog data, we return int32 values. But since from low level API, we return double array, these values are converted to double without any changes.

Also we add raw unprocessed bytes to the second and next channels returned by:

```
get_other_channels (board_id)
```

If Cyton End Byte is outside this range, we drop the entire package.

Check this example for details:

```
import argparse
import time
import numpy as np

import brainflow
from brainflow.board_shim import BoardShim, BrainFlowInputParams, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes

def main ():
    parser = argparse.ArgumentParser ()
    # use docs to check which parameters are required for specific board, e.g. for␣
↪Cyton - set serial port
    parser.add_argument ('--ip-port', type = int, help  = 'ip port', required = False,
↪ default = 0)
    parser.add_argument ('--ip-protocol', type = int, help  = 'ip protocol, check␣
↪IpProtocolType enum', required = False, default = 0)
    parser.add_argument ('--ip-address', type = str, help  = 'ip address', required =␣
↪False, default = '')
    parser.add_argument ('--serial-port', type = str, help  = 'serial port', required␣
↪= False, default = '')
    parser.add_argument ('--mac-address', type = str, help  = 'mac address', required␣
↪= False, default = '')
```

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```
    parser.add_argument ('--other-info', type = str, help  = 'other info', required =␣
↪False, default = '')
    parser.add_argument ('--streamer-params', type = str, help  = 'other info',␣
↪required = False, default = '')
    parser.add_argument ('--board-id', type = int, help  = 'board id, check docs to␣
↪get a list of supported boards', required = True)
    parser.add_argument ('--log', action = 'store_true')
    args = parser.parse_args ()

    params = BrainFlowInputParams ()
    params.ip_port = args.ip_port
    params.serial_port = args.serial_port
    params.mac_address = args.mac_address
    params.other_info = args.other_info
    params.ip_address = args.ip_address
    params.ip_protocol = args.ip_protocol

    if (args.log):
        BoardShim.enable_dev_board_logger ()
    else:
        BoardShim.disable_board_logger ()

    board = BoardShim (args.board_id, params)
    board.prepare_session ()

    board.start_stream ()
    time.sleep (5)
    board.config_board ('/2') # enable analog mode only for Cyton Based Boards!
    time.sleep (5)
    data = board.get_board_data ()
    board.stop_stream ()
    board.release_session ()

    """
    data[BoardShim.get_other_channels(args.board_id)[0]] contains cyton end byte
    data[BoardShim.get_other_channels(args.board_id)[1....]] contains unprocessed␣
↪bytes
    if end byte is 0xC0 there are accel data in data[BoardShim.get_accel_
↪channels(args.board_id)[....]] else there are zeros
    if end byte is 0xC1 there are analog data in data[BoardShim.get_analog_
↪channels(args.board_id)[....]] else there are zeros
    """
    print (data[BoardShim.get_other_channels(args.board_id)[0]][0:5]) # should be␣
↪standard end byte 0xC0
    print (data[BoardShim.get_other_channels(args.board_id)[0]][-5:]) # should be␣
↪analog and byte 0xC1

    DataFilter.write_file (data, 'cyton_data.csv', 'w')


if __name__ == "__main__":
    main ()
```

CHAPTER

FIVE

CODE SAMPLES

Make sure that you've installed BrainFlow package before running the code samples below.

See *Installation Instructions* for details.

5.1 Python

To run some signal processing samples, you may need to install:

- matplotlib
- pandas
- mne

BrainFlow doesn't use these packages and doesn't install them, but the packages will be used in demos below.

5.1.1 Python Get Data from a Board

```
import argparse
import time
import numpy as np

import brainflow
from brainflow.board_shim import BoardShim, BrainFlowInputParams
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations


def main ():
    parser = argparse.ArgumentParser ()
    # use docs to check which parameters are required for specific board, e.g. for␣
↪Cyton - set serial port
    parser.add_argument ('--timeout', type = int, help  = 'timeout for device␣
↪discovery or connection', required = False, default = 0)
    parser.add_argument ('--ip-port', type = int, help  = 'ip port', required = False,
↪ default = 0)
    parser.add_argument ('--ip-protocol', type = int, help  = 'ip protocol, check␣
↪IpProtocolType enum', required = False, default = 0)
    parser.add_argument ('--ip-address', type = str, help  = 'ip address', required =␣
↪False, default = '')
    parser.add_argument ('--serial-port', type = str, help  = 'serial port', required␣
↪= False, default = '')
    parser.add_argument ('--mac-address', type = str, help  = 'mac address', required␣
↪= False, default = '')
```

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```
    parser.add_argument ('--other-info', type = str, help  = 'other info', required =␣
↪False, default = '')
    parser.add_argument ('--streamer-params', type = str, help  = 'streamer params',␣
↪required = False, default = '')
    parser.add_argument ('--serial-number', type = str, help  = 'serial number',␣
↪required = False, default = '')
    parser.add_argument ('--board-id', type = int, help  = 'board id, check docs to␣
↪get a list of supported boards', required = True)
    parser.add_argument ('--file', type = str, help  = 'file', required = False,␣
↪default = '')
    parser.add_argument ('--log', action = 'store_true')
    args = parser.parse_args ()

    params = BrainFlowInputParams ()
    params.ip_port = args.ip_port
    params.serial_port = args.serial_port
    params.mac_address = args.mac_address
    params.other_info = args.other_info
    params.serial_number = args.serial_number
    params.ip_address = args.ip_address
    params.ip_protocol = args.ip_protocol
    params.timeout = args.timeout
    params.file = args.file

    if (args.log):
        BoardShim.enable_dev_board_logger ()
    else:
        BoardShim.disable_board_logger ()

    board = BoardShim (args.board_id, params)
    board.prepare_session ()

    # board.start_stream () # use this for default options
    board.start_stream (45000, args.streamer_params)
    time.sleep (10)
    # data = board.get_current_board_data (256) # get latest 256 packages or less,␣
↪doesnt remove them from internal buffer
    data = board.get_board_data () # get all data and remove it from internal buffer
    board.stop_stream ()
    board.release_session ()

    print (data)


if __name__ == "__main__":
    main ()
```

5.1.2 Python Read Write File

```
import argparse
import time
import numpy as np
import pandas as pd

import brainflow
from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations


def main ():
    BoardShim.enable_dev_board_logger ()

    # use synthetic board for demo
    params = BrainFlowInputParams ()
    board = BoardShim (BoardIds.SYNTHETIC_BOARD.value, params)
    board.prepare_session ()
    board.start_stream ()
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (10)
    data = board.get_current_board_data (20) # get 20 latest data points dont remove␣
↪them from internal buffer
    board.stop_stream ()
    board.release_session ()

    # demo how to convert it to pandas DF and plot data
    eeg_channels = BoardShim.get_eeg_channels (BoardIds.SYNTHETIC_BOARD.value)
    df = pd.DataFrame (np.transpose (data))
    print ('Data From the Board')
    print (df.head (10))

    # demo for data serialization using brainflow API, we recommend to use it instead␣
↪pandas.to_csv()
    DataFilter.write_file (data, 'test.csv', 'w') # use 'a' for append mode
    restored_data = DataFilter.read_file ('test.csv')
    restored_df = pd.DataFrame (np.transpose (restored_data))
    print ('Data From the File')
    print (restored_df.head (10))


if __name__ == "__main__":
    main ()
```

5.1.3 Python Downsample Data

```
import time
import numpy as np

import brainflow
from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations

```

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```
def main ():
    BoardShim.enable_dev_board_logger ()

    # use synthetic board for demo
    params = BrainFlowInputParams ()
    board = BoardShim (BoardIds.SYNTHETIC_BOARD.value, params)
    board.prepare_session ()
    board.start_stream ()
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (10)
    data = board.get_current_board_data (20) # get 20 latest data points dont remove␣
↪them from internal buffer
    board.stop_stream ()
    board.release_session ()

    eeg_channels = BoardShim.get_eeg_channels (BoardIds.SYNTHETIC_BOARD.value)
    # demo for downsampling, it just aggregates data
    for count, channel in enumerate (eeg_channels):
        print ('Original data for channel %d:' % channel)
        print (data[channel])
        if count == 0:
            downsampled_data = DataFilter.perform_downsampling (data[channel], 3,␣
↪AggOperations.MEDIAN.value)
        elif count == 1:
            downsampled_data = DataFilter.perform_downsampling (data[channel], 2,␣
↪AggOperations.MEAN.value)
        else:
            downsampled_data = DataFilter.perform_downsampling (data[channel], 2,␣
↪AggOperations.EACH.value)
        print ('Downsampled data for channel %d:' % channel)
        print (downsampled_data)


if __name__ == "__main__":
    main ()
```

5.1.4 Python Transforms

```
import argparse
import time
import brainflow
import numpy as np

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations,␣
↪WindowFunctions


def main ():
    BoardShim.enable_dev_board_logger ()

    # use synthetic board for demo
    params = BrainFlowInputParams ()
```

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```
    board_id = BoardIds.SYNTHETIC_BOARD.value
    sampling_rate = BoardShim.get_sampling_rate (board_id)
    board = BoardShim (board_id, params)
    board.prepare_session ()
    board.start_stream ()
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (10)
    data = board.get_current_board_data (DataFilter.get_nearest_power_of_two␣
↪(sampling_rate))
    board.stop_stream ()
    board.release_session ()

    eeg_channels = BoardShim.get_eeg_channels (board_id)
    # demo for transforms
    for count, channel in enumerate (eeg_channels):
        print ('Original data for channel %d:' % channel)
        print (data[channel])
        # demo for wavelet transforms
        # wavelet_coeffs format is[A(J) D(J) D(J-1) ..... D(1)] where J is␣
↪decomposition level, A - app coeffs, D - detailed coeffs
        # lengths array stores lengths for each block
        wavelet_coeffs, lengths = DataFilter.perform_wavelet_transform (data[channel],
↪ 'db5', 3)
        app_coefs = wavelet_coeffs[0: lengths[0]]
        detailed_coeffs_first_block = wavelet_coeffs[lengths[0] : lengths[1]]
        # you can do smth with wavelet coeffs here, for example denoising works via␣
↪thresholds
        # for wavelets coefficients
        restored_data = DataFilter.perform_inverse_wavelet_transform ((wavelet_coeffs,
↪ lengths), data[channel].shape[0], 'db5', 3)
        print ('Restored data after wavelet transform for channel %d:' % channel)
        print (restored_data)

        # demo for fft, len of data must be a power of 2
        fft_data = DataFilter.perform_fft (data[channel], WindowFunctions.NO_WINDOW.
↪value)
        # len of fft_data is N / 2 + 1
        restored_fft_data = DataFilter.perform_ifft (fft_data)
        print ('Restored data after fft for channel %d:' % channel)
        print (restored_fft_data)


if __name__ == "__main__":
    main ()
```

5.1.5 Python Signal Filtering

```
import argparse
import time
import brainflow
import numpy as np

import pandas as pd
import matplotlib
matplotlib.use ('Agg')
import matplotlib.pyplot as plt

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations


def main ():
    BoardShim.enable_dev_board_logger ()

    # use synthetic board for demo
    params = BrainFlowInputParams ()
    board_id = BoardIds.SYNTHETIC_BOARD.value
    board = BoardShim (board_id, params)
    board.prepare_session ()
    board.start_stream ()
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (10)
    data = board.get_board_data ()
    board.stop_stream ()
    board.release_session ()

    # demo how to convert it to pandas DF and plot data
    eeg_channels = BoardShim.get_eeg_channels (board_id)
    df = pd.DataFrame (np.transpose (data))
    plt.figure ()
    df[eeg_channels].plot (subplots = True)
    plt.savefig ('before_processing.png')

    # for demo apply different filters to different channels, in production choose one
    for count, channel in enumerate (eeg_channels):
        # filters work in-place
        if count == 0:
            DataFilter.perform_bandpass (data[channel], BoardShim.get_sampling_rate␣
↪(board_id), 15.0, 6.0, 4, FilterTypes.BESSEL.value, 0)
        elif count == 1:
            DataFilter.perform_bandstop (data[channel], BoardShim.get_sampling_rate␣
↪(board_id), 30.0, 1.0, 3, FilterTypes.BUTTERWORTH.value, 0)
        elif count == 2:
            DataFilter.perform_lowpass (data[channel], BoardShim.get_sampling_rate␣
↪(board_id), 20.0, 5, FilterTypes.CHEBYSHEV_TYPE_1.value, 1)
        elif count == 3:
            DataFilter.perform_highpass (data[channel], BoardShim.get_sampling_rate␣
↪(board_id), 3.0, 4, FilterTypes.BUTTERWORTH.value, 0)
        elif count == 4:
            DataFilter.perform_rolling_filter (data[channel], 3, AggOperations.MEAN.
↪value)
```

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```
        elif count == 5:
            DataFilter.perform_rolling_filter (data[channel], 3, AggOperations.MEDIAN.
↪value)

    df = pd.DataFrame (np.transpose (data))
    plt.figure ()
    df[eeg_channels].plot (subplots = True)
    plt.savefig ('after_processing.png')


if __name__ == "__main__":
    main ()
```

5.1.6 Python Denoising

```
import argparse
import time
import brainflow
import numpy as np

import pandas as pd
import matplotlib
matplotlib.use ('Agg')
import matplotlib.pyplot as plt

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations


def main ():
    BoardShim.enable_dev_board_logger ()

    # use synthetic board for demo
    params = BrainFlowInputParams ()
    board_id = BoardIds.SYNTHETIC_BOARD.value
    board = BoardShim (board_id, params)
    board.prepare_session ()
    board.start_stream ()
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (20)
    data = board.get_board_data ()
    board.stop_stream ()
    board.release_session ()

    # demo how to convert it to pandas DF and plot data
    eeg_channels = BoardShim.get_eeg_channels (board_id)
    df = pd.DataFrame (np.transpose (data))
    plt.figure ()
    df[eeg_channels].plot (subplots = True)
    plt.savefig ('before_processing.png')

    # demo for denoising, apply different methods to different channels for demo
    for count, channel in enumerate (eeg_channels):
        # first of all you can try simple moving median or moving average with␣
↪different window size
```

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```
        if count == 0:
            DataFilter.perform_rolling_filter (data[channel], 3, AggOperations.MEAN.
↪value)
        elif count == 1:
            DataFilter.perform_rolling_filter (data[channel], 3, AggOperations.MEDIAN.
↪value)
        # if methods above dont work for your signal you can try wavelet based␣
↪denoising
        # feel free to try different functions and decomposition levels
        elif count == 2:
            DataFilter.perform_wavelet_denoising (data[channel], 'db6', 3)
        elif count == 3:
            DataFilter.perform_wavelet_denoising (data[channel], 'bior3.9', 3)
        elif count == 4:
            DataFilter.perform_wavelet_denoising (data[channel], 'sym7', 3)
        elif count == 5:
            # with synthetic board this one looks like the best option, but it␣
↪depends on many circumstances
            DataFilter.perform_wavelet_denoising (data[channel], 'coif3', 3)


    df = pd.DataFrame (np.transpose (data))
    plt.figure ()
    df[eeg_channels].plot (subplots = True)
    plt.savefig ('after_processing.png')


if __name__ == "__main__":
    main ()
```

5.1.7 Python MNE Integration

```
import time
import numpy as np
import matplotlib
matplotlib.use ('Agg')
import matplotlib.pyplot as plt
import pandas as pd

import brainflow
from brainflow.board_shim import BoardShim, BrainFlowInputParams, BoardIds

import mne
from mne.channels import read_layout


def main():
    BoardShim.enable_dev_board_logger ()
    # use synthetic board for demo
    params = BrainFlowInputParams ()
    board = BoardShim (BoardIds.SYNTHETIC_BOARD.value, params)
    board.prepare_session ()
    board.start_stream ()
    time.sleep (10)
    data = board.get_board_data ()
```

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```
    board.stop_stream ()
    board.release_session ()

    eeg_channels = BoardShim.get_eeg_channels (BoardIds.SYNTHETIC_BOARD.value)
    eeg_data = data[eeg_channels, :]
    eeg_data = eeg_data / 1000000 # BrainFlow returns uV, convert to V for MNE

    # Creating MNE objects from brainflow data arrays
    ch_types = ['eeg'] * len (eeg_channels)
    ch_names = BoardShim.get_eeg_names (BoardIds.SYNTHETIC_BOARD.value)
    sfreq = BoardShim.get_sampling_rate (BoardIds.SYNTHETIC_BOARD.value)
    info = mne.create_info (ch_names = ch_names, sfreq = sfreq, ch_types = ch_types)
    raw = mne.io.RawArray (eeg_data, info)
    # its time to plot something!
    raw.plot_psd (average = True)
    plt.savefig ('psd.png')


if __name__ == '__main__':
    main ()
```

5.1.8 Python Band Power

```
import argparse
import time
import brainflow
import numpy as np

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations,␣
↪WindowFunctions, DetrendOperations


def main ():
    BoardShim.enable_dev_board_logger ()

    # use synthetic board for demo
    params = BrainFlowInputParams ()
    board_id = BoardIds.SYNTHETIC_BOARD.value
    sampling_rate = BoardShim.get_sampling_rate (board_id)
    board = BoardShim (board_id, params)
    board.prepare_session ()
    board.start_stream ()
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (10)
    nfft = DataFilter.get_nearest_power_of_two (sampling_rate)
    data = board.get_board_data ()
    board.stop_stream ()
    board.release_session ()

    eeg_channels = BoardShim.get_eeg_channels (board_id)
    # second eeg channel of synthetic board is a sine wave at 10Hz, should see huge␣
↪alpha
    eeg_channel = eeg_channels[1]
```

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```
    # optional detrend
    DataFilter.detrend (data[eeg_channel], DetrendOperations.LINEAR.value)
    psd = DataFilter.get_psd_welch (data[eeg_channel], nfft, nfft // 2, sampling_rate,
↪ WindowFunctions.BLACKMAN_HARRIS.value)

    band_power_alpha = DataFilter.get_band_power (psd, 7.0, 13.0)
    band_power_beta = DataFilter.get_band_power (psd, 14.0, 30.0)
    print ("alpha/beta:%f", band_power_alpha / band_power_beta)

    # fail test if ratio is not smth we expect
    if (band_power_alpha / band_power_beta < 100):
        raise ValueError ('Wrong Ratio')


if __name__ == "__main__":
    main ()
```

5.1.9 Python EEG Metrics

```
import argparse
import time
import brainflow
import numpy as np

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds,
↪BrainFlowError
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations,␣
↪WindowFunctions, DetrendOperations
from brainflow.ml_model import MLModel, BrainFlowMetrics, BrainFlowClassifiers,␣
↪BrainFlowModelParams
from brainflow.exit_codes import *


def main ():
    BoardShim.enable_board_logger ()
    DataFilter.enable_data_logger ()
    MLModel.enable_ml_logger ()

    parser = argparse.ArgumentParser ()
    # use docs to check which parameters are required for specific board, e.g. for␣
↪Cyton - set serial port
    parser.add_argument ('--timeout', type = int, help  = 'timeout for device␣
↪discovery or connection', required = False, default = 0)
    parser.add_argument ('--ip-port', type = int, help  = 'ip port', required = False,
↪ default = 0)
    parser.add_argument ('--ip-protocol', type = int, help  = 'ip protocol, check␣
↪IpProtocolType enum', required = False, default = 0)
    parser.add_argument ('--ip-address', type = str, help  = 'ip address', required =␣
↪False, default = '')
    parser.add_argument ('--serial-port', type = str, help  = 'serial port', required␣
↪= False, default = '')
    parser.add_argument ('--mac-address', type = str, help  = 'mac address', required␣
↪= False, default = '')
    parser.add_argument ('--other-info', type = str, help  = 'other info', required =␣
↪False, default = '')
```

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```
    parser.add_argument ('--streamer-params', type = str, help  = 'streamer params',␣
↪required = False, default = '')
    parser.add_argument ('--serial-number', type = str, help  = 'serial number',␣
↪required = False, default = '')
    parser.add_argument ('--board-id', type = int, help  = 'board id, check docs to␣
↪get a list of supported boards', required = True)
    parser.add_argument ('--file', type = str, help  = 'file', required = False,␣
↪default = '')
    args = parser.parse_args ()

    params = BrainFlowInputParams ()
    params.ip_port = args.ip_port
    params.serial_port = args.serial_port
    params.mac_address = args.mac_address
    params.other_info = args.other_info
    params.serial_number = args.serial_number
    params.ip_address = args.ip_address
    params.ip_protocol = args.ip_protocol
    params.timeout = args.timeout
    params.file = args.file

    board = BoardShim (args.board_id, params)
    master_board_id = board.get_board_id ()
    sampling_rate = BoardShim.get_sampling_rate (master_board_id)
    board.prepare_session ()
    board.start_stream (45000, args.streamer_params)
    BoardShim.log_message (LogLevels.LEVEL_INFO.value, 'start sleeping in the main␣
↪thread')
    time.sleep (5) # recommended window size for eeg metric calculation is at least 4␣
↪seconds, bigger is better
    data = board.get_board_data ()
    board.stop_stream ()
    board.release_session ()

    eeg_channels = BoardShim.get_eeg_channels (int (master_board_id))
    bands = DataFilter.get_avg_band_powers (data, eeg_channels, sampling_rate, True)
    feature_vector = np.concatenate ((bands[0], bands[1]))
    print(feature_vector)

    # calc concentration
    concentration_params = BrainFlowModelParams (BrainFlowMetrics.CONCENTRATION.value,
↪ BrainFlowClassifiers.KNN.value)
    concentration = MLModel (concentration_params)
    concentration.prepare ()
    print ('Concentration: %f' % concentration.predict (feature_vector))
    concentration.release ()

    # calc relaxation
    relaxation_params = BrainFlowModelParams (BrainFlowMetrics.RELAXATION.value,␣
↪BrainFlowClassifiers.REGRESSION.value)
    relaxation = MLModel (relaxation_params)
    relaxation.prepare ()
    print ('Relaxation: %f' % relaxation.predict (feature_vector))
    relaxation.release ()

if __name__ == "__main__":
    main ()
```

5.2 Java

5.2.1 Java Get Data from a Board

```
package brainflow.examples;

import java.util.Arrays;

import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.LogLevels;

public class BrainFlowGetData
{

    public static void main (String[] args) throws Exception
    {
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = parse_args (args, params);
        BoardShim board_shim = new BoardShim (board_id, params);

        board_shim.prepare_session ();
        // board_shim.start_stream (); // use this for default options
        board_shim.start_stream (450000, "file://file_stream.csv:w");
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in
↪the main thread");
        Thread.sleep (5000);
        board_shim.stop_stream ();
        System.out.println (board_shim.get_board_data_count ());
        double[][] data = board_shim.get_current_board_data (30); // doesnt flush it
↪from ring buffer
        // double[][] data = board_shim.get_board_data (); // get all data and flush
        // from ring buffer
        for (int i = 0; i < data.length; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
        board_shim.release_session ();
    }

    private static int parse_args (String[] args, BrainFlowInputParams params)
    {
        int board_id = -1;
        for (int i = 0; i < args.length; i++)
        {
            if (args[i].equals ("--ip-address"))
            {
                params.ip_address = args[i + 1];
            }
            if (args[i].equals ("--serial-port"))
            {
                params.serial_port = args[i + 1];
            }
            if (args[i].equals ("--ip-port"))
            {
```

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```
                params.ip_port = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--ip-protocol"))
            {
                params.ip_protocol = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--other-info"))
            {
                params.other_info = args[i + 1];
            }
            if (args[i].equals ("--board-id"))
            {
                board_id = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--timeout"))
            {
                params.timeout = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--serial-number"))
            {
                params.serial_number = args[i + 1];
            }
            if (args[i].equals ("--file"))
            {
                params.file = args[i + 1];
            }
        }
        return board_id;
    }
}
```

5.2.2 Java Read Write File

```
package brainflow.examples;

import java.util.Arrays;

import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.DataFilter;
import brainflow.LogLevels;

public class Serialization
{

    public static void main (String[] args) throws Exception
    {
        // use Synthetic board for demo
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = BoardIds.SYNTHETIC_BOARD.get_code ();
        BoardShim board_shim = new BoardShim (board_id, params);

        board_shim.prepare_session ();
```

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```
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in
↪the main thread");
        Thread.sleep (5000);
        board_shim.stop_stream ();
        System.out.println (board_shim.get_board_data_count ());
        int num_rows = BoardShim.get_num_rows (board_id);
        double[][] data = board_shim.get_current_board_data (30);
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
        board_shim.release_session ();

        // demo for serialization
        DataFilter.write_file (data, "test.csv", "w");
        double[][] restored_data = DataFilter.read_file ("test.csv");
        System.out.println ("After Serialization:");
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (restored_data[i]));
        }
    }

}
```

5.2.3 Java Downsample Data

```
package brainflow.examples;

import java.util.Arrays;

import brainflow.AggOperations;
import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.DataFilter;
import brainflow.LogLevels;

public class Downsampling
{

    public static void main (String[] args) throws Exception
    {
        // use synthetic board for demo
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = BoardIds.SYNTHETIC_BOARD.get_code ();

        BoardShim board_shim = new BoardShim (board_id, params);
        board_shim.prepare_session ();
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in
↪the main thread");
        Thread.sleep (5000);
```

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```
        board_shim.stop_stream ();
        System.out.println (board_shim.get_board_data_count ());
        double[][] data = board_shim.get_current_board_data (30);
        board_shim.release_session ();

        int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
        for (int i = 0; i < eeg_channels.length; i++)
        {
            System.out.println ("Original data:");
            System.out.println (Arrays.toString (data[i]));
            // keep each second element, you can use MEAN and MEDIAN as well
            double[] downsampled_data = DataFilter.perform_downsampling (data[eeg_
↪channels[i]], 2,
                    AggOperations.EACH.get_code ());
            System.out.println ("Downsampled data:");
            System.out.println (Arrays.toString (downsampled_data));
        }
    }
}
```

5.2.4 Java Transforms

```
package brainflow.examples;

import java.util.Arrays;

import org.apache.commons.lang3.tuple.Pair;
import org.apache.commons.math3.complex.Complex;

import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.DataFilter;
import brainflow.LogLevels;
import brainflow.WindowFunctions;

public class Transforms
{

    public static void main (String[] args) throws Exception
    {
        // use synthetic board for demo
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = BoardIds.SYNTHETIC_BOARD.get_code ();
        BoardShim board_shim = new BoardShim (board_id, params);

        board_shim.prepare_session ();
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in␣
↪the main thread");
        Thread.sleep (10000);
        board_shim.stop_stream ();
        System.out.println (board_shim.get_board_data_count ());
        int num_rows = BoardShim.get_num_rows (board_id);
```

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```
        double[][] data = board_shim.get_current_board_data (64);
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
        board_shim.release_session ();

        int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
        for (int i = 0; i < eeg_channels.length; i++)
        {
            System.out.println ("Original data:");
            System.out.println (Arrays.toString (data[eeg_channels[i]]));
            // demo for wavelet transform
            // Pair of coeffs array in format[A(J) D(J) D(J-1) ..... D(1)] where J is a
            // decomposition level, A - app coeffs, D - detailed coeffs, and array which
            // stores
            // length for each block, len of this array is decomposition_length + 1
            Pair<double[], int[]> wavelet_data = DataFilter.perform_wavelet_transform(data[eeg_channels[i]], "db4", 3);
            // print approximation coeffs
            for (int j = 0; j < wavelet_data.getRight ()[0]; j++)
            {
                System.out.print (wavelet_data.getLeft ()[j] + " ");
            }
            System.out.println ();
            // you can do smth with these coeffs here, for example denoising works via
            // thresholds for wavelet coeffs
            double[] restored_data = DataFilter.perform_inverse_wavelet_transform(wavelet_data,
                    data[eeg_channels[i]].length, "db4", 3);
            System.out.println ("Restored data after wavelet:");
            System.out.println (Arrays.toString (restored_data));

            // demo for fft works only for power of 2
            // len of fft_data is N / 2 + 1
            Complex[] fft_data = DataFilter.perform_fft (data[eeg_channels[i]], 0, 64,
                    WindowFunctions.NO_WINDOW.get_code ());
            double[] restored_fft_data = DataFilter.perform_ifft (fft_data);
            System.out.println ("Restored data after fft:");
            System.out.println (Arrays.toString (restored_fft_data));
        }
    }
}
```

5.2.5 Java Signal Filtering

```
package brainflow.examples;

import java.util.Arrays;

import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.DataFilter;
import brainflow.FilterTypes;
import brainflow.LogLevels;

public class SignalFiltering
{

    public static void main (String[] args) throws Exception
    {
        // use synthetic board for demo
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = BoardIds.SYNTHETIC_BOARD.get_code ();
        BoardShim board_shim = new BoardShim (board_id, params);

        board_shim.prepare_session ();
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in␣
↪the main thread");
        Thread.sleep (5000);
        board_shim.stop_stream ();
        System.out.println (board_shim.get_board_data_count ());
        int num_rows = BoardShim.get_num_rows (board_id);
        double[][] data = board_shim.get_current_board_data (30);
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
        board_shim.release_session ();

        int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
        for (int i = 0; i < eeg_channels.length; i++)
        {
            // just for demo - apply different filters to different eeg channels
            switch (i)
            {
                case 0:
                    DataFilter.perform_lowpass (data[eeg_channels[i]], BoardShim.get_
↪sampling_rate (board_id), 20.0, 4,
                            FilterTypes.BESSEL.get_code (), 0.0);
                    break;
                case 1:
                    DataFilter.perform_highpass (data[eeg_channels[i]], BoardShim.get_
↪sampling_rate (board_id), 5.0, 4,
                            FilterTypes.BUTTERWORTH.get_code (), 0.0);
                    break;
                case 2:
                    DataFilter.perform_bandpass (data[eeg_channels[i]], BoardShim.get_
↪sampling_rate (board_id), 15.0,
```

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```
                            5.0, 4, FilterTypes.CHEBYSHEV_TYPE_1.get_code (), 1.0);
                    break;
                case 3:
                    DataFilter.perform_bandstop (data[eeg_channels[i]], BoardShim.get_
↪sampling_rate (board_id), 50.0,
                            1.0, 4, FilterTypes.CHEBYSHEV_TYPE_1.get_code (), 1.0);
                    break;
            }
        }
        System.out.println ("After signal processing:");
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
    }
}
```

5.2.6 Java Denoising

```
package brainflow.examples;

import brainflow.AggOperations;
import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.DataFilter;
import brainflow.LogLevels;

import java.util.Arrays;

public class Denoising
{

    public static void main (String[] args) throws Exception
    {
        // use synthetic board for demo
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = BoardIds.SYNTHETIC_BOARD.get_code ();
        BoardShim board_shim = new BoardShim (board_id, params);

        board_shim.prepare_session ();
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in␣
↪the main thread");
        Thread.sleep (5000);
        board_shim.stop_stream ();
        System.out.println (board_shim.get_board_data_count ());
        int num_rows = BoardShim.get_num_rows (board_id);
        double[][] data = board_shim.get_current_board_data (64);
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
        board_shim.release_session ();
```

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```
        int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
        for (int i = 0; i < eeg_channels.length; i++)
        {
            // just for demo - apply different methods to different eeg channels
            switch (i)
            {
                // first of all you can try simple moving average or moving median
                case 0:
                    DataFilter.perform_rolling_filter (data[eeg_channels[i]], 3,␣
↪AggOperations.MEAN.get_code ());
                    break;
                case 1:
                    DataFilter.perform_rolling_filter (data[eeg_channels[i]], 3,␣
↪AggOperations.MEDIAN.get_code ());
                    break;
                // if methods above dont work good for you you should try wavelet␣
↪based
                // denoising
                default:
                    // try different functions and different decomposition levels here
                    DataFilter.perform_wavelet_denoising (data[eeg_channels[i]], "db4
↪", 3);
                    break;
            }
        }
        System.out.println ("After signal processing:");
        for (int i = 0; i < num_rows; i++)
        {
            System.out.println (Arrays.toString (data[i]));
        }
    }
}
```

5.2.7 Java Band Power

```
package brainflow.examples;

import java.util.Arrays;

import org.apache.commons.lang3.tuple.Pair;
import org.apache.commons.math3.complex.Complex;

import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowInputParams;
import brainflow.DataFilter;
import brainflow.DetrendOperations;
import brainflow.LogLevels;
import brainflow.WindowFunctions;

public class BandPower
{

    public static void main (String[] args) throws Exception
```

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```
    {
        // use synthetic board for demo
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = BoardIds.SYNTHETIC_BOARD.get_code ();
        BoardShim board_shim = new BoardShim (board_id, params);
        int sampling_rate = BoardShim.get_sampling_rate (board_id);
        int nfft = DataFilter.get_nearest_power_of_two (sampling_rate);

        board_shim.prepare_session ();
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in␣
↪the main thread");
        Thread.sleep (10000);
        board_shim.stop_stream ();
        double[][] data = board_shim.get_board_data ();
        board_shim.release_session ();

        int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
        // seconds channel of synthetic board has big 'alpha' use it for test
        int eeg_channel = eeg_channels[1];
        // optional: detrend before psd
        DataFilter.detrend (data[eeg_channel], DetrendOperations.LINEAR.get_code ());
        Pair<double[], double[]> psd = DataFilter.get_psd_welch (data[eeg_channel],␣
↪nfft, nfft / 2, sampling_rate,
                WindowFunctions.HANNING.get_code ());
        double band_power_alpha = DataFilter.get_band_power (psd, 7.0, 13.0);
        double band_power_beta = DataFilter.get_band_power (psd, 14.0, 30.0);
        System.out.println ("Alpha/Beta Ratio: " + (band_power_alpha / band_power_
↪beta));
    }
}
```

5.2.8 Java EEG Metrics

```
package brainflow.examples;

import org.apache.commons.lang3.ArrayUtils;
import org.apache.commons.lang3.tuple.Pair;

import brainflow.BoardIds;
import brainflow.BoardShim;
import brainflow.BrainFlowClassifiers;
import brainflow.BrainFlowInputParams;
import brainflow.BrainFlowMetrics;
import brainflow.BrainFlowModelParams;
import brainflow.DataFilter;
import brainflow.LogLevels;
import brainflow.MLModel;

public class EEGMetrics
{

    public static void main (String[] args) throws Exception
    {
```

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```
        BoardShim.enable_board_logger ();
        BrainFlowInputParams params = new BrainFlowInputParams ();
        int board_id = parse_args (args, params);
        BoardShim board_shim = new BoardShim (board_id, params);
        int master_board_id = board_shim.get_board_id ();
        int sampling_rate = BoardShim.get_sampling_rate (master_board_id);
        int[] eeg_channels = BoardShim.get_eeg_channels (master_board_id);

        board_shim.prepare_session ();
        board_shim.start_stream (3600);
        BoardShim.log_message (LogLevels.LEVEL_INFO.get_code (), "Start sleeping in␣
↪the main thread");
        // recommended window size for eeg metric calculation is at least 4 seconds,
        // bigger is better
        Thread.sleep (5000);
        board_shim.stop_stream ();
        double[][] data = board_shim.get_board_data ();
        board_shim.release_session ();

        Pair<double[], double[]> bands = DataFilter.get_avg_band_powers (data, eeg_
↪channels, sampling_rate, true);
        double[] feature_vector = ArrayUtils.addAll (bands.getLeft (), bands.getRight␣
↪());
        BrainFlowModelParams model_params = new BrainFlowModelParams␣
↪(BrainFlowMetrics.CONCENTRATION.get_code (),
                BrainFlowClassifiers.REGRESSION.get_code ());
        MLModel concentration = new MLModel (model_params);
        concentration.prepare ();
        System.out.print ("Concentration: " + concentration.predict (feature_vector));
        concentration.release ();
    }

    private static int parse_args (String[] args, BrainFlowInputParams params)
    {
        int board_id = -1;
        for (int i = 0; i < args.length; i++)
        {
            if (args[i].equals ("--ip-address"))
            {
                params.ip_address = args[i + 1];
            }
            if (args[i].equals ("--serial-port"))
            {
                params.serial_port = args[i + 1];
            }
            if (args[i].equals ("--ip-port"))
            {
                params.ip_port = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--ip-protocol"))
            {
                params.ip_protocol = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--other-info"))
            {
                params.other_info = args[i + 1];
            }
```

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```
            if (args[i].equals ("--board-id"))
            {
                board_id = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--timeout"))
            {
                params.timeout = Integer.parseInt (args[i + 1]);
            }
            if (args[i].equals ("--serial-number"))
            {
                params.serial_number = args[i + 1];
            }
            if (args[i].equals ("--file"))
            {
                params.file = args[i + 1];
            }
        }
        return board_id;
    }
}
```

5.3 C#

5.3.1 C# Read Data from a Board

```
using System;
using brainflow;

using Accord.Math;

namespace test
{
    class GetBoardData
    {
        static void Main (string[] args)
        {
            BoardShim.enable_dev_board_logger ();

            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = parse_args (args, input_params);

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            // board_shim.start_stream (); // use this for default options
            board_shim.start_stream (450000, "file://file_stream.csv:w");
            System.Threading.Thread.Sleep (5000);
            board_shim.stop_stream ();
            double[,] unprocessed_data = board_shim.get_current_board_data (20);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
            foreach (var index in eeg_channels)
                Console.WriteLine ("[{0}]", string.Join (", ", unprocessed_data.
↪GetRow (index)));
            board_shim.release_session ();
```

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```
        }

        static int parse_args (string[] args, BrainFlowInputParams input_params)
        {
            int board_id = (int)BoardIds.SYNTHETIC_BOARD; //assume synthetic board by␣
↪default
            // use docs to get params for your specific board, e.g. set serial_port␣
↪for Cyton
            for (int i = 0; i < args.Length; i++)
            {
                if (args[i].Equals ("--ip-address"))
                {
                    input_params.ip_address = args[i + 1];
                }
                if (args[i].Equals ("--mac-address"))
                {
                    input_params.mac_address = args[i + 1];
                }
                if (args[i].Equals ("--serial-port"))
                {
                    input_params.serial_port = args[i + 1];
                }
                if (args[i].Equals ("--other-info"))
                {
                    input_params.other_info = args[i + 1];
                }
                if (args[i].Equals ("--ip-port"))
                {
                    input_params.ip_port = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals ("--ip-protocol"))
                {
                    input_params.ip_protocol = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals ("--board-id"))
                {
                    board_id = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals("--timeout"))
                {
                    input_params.timeout = Convert.ToInt32(args[i + 1]);
                }
                if (args[i].Equals("--serial-number"))
                {
                    input_params.serial_number = args[i + 1];
                }
                if (args[i].Equals ("--file"))
                {
                    input_params.file = args[i + 1];
                }
            }
            return board_id;
        }
    }
}
```

5.3.2 C# Read Write File

```
using System;
using brainflow;

using Accord.Math;

namespace test
{
    class Serialization
    {
        static void Main (string[] args)
        {
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (5000);
            board_shim.stop_stream ();
            double[,] unprocessed_data = board_shim.get_current_board_data (20);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
            Console.WriteLine ("Before serialization:");
            foreach (var index in eeg_channels)
                Console.WriteLine ("[{0}]", string.Join (", ", unprocessed_data.
↪GetRow (index)));
            board_shim.release_session ();

            // demo for data serialization
            DataFilter.write_file (unprocessed_data, "test.csv", "w");
            double[,] restored_data = DataFilter.read_file ("test.csv");
            Console.WriteLine ("After Serialization:");
            foreach (var index in eeg_channels)
                Console.WriteLine ("[{0}]", string.Join (", ", restored_data.GetRow␣
↪(index)));
        }
    }
}
```

5.3.3 C# Downsample Data

```
using System;
using brainflow;

using Accord.Math;

namespace test
{
    class Downsampling
    {
        static void Main (string[] args)
        {
```

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```
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (5000);
            board_shim.stop_stream ();
            double[,] unprocessed_data = board_shim.get_current_board_data (20);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
            board_shim.release_session ();

            for (int i = 0; i < eeg_channels.Length; i++)
            {
                Console.WriteLine ("Before processing:");
                Console.WriteLine ("[{0}]", string.Join (", ", unprocessed_data.
↪GetRow(eeg_channels[i])));
                // you can use MEAN, MEDIAN or EACH for downsampling
                double[] filtered = DataFilter.perform_downsampling (unprocessed_data.
↪GetRow (eeg_channels[i]), 3, (int)AggOperations.MEDIAN);
                Console.WriteLine ("Before processing:");
                Console.WriteLine ("[{0}]", string.Join (", ", filtered));
            }
        }
    }
}
```

5.3.4 C# Transforms

```
using System;
using System.Numerics;
using brainflow;

using Accord.Math;

namespace test
{
    class Transforms
    {
        static void Main (string[] args)
        {
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (5000);
            board_shim.stop_stream ();
            double[,] unprocessed_data = board_shim.get_current_board_data (64);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
```

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```
            board_shim.release_session ();

            for (int i = 0; i < eeg_channels.Length; i++)
            {
                Console.WriteLine ("Original data:");
                Console.WriteLine ("[{0}]", string.Join (", ", unprocessed_data.
↪GetRow (eeg_channels[i])));
                // demo for wavelet transform
                // tuple of coeffs array in format[A(J) D(J) D(J-1) ..... D(1)] where␣
↪J is a
                // decomposition level, A - app coeffs, D - detailed coeffs, and␣
↪array which stores
                // length for each block, len of this array is decomposition_length +␣
↪1
                Tuple<double[], int[]> wavelet_data = DataFilter.perform_wavelet_
↪transform(unprocessed_data.GetRow (eeg_channels[i]), "db4", 3);
                // print app coeffs
                for (int j = 0; j < wavelet_data.Item2[0]; j++)
                {
                    Console.Write (wavelet_data.Item1[j] + " ");
                }
                Console.WriteLine ();
                // you can do smth with wavelet coeffs here, for example denoising␣
↪works via thresholds for wavelets coeffs
                double[] restored_data = DataFilter.perform_inverse_wavelet_transform␣
↪(wavelet_data, unprocessed_data.GetRow (eeg_channels[i]).Length, "db4", 3);
                Console.WriteLine ("Restored wavelet data:");
                Console.WriteLine ("[{0}]", string.Join (", ", restored_data));

                // demo for fft
                // end_pos - start_pos must be a power of 2
                Complex[] fft_data = DataFilter.perform_fft (unprocessed_data.GetRow␣
↪(eeg_channels[i]), 0, 64, (int)WindowFunctions.HAMMING);
                // len of fft_data is N / 2 + 1
                double[] restored_fft_data = DataFilter.perform_ifft (fft_data);
                Console.WriteLine ("Restored fft data:");
                Console.WriteLine ("[{0}]", string.Join (", ", restored_fft_data));
            }
        }
    }
}
```

5.3.5 C# Signal Filtering

```
using System;
using brainflow;

using Accord.Math;

namespace test
{
    class SignalFiltering
    {
        static void Main (string[] args)
        {
```

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```
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (5000);
            board_shim.stop_stream ();
            double[,] unprocessed_data = board_shim.get_current_board_data (20);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
            board_shim.release_session ();

            // for demo apply different filters to different channels
            double[] filtered;
            for (int i = 0; i < eeg_channels.Length; i++)
            {
                Console.WriteLine ("Before processing:");
                Console.WriteLine ("[{0}]", string.Join (", ", unprocessed_data.
↪GetRow (eeg_channels[i])));
                switch (i)
                {
                    case 0:
                        filtered = DataFilter.perform_lowpass (unprocessed_data.
↪GetRow(eeg_channels[i]), BoardShim.get_sampling_rate (board_id), 20.0, 4,␣
↪(int)FilterTypes.BESSEL, 0.0);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                    case 1:
                        filtered = DataFilter.perform_highpass (unprocessed_data.
↪GetRow (eeg_channels[i]), BoardShim.get_sampling_rate (board_id), 2.0, 4,␣
↪(int)FilterTypes.BUTTERWORTH, 0.0);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                    case 2:
                        filtered = DataFilter.perform_bandpass (unprocessed_data.
↪GetRow (eeg_channels[i]), BoardShim.get_sampling_rate (board_id), 15.0, 5.0, 2,␣
↪(int)FilterTypes.BUTTERWORTH, 0.0);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                    case 3:
                        filtered = DataFilter.perform_bandstop (unprocessed_data.
↪GetRow (eeg_channels[i]), BoardShim.get_sampling_rate (board_id), 50.0, 1.0, 6,␣
↪(int)FilterTypes.CHEBYSHEV_TYPE_1, 1.0);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                }
            }
        }
    }
}
```

5.3.6 C# Denoising

```
using System;
using brainflow;

using Accord.Math;

namespace test
{
    class Denoising
    {
        static void Main (string[] args)
        {
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (5000);
            board_shim.stop_stream ();
            double[,] unprocessed_data = board_shim.get_current_board_data (64);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
            foreach (var index in eeg_channels)
                Console.WriteLine ("[{0}]", string.Join (", ", unprocessed_data.
↪GetRow (index)));
            board_shim.release_session ();

            // for demo apply different methods to different channels
            double[] filtered;
            for (int i = 0; i < eeg_channels.Length; i++)
            {
                switch (i)
                {
                    // first of all you can try simple moving average or moving median
                    case 0:
                        filtered = DataFilter.perform_rolling_filter (unprocessed_
↪data.GetRow (eeg_channels[i]), 3, (int)AggOperations.MEAN);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                    case 1:
                        filtered = DataFilter.perform_rolling_filter (unprocessed_
↪data.GetRow (eeg_channels[i]), 3, (int)AggOperations.MEDIAN);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                    // if for your signal these methods dont work good you can try␣
↪wavelet based denoising
                    default:
                        // feel free to try different functions and different␣
↪decomposition levels
                        filtered = DataFilter.perform_wavelet_denoising (unprocessed_
↪data.GetRow (eeg_channels[i]), "db4", 3);
                        Console.WriteLine ("Filtered channel " + eeg_channels[i]);
```

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```
                        Console.WriteLine ("[{0}]", string.Join (", ", filtered));
                        break;
                }
            }
        }
    }
}
```

5.3.7 C# Band Power

```
using System;
using System.Numerics;
using brainflow;

using Accord.Math;

namespace test
{
    class BandPower
    {
        static void Main (string[] args)
        {
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;
            int sampling_rate = BoardShim.get_sampling_rate (board_id);
            int nfft = DataFilter.get_nearest_power_of_two(sampling_rate);

            BoardShim board_shim = new BoardShim (board_id, input_params);
            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (10000);
            board_shim.stop_stream ();
            double[,] data = board_shim.get_board_data ();
            int[] eeg_channels = BoardShim.get_eeg_channels (board_id);
            // use second channel of synthetic board to see 'alpha'
            int channel = eeg_channels[1];
            board_shim.release_session ();
            double[] detrend = DataFilter.detrend(data.GetRow(channel),␣
↪(int)DetrendOperations.LINEAR);
            Tuple<double[], double[]> psd = DataFilter.get_psd_welch (detrend, nfft,␣
↪nfft / 2, sampling_rate, (int)WindowFunctions.HANNING);
            double band_power_alpha = DataFilter.get_band_power (psd, 7.0, 13.0);
            double band_power_beta = DataFilter.get_band_power (psd, 14.0, 30.0);
            Console.WriteLine ("Alpha/Beta Ratio:" + (band_power_alpha/ band_power_
↪beta));
        }
    }
}
```

5.3.8 C# EEG Metrics

```
using System;
using System.Numerics;
using brainflow;

using Accord.Math;

namespace test
{
    class EEGMetrics
    {
        static void Main (string[] args)
        {
            // use synthetic board for demo
            BoardShim.enable_dev_board_logger ();
            BrainFlowInputParams input_params = new BrainFlowInputParams ();
            int board_id = parse_args (args, input_params);
            BoardShim board_shim = new BoardShim (board_id, input_params);
            int sampling_rate = BoardShim.get_sampling_rate (board_shim.get_board_id␣
↪());
            int nfft = DataFilter.get_nearest_power_of_two (sampling_rate);
            int[] eeg_channels = BoardShim.get_eeg_channels (board_shim.get_board_id␣
↪());

            board_shim.prepare_session ();
            board_shim.start_stream (3600);
            System.Threading.Thread.Sleep (10000);
            board_shim.stop_stream ();
            double[,] data = board_shim.get_board_data ();
            board_shim.release_session ();

            Tuple<double[], double[]> bands = DataFilter.get_avg_band_powers (data,␣
↪eeg_channels, sampling_rate, true);
            double[] feature_vector = bands.Item1.Concatenate (bands.Item2);
            BrainFlowModelParams model_params = new BrainFlowModelParams␣
↪((int)BrainFlowMetrics.CONCENTRATION, (int)BrainFlowClassifiers.REGRESSION);
            MLModel concentration = new MLModel (model_params);
            concentration.prepare ();
            Console.WriteLine ("Concentration: " + concentration.predict (feature_
↪vector));
            concentration.release ();
        }

        static int parse_args (string[] args, BrainFlowInputParams input_params)
        {
            int board_id = (int)BoardIds.SYNTHETIC_BOARD; //assume synthetic board by␣
↪default
            // use docs to get params for your specific board, e.g. set serial_port␣
↪for Cyton
            for (int i = 0; i < args.Length; i++)
            {
                if (args[i].Equals ("--ip-address"))
                {
                    input_params.ip_address = args[i + 1];
                }
                if (args[i].Equals ("--mac-address"))
```

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```
                {
                    input_params.mac_address = args[i + 1];
                }
                if (args[i].Equals ("--serial-port"))
                {
                    input_params.serial_port = args[i + 1];
                }
                if (args[i].Equals ("--other-info"))
                {
                    input_params.other_info = args[i + 1];
                }
                if (args[i].Equals ("--ip-port"))
                {
                    input_params.ip_port = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals ("--ip-protocol"))
                {
                    input_params.ip_protocol = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals ("--board-id"))
                {
                    board_id = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals ("--timeout"))
                {
                    input_params.timeout = Convert.ToInt32 (args[i + 1]);
                }
                if (args[i].Equals ("--serial-number"))
                {
                    input_params.serial_number = args[i + 1];
                }
                if (args[i].Equals ("--file"))
                {
                    input_params.file = args[i + 1];
                }
            }
            return board_id;
        }
    }
}
```

5.4 C++

To compile examples below for Linux or MacOS run:

```
cd tests/cpp/get_data_demo
mkdir build
cd build
cmake -DCMAKE_PREFIX_PATH=TYPE_FULL_PATH_TO_BRAINFLOW_INSTALLED_FOLDER ..
# e.g. cmake -DCMAKE_PREFIX_PATH=/home/andrey/brainflow/installed_linux ..
make
```

For Windows it's almost the same.

Make sure that compiled dynamic libraries exist in search path before running an executable by doing one of

the following:

- for Linux and MacOS add them to LD_LIBRARY_PATH env variable
- for Windows add them to PATH env variable
- or just copypaste them to the folder where your executable is located

5.4.1 CMake File Example

```
cmake_minimum_required (VERSION 3.10)
project (BRAINFLOW_GET_DATA)

set (CMAKE_CXX_STANDARD 11)
set (CMAKE_VERBOSE_MAKEFILE ON)

macro (configure_msvc_runtime)
    if (MSVC)
        # Default to statically-linked runtime.
        if ("${MSVC_RUNTIME}" STREQUAL "")
            set (MSVC_RUNTIME "static")
        endif ()
        # Set compiler options.
        set (variables
            CMAKE_C_FLAGS_DEBUG
            CMAKE_C_FLAGS_MINSIZEREL
            CMAKE_C_FLAGS_RELEASE
            CMAKE_C_FLAGS_RELWITHDEBINFO
            CMAKE_CXX_FLAGS_DEBUG
            CMAKE_CXX_FLAGS_MINSIZEREL
            CMAKE_CXX_FLAGS_RELEASE
            CMAKE_CXX_FLAGS_RELWITHDEBINFO
        )
        if (${MSVC_RUNTIME} STREQUAL "static")
            message(STATUS
                "MSVC -> forcing use of statically-linked runtime."
            )
            foreach (variable ${variables})
                if (${variable} MATCHES "/MD")
                    string (REGEX REPLACE "/MD" "/MT" ${variable} "${${variable}}")
                endif ()
            endforeach ()
        else ()
            message (STATUS
                "MSVC -> forcing use of dynamically-linked runtime."
            )
            foreach (variable ${variables})
                if (${variable} MATCHES "/MT")
                    string (REGEX REPLACE "/MT" "/MD" ${variable} "${${variable}}")
                endif ()
            endforeach ()
        endif ()
    endif ()
endmacro ()

# link msvc runtime statically
configure_msvc_runtime()
```

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```
find_package (
    brainflow CONFIG REQUIRED
)

add_executable (
    brainflow_get_data
    src/brainflow_get_data.cpp
)

target_include_directories (
    brainflow_get_data PUBLIC
    ${brainflow_INCLUDE_DIRS}
)

target_link_libraries (
    brainflow_get_data PUBLIC
    # for some systems(ubuntu for example) order matters
    ${BrainflowPath}
    ${MLModulePath}
    ${DataHandlerPath}
    ${BoardControllerPath}
)
```

5.4.2 C++ Read Data from a Board

```
#include <iostream>
#include <stdlib.h>
#include <string>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"

using namespace std;

void print_head (double **data_buf, int num_channels, int num_data_points);
bool parse_args (int argc, char *argv[], struct BrainFlowInputParams *params, int␣
↪*board_id);


int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    int board_id = 0;
    if (!parse_args (argc, argv, &params, &board_id))
    {
        return -1;
    }

    BoardShim::enable_dev_board_logger ();
```

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```
    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int res = 0;
    int num_rows = 0;

    try
    {
        board->prepare_session ();
        board->start_stream ();
        // board->start_stream (45000, (char *)"file://file_stream_test.csv:a"); //␣
↪store data in a
        // file directly during streaming
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (5000);
#else
        sleep (5);
#endif

        board->stop_stream ();
        int data_count = 0;
        data = board->get_board_data (&data_count);
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "read %d packages", data_
↪count);
        board->release_session ();
        // for STREAMING_BOARD and PLAYBACK_FILE_BOARD you have to query information␣
↪using board id
        // for master board because for STREAMING_BOARD data format is determined by␣
↪master board!
        if ((board_id == (int)BoardIds::STREAMING_BOARD) ||
            (board_id == (int)BoardIds::PLAYBACK_FILE_BOARD))
        {
            board_id = std::stoi (params.other_info);
            BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Use Board Id %d",␣
↪board_id);
        }
        num_rows = BoardShim::get_num_rows (board_id);
        std::cout << std::endl << "Data from the board" << std::endl << std::endl;
        print_head (data, num_rows, data_count);
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
        if (board->is_prepared ())
        {
            board->release_session ();
        }
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
```

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```
        }
    }
    delete[] data;
    delete board;

    return res;
}

void print_head (double **data_buf, int num_channels, int num_data_points)
{
    std::cout << "Total Channels for this board: " << num_channels << std::endl;
    int num_points = (num_data_points < 5) ? num_data_points : 5;
    for (int i = 0; i < num_channels; i++)
    {
        std::cout << "Channel " << i << ": ";
        for (int j = 0; j < num_points; j++)
        {
            std::cout << data_buf[i][j] << ",";
        }
        std::cout << std::endl;
    }
}

bool parse_args (int argc, char *argv[], struct BrainFlowInputParams *params, int␣
↪*board_id)
{
    bool board_id_found = false;
    for (int i = 1; i < argc; i++)
    {
        if (std::string (argv[i]) == std::string ("--board-id"))
        {
            if (i + 1 < argc)
            {
                i++;
                board_id_found = true;
                *board_id = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--ip-address"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->ip_address = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--ip-port"))
```

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```
        {
            if (i + 1 < argc)
            {
                i++;
                params->ip_port = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--serial-port"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->serial_port = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--ip-protocol"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->ip_protocol = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--timeout"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->timeout = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--other-info"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->other_info = std::string (argv[i]);
```

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```
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--mac-address"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->mac_address = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--serial-number"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->serial_number = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--file"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->file = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
    }
    if (!board_id_found)
    {
        std::cerr << "board id is not provided" << std::endl;
        return false;
    }
    return true;
}
```

5.4.3 C++ Read Write File

```
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"

using namespace std;

void print_head (double **data_buf, int num_channels, int num_data_points);

int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    // use synthetic board for demo
    int board_id = (int)BoardIds::SYNTHETIC_BOARD;

    BoardShim::enable_dev_board_logger ();

    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int res = 0;
    int num_rows = 0;

    try
    {
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (5000);
#else
        sleep (5);
#endif

        board->stop_stream ();
        int data_count = 0;
        data = board->get_board_data (&data_count);
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "read %d packages", data_
↪count);
        board->release_session ();
        num_rows = BoardShim::get_num_rows (board_id);
        std::cout << std::endl << "Data from the board" << std::endl << std::endl;
        print_head (data, num_rows, data_count);

        // demo for serialization
        DataFilter::write_file (
            data, num_rows, data_count, "test.csv", "w"); // use "a" for append mode
        int restored_num_rows = 0;
```

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```
        int restored_num_cols = 0;
        double **restored_data =
            DataFilter::read_file (&restored_num_rows, &restored_num_cols, "test.csv
↪");
        std::cout << std::endl
                  << "Data from the file, num packages is " << restored_num_cols <<␣
↪std::endl
                  << std::endl;
        print_head (restored_data, restored_num_rows, restored_num_cols);
        for (int i = 0; i < restored_num_rows; i++)
        {
            delete[] restored_data[i];
        }
        delete[] restored_data;
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete board;

    return res;
}

void print_head (double **data_buf, int num_channels, int num_data_points)
{
    std::cout << "Total Channels for this board: " << num_channels << std::endl;
    int num_points = (num_data_points < 5) ? num_data_points : 5;
    for (int i = 0; i < num_channels; i++)
    {
        std::cout << "Channel " << i << ": ";
        for (int j = 0; j < num_points; j++)
        {
            std::cout << data_buf[i][j] << ",";
        }
        std::cout << std::endl;
    }
}
```

5.4.4 C++ Downsample Data

```
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"

using namespace std;

void print_one_row (double *data, int num_data_points);

int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    // use synthetic board for demo
    int board_id = (int)BoardIds::SYNTHETIC_BOARD;

    BoardShim::enable_dev_board_logger ();

    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int *eeg_channels = NULL;
    int num_rows = 0;
    int res = 0;

    try
    {
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (5000);
#else
        sleep (5);
#endif

        board->stop_stream ();
        int data_count = 0;
        data = board->get_board_data (&data_count);
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "read %d packages", data_
↪count);
        board->release_session ();
        num_rows = BoardShim::get_num_rows (board_id);

        // downsample only eeg channels and print them
        int eeg_num_channels = 0;
        eeg_channels = BoardShim::get_eeg_channels (board_id, &eeg_num_channels);
        double *downsampled_data = NULL;
        int filtered_size = 0;
```

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```
        for (int i = 0; i < eeg_num_channels; i++)
        {
            std::cout << "Data from :" << eeg_channels[i] << " before downsampling " <
↪< std::endl;
            print_one_row (data[eeg_channels[i]], data_count);

            // just for demo apply different downsampling algorithms to different␣
↪channels
            // downsampling here doesnt apply lowpass filter for you, it just␣
↪aggregates data points
            switch (i)
            {
                case 0:
                    downsampled_data = DataFilter::perform_downsampling (data[eeg_
↪channels[i]],
                        data_count, 2, (int)AggOperations::MEAN, &filtered_size);
                    break;
                case 1:
                    downsampled_data = DataFilter::perform_downsampling (data[eeg_
↪channels[i]],
                        data_count, 3, (int)AggOperations::MEDIAN, &filtered_size);
                    break;
                default:
                    downsampled_data = DataFilter::perform_downsampling (data[eeg_
↪channels[i]],
                        data_count, 2, (int)AggOperations::EACH, &filtered_size);
                    break;
            }

            std::cout << "Data from :" << eeg_channels[i] << " after downsampling " <
↪< std::endl;
            print_one_row (downsampled_data, filtered_size);
            delete[] downsampled_data;
        }
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete[] eeg_channels;
    delete board;

    return res;
}

void print_one_row (double *data, int num_data_points)
{
```

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```
    // print only first 10 data points
    int num_points = (num_data_points < 10) ? num_data_points : 10;
    for (int i = 0; i < num_points; i++)
    {
        std::cout << data[i] << " ";
    }
    std::cout << std::endl;
}
```

5.4.5 C++ Transforms

```
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"

using namespace std;

void print_one_row (double *data, int num_data_points);

int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    // use synthetic board for demo
    int board_id = (int)BoardIds::SYNTHETIC_BOARD;

    BoardShim::enable_dev_board_logger ();

    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int *eeg_channels = NULL;
    int num_rows = 0;
    int res = 0;

    try
    {
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (10000);
#else
        sleep (10);
#endif

        board->stop_stream ();
        int data_count = 0;
```

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```
        data = board->get_current_board_data (128, &data_count);
        if (data_count != 128)
        {
            BoardShim::log_message ((int)LogLevels::LEVEL_ERROR,
                "read %d packages, for this test we want exactly 128 packages", data_
↪count);
            return (int)BrainFlowExitCodes::GENERAL_ERROR;
        }
        board->release_session ();
        num_rows = BoardShim::get_num_rows (board_id);

        int eeg_num_channels = 0;
        eeg_channels = BoardShim::get_eeg_channels (board_id, &eeg_num_channels);
        for (int i = 0; i < eeg_num_channels; i++)
        {
            // demo for wavelet transform
            // std::pair of coeffs array in format[A(J) D(J) D(J-1) ..... D(1)] where␣
↪J is a
            // decomposition level, A - app coeffs, D - detailed coeffs, and array␣
↪which stores
            // length for each block, len of this array is decomposition_length + 1
            std::pair<double *, int *> wavelet_output =
                DataFilter::perform_wavelet_transform (data[eeg_channels[i]], data_
↪count, "db4", 4);

            // you can do smth with wavelet coeffs here, for example denoising works␣
↪via thresholds
            // for wavelet coefficients
            std::cout << "approximation coefficients:" << std::endl;
            for (int i = 0; i < wavelet_output.second[0]; i++)
            {
                std::cout << wavelet_output.first[i] << " ";
            }
            std::cout << std::endl;
            std::cout << "first block of detailed coefficients:" << std::endl;
            for (int i = wavelet_output.second[0];
                 i < wavelet_output.second[0] + wavelet_output.second[1]; i++)
            {
                std::cout << wavelet_output.first[i] << " ";
            }
            std::cout << std::endl;

            double *restored_data = DataFilter::perform_inverse_wavelet_transform (
                wavelet_output, data_count, "db4", 4);

            std::cout << "Original data:" << std::endl;
            print_one_row (data[eeg_channels[i]], data_count);
            std::cout << "Restored after inverse wavelet transform data:" << std::
↪endl;
            print_one_row (restored_data, data_count);

            delete[] wavelet_output.first;
            delete[] restored_data;
            delete[] wavelet_output.second;

            // demo for fft
            // data count must be power of 2 for fft!
```

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```
            std::complex<double> *fft_data = DataFilter::perform_fft (
                data[eeg_channels[i]], data_count, (int)WindowFunctions::NO_WINDOW);
            // len of fft_data array is N / 2 + 1
            std::cout << "FFT coeffs:" << std::endl;
            for (int i = 0; i < data_count / 2 + 1; i++)
            {
                std::cout << fft_data[i] << " ";
            }
            std::cout << std::endl;
            double *restored_from_fft_data = DataFilter::perform_ifft (fft_data, data_
↪count);
            std::cout << "Restored after inverse fft transform data:" << std::endl;
            print_one_row (restored_from_fft_data, data_count);

            delete[] fft_data;
            delete[] restored_from_fft_data;
        }
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete[] eeg_channels;
    delete board;

    return res;
}

void print_one_row (double *data, int num_data_points)
{
    for (int i = 0; i < num_data_points; i++)
    {
        std::cout << data[i] << " ";
    }
    std::cout << std::endl;
}
```

5.4.6 C++ Signal Filtering

```
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"

using namespace std;

void print_head (double **data_buf, int num_channels, int num_data_points);

int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    // use synthetic board for demo
    int board_id = (int)BoardIds::SYNTHETIC_BOARD;

    BoardShim::enable_dev_board_logger ();
    DataFilter::enable_dev_data_logger ();

    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int *eeg_channels = NULL;
    int num_rows = 0;
    int res = 0;

    try
    {
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (5000);
#else
        sleep (5);
#endif

        board->stop_stream ();
        int data_count = 0;
        data = board->get_board_data (&data_count);
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "read %d packages", data_
↪count);
        board->release_session ();
        num_rows = BoardShim::get_num_rows (board_id);
        std::cout << std::endl << "Data from the board" << std::endl << std::endl;
        print_head (data, num_rows, data_count);

        int eeg_num_channels = 0;
        eeg_channels = BoardShim::get_eeg_channels (board_id, &eeg_num_channels);
```

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```
        int filtered_size = 0;
        double *downsampled_data = NULL;
        for (int i = 0; i < eeg_num_channels; i++)
        {
            switch (i)
            {
                // just for test and demo - apply different filters to different eeg
↪channels
                // signal filtering methods work in-place
                case 0:
                    DataFilter::perform_lowpass (data[eeg_channels[i]], data_count,
                        BoardShim::get_sampling_rate (board_id), 30.0, 3,
                        (int)FilterTypes::BUTTERWORTH, 0);
                    break;
                case 1:
                    DataFilter::perform_highpass (data[eeg_channels[i]], data_count,
                        BoardShim::get_sampling_rate (board_id), 5.0, 5,
                        (int)FilterTypes::CHEBYSHEV_TYPE_1, 1);
                    break;
                case 2:
                    DataFilter::perform_bandpass (data[eeg_channels[i]], data_count,
                        BoardShim::get_sampling_rate (board_id), 15.0, 5.0, 3,
                        (int)FilterTypes::BESSEL, 0);
                    break;
                default:
                    DataFilter::perform_bandstop (data[eeg_channels[i]], data_count,
                        BoardShim::get_sampling_rate (board_id), 30.0, 1.0, 3,
                        (int)FilterTypes::BUTTERWORTH, 0);
                    break;
            }
        }
        std::cout << std::endl << "Data after processing" << std::endl << std::endl;
        print_head (data, num_rows, data_count);
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete[] eeg_channels;
    delete board;

    return res;
}

void print_head (double **data_buf, int num_channels, int num_data_points)
{
    std::cout << "Total Channels for this board: " << num_channels << std::endl;
```

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```
    int num_points = (num_data_points < 5) ? num_data_points : 5;
    for (int i = 0; i < num_channels; i++)
    {
        std::cout << "Channel " << i << ": ";
        for (int j = 0; j < num_points; j++)
        {
            std::cout << data_buf[i][j] << ",";
        }
        std::cout << std::endl;
    }
}
```

5.4.7 C++ Denoising

```
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"

using namespace std;

void print_head (double **data_buf, int num_channels, int num_data_points);

int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    // use synthetic board for demo
    int board_id = (int)BoardIds::SYNTHETIC_BOARD;

    BoardShim::enable_dev_board_logger ();

    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int *eeg_channels = NULL;
    int num_rows = 0;
    int res = 0;

    try
    {
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (5000);
#else
        sleep (5);
#endif
```

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```
        board->stop_stream ();
        int data_count = 0;
        data = board->get_board_data (&data_count);
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "read %d packages", data_
↪count);
        board->release_session ();
        num_rows = BoardShim::get_num_rows (board_id);
        std::cout << std::endl << "Data from the board" << std::endl << std::endl;
        print_head (data, num_rows, data_count);

        int eeg_num_channels = 0;
        eeg_channels = BoardShim::get_eeg_channels (board_id, &eeg_num_channels);
        for (int i = 0; i < eeg_num_channels; i++)
        {
            switch (i)
            {
                // for demo apply different methods to different channels, in␣
↪production you should
                // choose one
                // first of all you can try simple moving average or moving median to␣
↪remove noise
                case 0:
                    DataFilter::perform_rolling_filter (
                        data[eeg_channels[i]], data_count, 3, (int)AggOperations::
↪MEDIAN);
                    break;
                case 1:
                    DataFilter::perform_rolling_filter (
                        data[eeg_channels[i]], data_count, 3, (int)AggOperations::
↪MEAN);
                    break;
                case 2:
                    DataFilter::perform_rolling_filter (
                        data[eeg_channels[i]], data_count, 5, (int)AggOperations::
↪MEDIAN);
                    break;
                case 3:
                    DataFilter::perform_rolling_filter (
                        data[eeg_channels[i]], data_count, 5, (int)AggOperations::
↪MEAN);
                    break;
                    // if moving average and moving median dont work well for your␣
↪signal you can
                    // try wavelet based denoising, feel free to try different␣
↪wavelet functions and
                    // decomposition levels
                case 4:
                    DataFilter::perform_wavelet_denoising (
                        data[eeg_channels[i]], data_count, "db4", 3);
                    break;
                case 5:
                    DataFilter::perform_wavelet_denoising (
                        data[eeg_channels[i]], data_count, "coif3", 3);
                    break;
            }
        }
```

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```
        std::cout << std::endl << "Data after denoising" << std::endl << std::endl;
        print_head (data, num_rows, data_count);
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete[] eeg_channels;
    delete board;

    return res;
}

void print_head (double **data_buf, int num_channels, int num_data_points)
{
    std::cout << "Total Channels for this board: " << num_channels << std::endl;
    int num_points = (num_data_points < 5) ? num_data_points : 5;
    for (int i = 0; i < num_channels; i++)
    {
        std::cout << "Channel " << i << ": ";
        for (int j = 0; j < num_points; j++)
        {
            std::cout << data_buf[i][j] << ",";
        }
        std::cout << std::endl;
    }
}
```

5.4.8 C++ Band Power

```
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"

using namespace std;

int main (int argc, char *argv[])
```

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```
{
    struct BrainFlowInputParams params;
    // use synthetic board for demo
    int board_id = (int)BoardIds::SYNTHETIC_BOARD;

    BoardShim::enable_dev_board_logger ();

    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int *eeg_channels = NULL;
    int num_rows = 0;
    int res = 0;
    int sampling_rate = BoardShim::get_sampling_rate (board_id);

    try
    {
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
#ifdef _WIN32
        Sleep (10000);
#else
        sleep (10);
#endif

        board->stop_stream ();
        int data_count = 0;
        int fft_len = DataFilter::get_nearest_power_of_two (sampling_rate);
        data = board->get_board_data (&data_count);
        board->release_session ();
        num_rows = BoardShim::get_num_rows (board_id);

        int eeg_num_channels = 0;
        eeg_channels = BoardShim::get_eeg_channels (board_id, &eeg_num_channels);
        // for synthetic board second channel is a sine wave at 10 Hz, should see big␣
↪alpha
        int channel = eeg_channels[1];
        // optional - detrend
        DataFilter::detrend (data[channel], data_count, (int)DetrendOperations::
↪LINEAR);
        std::pair<double *, double *> psd = DataFilter::get_psd_welch (data[channel],␣
↪data_count,
            fft_len, fft_len / 2, sampling_rate, (int)WindowFunctions::HANNING);
        // calc band power
        double band_power_alpha = DataFilter::get_band_power (psd, fft_len / 2 + 1, 7.
↪0, 13.0);
        double band_power_beta = DataFilter::get_band_power (psd, fft_len / 2 + 1, 14.
↪0, 30.0);
        std::cout << "alpha/beta:" << band_power_alpha / band_power_beta << std::endl;
        // fail test if unexpected ratio
        if (band_power_alpha / band_power_beta < 100)
        {
            res = -1;
        }
        delete[] psd.first;
        delete[] psd.second;
```

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```
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete[] eeg_channels;
    delete board;

    return res;
}
```

5.4.9 C++ EEG Metrics

```
#include <chrono>
#include <iostream>
#include <stdlib.h>

#ifdef _WIN32
#include <windows.h>
#else
#include <unistd.h>
#endif

#include "board_shim.h"
#include "data_filter.h"
#include "ml_model.h"

using namespace std;
using namespace std::chrono;


bool parse_args (int argc, char *argv[], struct BrainFlowInputParams *params, int␣
↪*board_id);

int main (int argc, char *argv[])
{
    struct BrainFlowInputParams params;
    int board_id = 0;
    if (!parse_args (argc, argv, &params, &board_id))
    {
        return -1;
    }

    BoardShim::enable_dev_board_logger ();
```

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```
    BoardShim *board = new BoardShim (board_id, params);
    double **data = NULL;
    int *eeg_channels = NULL;
    int num_rows = 0;
    int res = 0;
    int master_board_id = board->get_board_id ();

    int sampling_rate = BoardShim::get_sampling_rate (master_board_id);

    try
    {
        // Collect data from device
        board->prepare_session ();
        board->start_stream ();
        BoardShim::log_message ((int)LogLevels::LEVEL_INFO, "Start sleeping in the␣
↪main thread");
        // recommended window size for eeg metric calculation is at least 4 seconds,␣
↪bigger is
        // better
#ifdef _WIN32
        Sleep (5000);
#else
        sleep (5);
#endif
        int data_count = 0;
        data = board->get_board_data (&data_count);
        board->stop_stream ();
        std::cout << "Data Count: " << data_count << std::endl;
        board->release_session ();
        num_rows = BoardShim::get_num_rows (master_board_id);

        // Calc bandpowers and build feature vector
        int eeg_num_channels = 0;
        eeg_channels = BoardShim::get_eeg_channels (master_board_id, &eeg_num_
↪channels);
        std::pair<double *, double *> bands = DataFilter::get_avg_band_powers (
            data, data_count, eeg_channels, eeg_num_channels, sampling_rate, true);
        double feature_vector[10];
        for (int i = 0; i < 5; i++)
        {
            feature_vector[i] = bands.first[i];
            feature_vector[i + 5] = bands.second[i];
        }
        for (int i = 0; i < 10; i++)
        {
            std::cout << feature_vector[i] << " ";
        }
        std::cout << std::endl;

        // Testing all classifiers and metric types
        struct BrainFlowModelParams conc_model_params ((int)BrainFlowMetrics::
↪CONCENTRATION, (int)BrainFlowClassifiers::REGRESSION);
        MLModel concentration_model (conc_model_params);
        concentration_model.prepare ();
        std::cout << "Concentration Regression :" << concentration_model.predict␣
↪(feature_vector, 10) << std::endl;
        concentration_model.release ();
```

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```
        struct BrainFlowModelParams relax_model_params ((int)BrainFlowMetrics::
↪RELAXATION, (int)BrainFlowClassifiers::KNN);
        MLModel relaxation_model (relax_model_params);
        relaxation_model.prepare ();
        std::cout << "Relaxation KNN :" << relaxation_model.predict (feature_vector,␣
↪10) << std::endl;
        relaxation_model.release ();

        delete[] bands.first;
        delete[] bands.second;
    }
    catch (const BrainFlowException &err)
    {
        BoardShim::log_message ((int)LogLevels::LEVEL_ERROR, err.what ());
        res = err.exit_code;
    }

    if (data != NULL)
    {
        for (int i = 0; i < num_rows; i++)
        {
            delete[] data[i];
        }
    }
    delete[] data;
    delete[] eeg_channels;
    delete board;

    return res;
}


bool parse_args (int argc, char *argv[], struct BrainFlowInputParams *params, int␣
↪*board_id)
{
    bool board_id_found = false;
    for (int i = 1; i < argc; i++)
    {
        if (std::string (argv[i]) == std::string ("--board-id"))
        {
            if (i + 1 < argc)
            {
                i++;
                board_id_found = true;
                *board_id = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--ip-address"))
        {
            if (i + 1 < argc)
            {
```

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```
                i++;
                params->ip_address = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--ip-port"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->ip_port = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--serial-port"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->serial_port = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--ip-protocol"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->ip_protocol = std::stoi (std::string (argv[i]));
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--timeout"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->timeout = std::stoi (std::string (argv[i]));
            }
            else
            {
```

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```
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--other-info"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->other_info = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--mac-address"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->mac_address = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--serial-number"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->serial_number = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
        if (std::string (argv[i]) == std::string ("--file"))
        {
            if (i + 1 < argc)
            {
                i++;
                params->file = std::string (argv[i]);
            }
            else
            {
                std::cerr << "missed argument" << std::endl;
                return false;
            }
        }
    }
```

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```
    if (!board_id_found)
    {
        std::cerr << "board id is not provided" << std::endl;
        return false;
    }
    return true;
}
```

5.5 R

5.5.1 R Get Data from a Board

```
library (brainflow)

params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (brainflow_python$BoardIds$SYNTHETIC_BOARD
↪$value, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 5)
board_shim$stop_stream ()
data <- board_shim$get_current_board_data (as.integer (250))
board_shim$release_session ()
```

5.5.2 R Read Write File

```
library (brainflow)

params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (brainflow_python$BoardIds$SYNTHETIC_BOARD
↪$value, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 5)
board_shim$stop_stream ()
data <- board_shim$get_current_board_data (as.integer (250))
board_shim$release_session ()

brainflow_python$DataFilter$write_file (data, "test.csv", "w")
data_restored <- brainflow_python$DataFilter$read_file ("test.csv")
print (restored_data)
```

5.5.3 R Transforms

```
library (brainflow)

params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (brainflow_python$BoardIds$SYNTHETIC_BOARD
↪$value, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 5)
board_shim$stop_stream ()
data <- board_shim$get_current_board_data (as.integer (250))
board_shim$release_session ()

# need to convert to numpy array manually
numpy_data <- np$array (data[2,])
print (numpy_data)
wavelet_data <- brainflow_python$DataFilter$perform_wavelet_transform (numpy_data,
↪"db4", as.integer (3))
restored_data <- brainflow_python$DataFilter$perform_inverse_wavelet_transform␣
↪(wavelet_data, length (numpy_data), "db4", as.integer (3))
print (restored_data)
```

5.5.4 R Signal Filtering

```
library (brainflow)

params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (brainflow_python$BoardIds$SYNTHETIC_BOARD
↪$value, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 5)
board_shim$stop_stream ()
data <- board_shim$get_current_board_data (as.integer (250))
board_shim$release_session ()

# need to convert to numpy array manually
numpy_data <- np$array (data[2,])
print (numpy_data)
sampling_rate <- board_shim$get_sampling_rate (brainflow_python$BoardIds$SYNTHETIC_
↪BOARD$value)
brainflow_python$DataFilter$perform_bandpass (numpy_data, sampling_rate, 10.0, 5.0,␣
↪as.integer (3), brainflow_python$FilterTypes$BESSEL$value, 0)
print (numpy_data)
```

5.5.5 R Denoising

```
library (brainflow)

params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (brainflow_python$BoardIds$SYNTHETIC_BOARD
↪$value, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 5)
board_shim$stop_stream ()
data <- board_shim$get_current_board_data (as.integer (250))
board_shim$release_session ()

# need to convert to numpy array manually
numpy_data <- np$array (data[2,])
print (numpy_data)
brainflow_python$DataFilter$perform_wavelet_denoising (numpy_data, "db4", as.integer␣
↪(3))
print (numpy_data)
```

5.5.6 R Band Power

```
library (brainflow)

board_id <- brainflow_python$BoardIds$SYNTHETIC_BOARD$value
sampling_rate <- brainflow_python$BoardShim$get_sampling_rate(board_id)
nfft <- brainflow_python$DataFilter$get_nearest_power_of_two(sampling_rate)
params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (board_id, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 10)
board_shim$stop_stream ()
data <- board_shim$get_board_data ()
board_shim$release_session ()

# need to convert to numpy array manually
numpy_data <- np$array (data[3,])
psd <- brainflow_python$DataFilter$get_psd_welch (numpy_data, as.integer (nfft), as.
↪integer (nfft / 2),
    sampling_rate, brainflow_python$WindowFunctions$BLACKMAN_HARRIS$value)
band_power_alpha <- brainflow_python$DataFilter$get_band_power (psd, 7.0, 13.0)
band_power_beta <- brainflow_python$DataFilter$get_band_power (psd, 14.0, 30.0)
ratio <- band_power_alpha / band_power_beta
```

5.5.7 R EEG Metrics

```
library (brainflow)

board_id <- brainflow_python$BoardIds$SYNTHETIC_BOARD$value
sampling_rate <- brainflow_python$BoardShim$get_sampling_rate(board_id)
nfft <- brainflow_python$DataFilter$get_nearest_power_of_two(sampling_rate)
params <- brainflow_python$BrainFlowInputParams ()
board_shim <- brainflow_python$BoardShim (board_id, params)
board_shim$prepare_session ()
board_shim$start_stream ()
Sys.sleep (time = 10)
board_shim$stop_stream ()
data <- board_shim$get_board_data ()
board_shim$release_session ()

eeg_channels <- brainflow_python$BoardShim$get_eeg_channels (board_id)
bands <- brainflow_python$DataFilter$get_avg_band_powers (data, eeg_channels,␣
↪sampling_rate, TRUE)
feature_vector <- np$array(c(bands[[1]], bands[[2]]))

concentration_params <- brainflow_python$BrainFlowModelParams (brainflow_python
↪$BrainFlowMetrics$CONCENTRATION$value, brainflow_python$BrainFlowClassifiers
↪$REGRESSION$value)
concentration <- brainflow_python$MLModel (concentration_params)
concentration$prepare()
score <- concentration$predict(feature_vector)
concentration$release()
```

5.6 Matlab

5.6.1 Matlab Get Data from a Board

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
board_shim.prepare_session ();
a = board_shim.config_board ('~6');
board_shim.start_stream (45000, '');
pause (5);
board_shim.stop_stream ();
data = board_shim.get_current_board_data (10);
disp (data);
board_shim.release_session ();
```

5.6.2 Matlab Read Write File

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (2)
board_shim.stop_stream ()
data = board_shim.get_current_board_data (20);
board_shim.release_session ();

DataFilter.write_file (data, 'data.csv', 'w');
restored_data = DataFilter.read_file ('data.csv');
```

5.6.3 Matlab Transforms

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
sampling_rate = BoardShim.get_sampling_rate (int32 (BoardIDs.SYNTHETIC_BOARD));
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (5);
board_shim.stop_stream ();
data = board_shim.get_current_board_data (DataFilter.get_nearest_power_of_two␣
↪(sampling_rate));
board_shim.release_session ();

eeg_channels = BoardShim.get_eeg_channels (int32 (BoardIDs.SYNTHETIC_BOARD));
% wavelet for first eeg channel %
first_eeg_channel = eeg_channels (1);
original_data = data (first_eeg_channel, :);
[wavelet_data, wavelet_lenghts] = DataFilter.perform_wavelet_transform (original_data,
↪ 'db4', 2);
restored_data = DataFilter.perform_inverse_wavelet_transform (wavelet_data, wavelet_
↪lenghts, size (original_data, 2), 'db4', 2);
% fft for first eeg channel %
fft_data = DataFilter.perform_fft (original_data, int32 (WindowFunctions.NO_WINDOW));
restored_fft_data = DataFilter.perform_ifft (fft_data);
```

5.6.4 Matlab Signal Filtering

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (5);
board_shim.stop_stream ();
data = board_shim.get_current_board_data (64);
board_shim.release_session ();

eeg_channels = BoardShim.get_eeg_channels (int32 (BoardIDs.SYNTHETIC_BOARD));
% apply iir filter to the first eeg channel %
first_eeg_channel = eeg_channels (1);
original_data = data (first_eeg_channel, :);
sampling_rate = BoardShim.get_sampling_rate (int32 (BoardIDs.SYNTHETIC_BOARD));
filtered_data = DataFilter.perform_lowpass (original_data, sampling_rate, 10.0, 3,␣
↪int32 (FilterTypes.BUTTERWORTH), 0.0);
```

5.6.5 Matlab Denoising

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (5);
board_shim.stop_stream ();
data = board_shim.get_current_board_data (64);
board_shim.release_session ();

eeg_channels = BoardShim.get_eeg_channels (int32 (BoardIDs.SYNTHETIC_BOARD));
% apply wavelet denoising to the first eeg channel %
first_eeg_channel = eeg_channels (1);
noisy_data = data (first_eeg_channel, :);
denoised_data = DataFilter.perform_wavelet_denoising (noisy_data, 'db4', 2);
```

5.6.6 Matlab Band Power

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
sampling_rate = BoardShim.get_sampling_rate (int32 (BoardIDs.SYNTHETIC_BOARD));
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (10);
```

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```
board_shim.stop_stream ();
nfft = DataFilter.get_nearest_power_of_two (sampling_rate);
data = board_shim.get_board_data ();
board_shim.release_session ();

eeg_channels = BoardShim.get_eeg_channels (int32 (BoardIDs.SYNTHETIC_BOARD));
eeg_channel = eeg_channels (2);
original_data = data (eeg_channel, :);
detrended = DataFilter.detrend (original_data, int32 (DetrendOperations.LINEAR));
[ampls, freqs] = DataFilter.get_psd_welch (detrended, nfft, nfft / 2, sampling_rate,␣
↪int32 (WindowFunctions.HANNING));
band_power_alpha = DataFilter.get_band_power (ampls, freqs, 7.0, 13.0);
band_power_beta = DataFilter.get_band_power (ampls, freqs, 14.0, 30.0);
ratio = band_power_alpha / band_power_beta;
```

5.6.7 Matlab EEG Metrics

```
BoardShim.set_log_file ('brainflow.log');
BoardShim.enable_dev_board_logger ();

params = BrainFlowInputParams ();
board_shim = BoardShim (int32 (BoardIDs.SYNTHETIC_BOARD), params);
sampling_rate = BoardShim.get_sampling_rate (int32 (BoardIDs.SYNTHETIC_BOARD));
board_shim.prepare_session ();
board_shim.start_stream (45000, '');
pause (5);
board_shim.stop_stream ();
nfft = DataFilter.get_nearest_power_of_two (sampling_rate);
data = board_shim.get_board_data ();
board_shim.release_session ();

eeg_channels = BoardShim.get_eeg_channels (int32 (BoardIDs.SYNTHETIC_BOARD));
[avgs, stddevs] = DataFilter.get_avg_band_powers (data, eeg_channels, sampling_rate,␣
↪true);
feature_vector = double([avgs, stddevs]);

concentration_params = BrainFlowModelParams (int32(BrainFlowMetrics.CONCENTRATION),␣
↪int32(BrainFlowClassifiers.REGRESSION));
concentration = MLModel (concentration_params);
concentration.prepare ();
score = concentration.predict (feature_vector);
concentration.release ();
```

5.7 Julia

5.7.1 Julia Get Data from a Board

```
import brainflow


# specify logging library to use
```

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```
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_current_board_data(256, board_shim)
brainflow.release_session(board_shim)
```

5.7.2 Julia Read Write File

```
import brainflow


# specify logging library to use
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_current_board_data(32, board_shim)
brainflow.release_session(board_shim)

brainflow.write_file(data, "test.csv", "w")
restored_data = brainflow.read_file("test.csv")

println("Original Data")
println(data)
println("Restored Data")
println(restored_data)
```

5.7.3 Julia Transforms

```
import brainflow

# enable logs
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))
brainflow.enable_dev_brainflow_logger(Integer(brainflow.DATA_HANDLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)
sampling_rate = brainflow.get_sampling_rate(Integer(brainflow.SYNTHETIC_BOARD))

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
```

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```
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_current_board_data(brainflow.get_nearest_power_of_two(sampling_
↪rate), board_shim)
brainflow.release_session(board_shim)

eeg_channels = brainflow.get_eeg_channels(Integer(brainflow.SYNTHETIC_BOARD))
data_first_channel = data[eeg_channels[1], :]

# returns tuple of wavelet coeffs and lengths
wavelet_data = brainflow.perform_wavelet_transform(data_first_channel, "db4", 2)
restored_wavelet_data = brainflow.perform_inverse_wavelet_transform(wavelet_data,␣
↪length(data_first_channel), "db4", 2)

fft_data = brainflow.perform_fft(data_first_channel, Integer(brainflow.NO_WINDOW))
restored_fft_data = brainflow.perform_ifft(fft_data)

println("Original Data")
println(data_first_channel)
println("Restored from Wavelet Data")
println(restored_wavelet_data)
println("Restored from FFT Data")
println(restored_fft_data)
```

5.7.4 Julia Signal Filtering

```
import brainflow


# specify logging library to use
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_current_board_data(32, board_shim)
brainflow.release_session(board_shim)

eeg_channels = brainflow.get_eeg_channels(Integer(brainflow.SYNTHETIC_BOARD))
sampling_rate = brainflow.get_sampling_rate(Integer(brainflow.SYNTHETIC_BOARD))

data_first_channel = data[eeg_channels[1], :]
println("Original Data First Channel")
println(data_first_channel)
brainflow.perform_lowpass(data_first_channel, sampling_rate, 10.0, 3,␣
↪Integer(brainflow.BUTTERWORTH), 0.0)
println("After LowPass Filter")
println(data_first_channel)

data_second_channel = data[eeg_channels[2], :]
println("Original Data Second Channel")
```

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```
println(data_second_channel)
brainflow.perform_highpass(data_second_channel, sampling_rate, 5.0, 3,␣
↪Integer(brainflow.CHEBYSHEV_TYPE_1), 1.0)
println("After HighPass Filter")
println(data_second_channel)

data_third_channel = data[eeg_channels[3], :]
println("Original Data Third Channel")
println(data_third_channel)
brainflow.perform_bandpass(data_third_channel, sampling_rate, 25.0, 20.0, 3,␣
↪Integer(brainflow.BESSEL), 0.0)
println("After BandPass Filter")
println(data_third_channel)

data_fourth_channel = data[eeg_channels[4], :]
println("Original Data Fourth Channel")
println(data_fourth_channel)
brainflow.perform_bandstop(data_fourth_channel, sampling_rate, 50.0, 2.0, 3,␣
↪Integer(brainflow.BESSEL), 0.0)
println("After BandStop Filter")
println(data_fourth_channel)
```

5.7.5 Julia Denoising

```
import brainflow


# specify logging library to use
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_current_board_data(32, board_shim)
brainflow.release_session(board_shim)

eeg_channels = brainflow.get_eeg_channels(Integer(brainflow.SYNTHETIC_BOARD))
sampling_rate = brainflow.get_sampling_rate(Integer(brainflow.SYNTHETIC_BOARD))

data_first_channel = data[eeg_channels[1], :]
println("Original Data First Channel")
println(data_first_channel)
brainflow.perform_rolling_filter(data_first_channel, 3, Integer(brainflow.MEAN))
println("After Rolling Filter")
println(data_first_channel)

data_second_channel = data[eeg_channels[2], :]
println("Original Data Second Channel")
println(data_second_channel)
brainflow.perform_wavelet_denoising(data_second_channel, "db4", 2)
println("After Wavelet Denoising")
```

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```
println(data_second_channel)
```

5.7.6 Julia Band Power

```
import brainflow


# specify logging library to use
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)
sampling_rate = brainflow.get_sampling_rate(Integer(brainflow.SYNTHETIC_BOARD))
nfft = brainflow.get_nearest_power_of_two(sampling_rate)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_board_data(board_shim)
brainflow.release_session(board_shim)

eeg_channels = brainflow.get_eeg_channels(Integer(brainflow.SYNTHETIC_BOARD))
# second channel of synthetic board is sine wave at 10 Hz, should see huge 'alpha'
data_second_channel = data[eeg_channels[2], :]

# optional: detrend
brainflow.detrend(data_second_channel, Integer(brainflow.LINEAR))
# psd is a tuple of ampls and freqs
psd = brainflow.get_psd_welch(data_second_channel, nfft, Integer(nfft / 2), sampling_
↪rate, Integer(brainflow.BLACKMAN_HARRIS))
band_power_alpha = brainflow.get_band_power(psd, 7.0, 13.0)
band_power_beta = brainflow.get_band_power(psd, 14.0, 30.0)
println(band_power_alpha / band_power_beta)
```

5.7.7 Julia EEG Metrics

```
import brainflow


# enable all possible logs from all three libs
brainflow.enable_dev_brainflow_logger(Integer(brainflow.BOARD_CONTROLLER))
brainflow.enable_dev_brainflow_logger(Integer(brainflow.DATA_HANDLER))
brainflow.enable_dev_brainflow_logger(Integer(brainflow.ML_MODULE))

params = brainflow.BrainFlowInputParams()
board_shim = brainflow.BoardShim(Integer(brainflow.SYNTHETIC_BOARD), params)
sampling_rate = brainflow.get_sampling_rate(Integer(brainflow.SYNTHETIC_BOARD))
nfft = brainflow.get_nearest_power_of_two(sampling_rate)

brainflow.prepare_session(board_shim)
brainflow.start_stream(board_shim)
```

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```
sleep(5)
brainflow.stop_stream(board_shim)
data = brainflow.get_board_data(board_shim)
brainflow.release_session(board_shim)

eeg_channels = brainflow.get_eeg_channels(Integer(brainflow.SYNTHETIC_BOARD))

bands = brainflow.get_avg_band_powers(data, eeg_channels, sampling_rate, true)
feature_vector = vcat(bands[1], bands[2])

# calc concentration
model_params = brainflow.BrainFlowModelParams(Integer(brainflow.CONCENTRATION),␣
↪Integer(brainflow.KNN))
concentration = brainflow.MLModel(model_params)
brainflow.prepare(concentration)
print(brainflow.predict(feature_vector, concentration))
brainflow.release(concentration)

# calc relaxation
model_params = brainflow.BrainFlowModelParams(Integer(brainflow.RELAXATION),␣
↪Integer(brainflow.REGRESSION))
relaxation = brainflow.MLModel(model_params)
brainflow.prepare(relaxation)
print(brainflow.predict(feature_vector, relaxation))
brainflow.release(relaxation)
```

5.8 Notebooks

5.8.1 BrainFlow to MNE Python Notebook

In [1]:
```
import time
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

import brainflow
from brainflow.board_shim import BoardShim, BrainFlowInputParams, BoardIds

import mne
from mne.channels import read_layout
```

```
/home/docs/checkouts/readthedocs.org/user_builds/brainflow-openbci/envs/stable/lib/
↪python3.7/site-packages/traitlets/traitlets.py:3036: FutureWarning: --rc={'figure.
↪dpi': 96} for dict-traits is deprecated in traitlets 5.0. You can pass --rc
↪<key=value> ... multiple times to add items to a dict.
  FutureWarning,
```

In [2]:
```
# use synthetic board for demo
params = BrainFlowInputParams ()
board = BoardShim (BoardIds.SYNTHETIC_BOARD.value, params)
board.prepare_session ()
board.start_stream ()
time.sleep (10)
```

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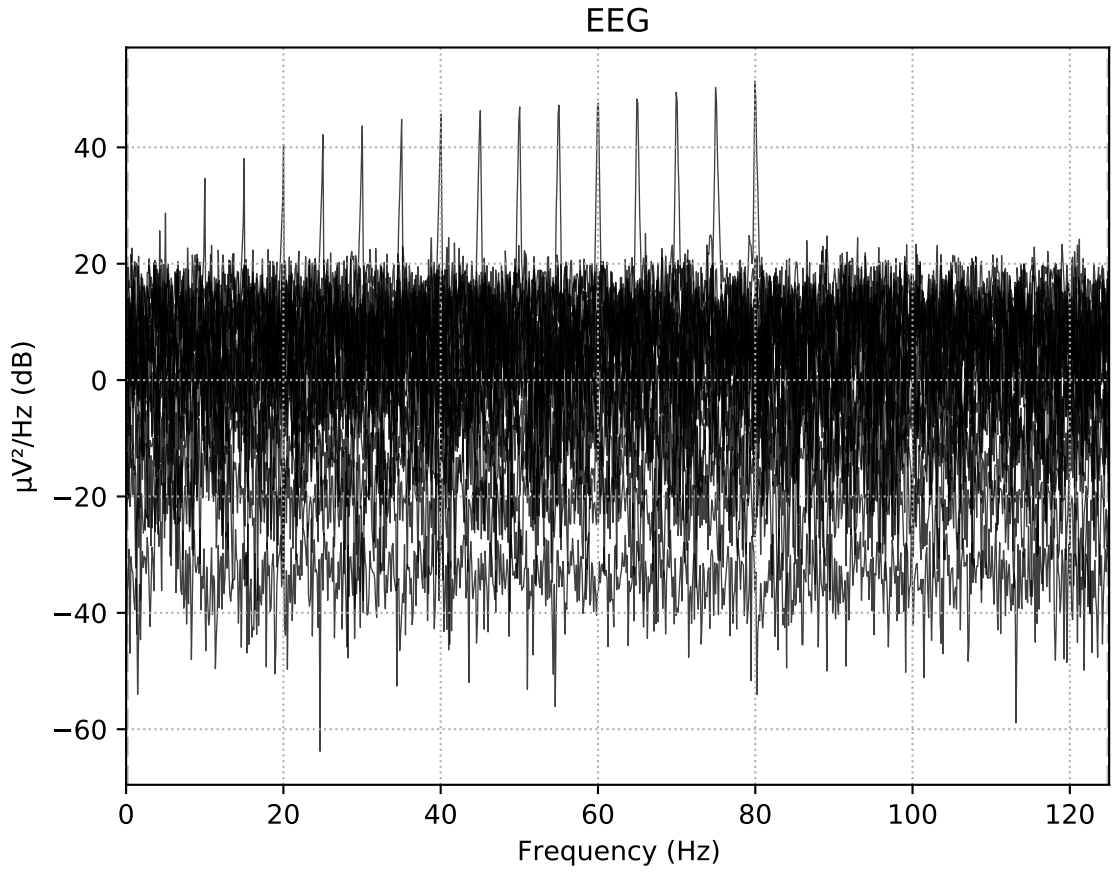
```
data = board.get_board_data ()
board.stop_stream ()
board.release_session ()
```

In [3]:
```
eeg_channels = BoardShim.get_eeg_channels (BoardIds.SYNTHETIC_BOARD.value)
eeg_data = data[eeg_channels, :]
eeg_data = eeg_data / 1000000 # BrainFlow returns uV, convert to V for MNE
```

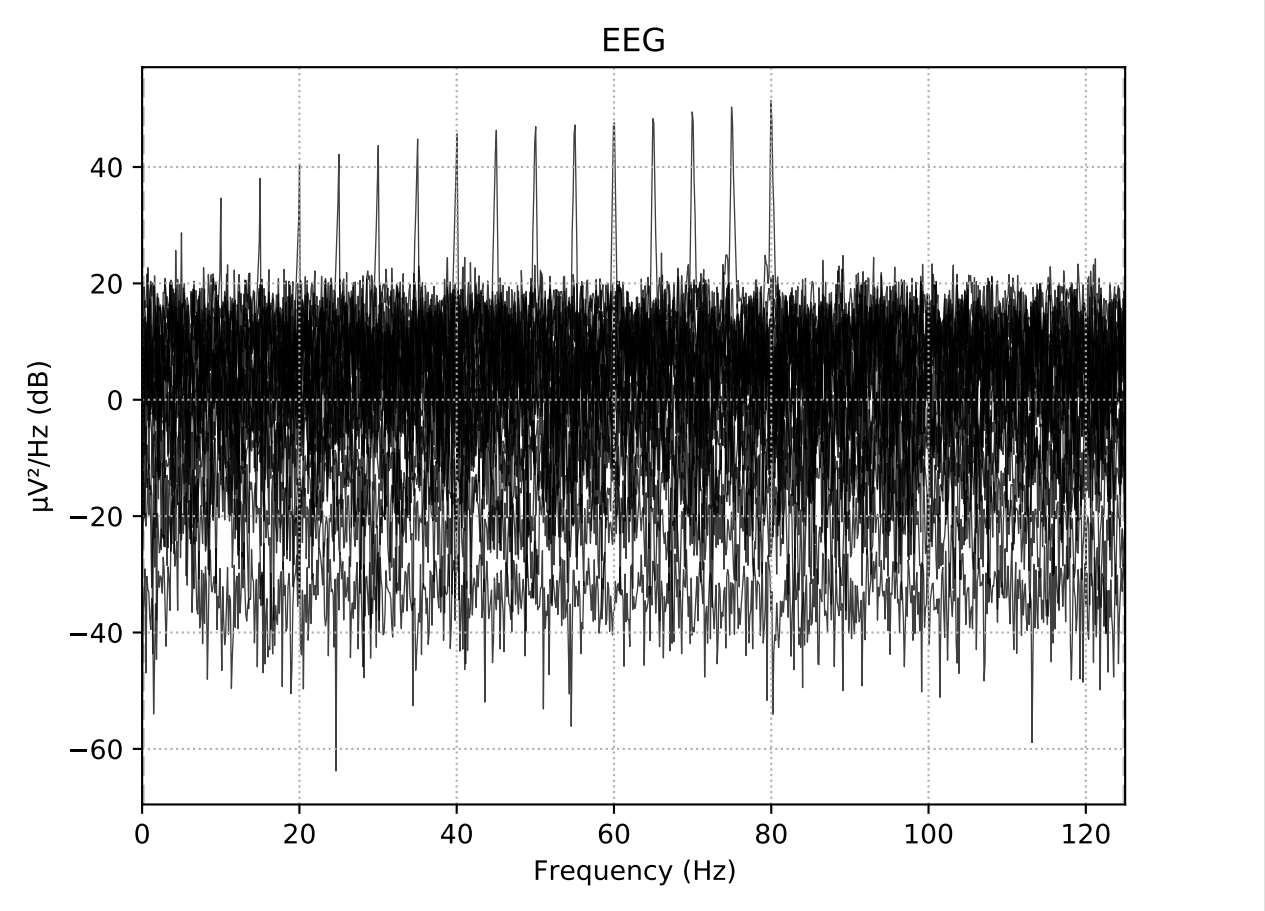
In [4]:
```
# Creating MNE objects from brainflow data arrays
ch_types = ['eeg'] * len (eeg_channels)
ch_names = BoardShim.get_eeg_names (BoardIds.SYNTHETIC_BOARD.value)
sfreq = BoardShim.get_sampling_rate (BoardIds.SYNTHETIC_BOARD.value)
info = mne.create_info (ch_names = ch_names, sfreq = sfreq, ch_types = ch_types)
raw = mne.io.RawArray (eeg_data, info)
# its time to plot something!
raw.plot_psd (average = False)
```

```
Creating RawArray with float64 data, n_channels=16, n_times=3212
    Range : 0 ... 3211 =      0.000 ...    12.844 secs
Ready.
Effective window size : 8.192 (s)
```

```
<ipython-input-1-9872dda7122d>:8: RuntimeWarning: Channel locations not available.
↪Disabling spatial colors.
  raw.plot_psd (average = False)
```



Out[4]:



5.8.2 Denoising Notebook

In [1]:
```
import argparse
import time
import brainflow
import numpy as np

import pandas as pd
import matplotlib
import matplotlib.pyplot as plt

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations
```

```
/home/docs/checkouts/readthedocs.org/user_builds/brainflow-openbci/envs/stable/lib/
↪python3.7/site-packages/traitlets/traitlets.py:3036: FutureWarning: --rc={'figure.
↪dpi': 96} for dict-traits is deprecated in traitlets 5.0. You can pass --rc
↪<key=value> ... multiple times to add items to a dict.
  FutureWarning,
```

In [2]:
```
# use synthetic board for demo
params = BrainFlowInputParams ()
board_id = BoardIds.SYNTHETIC_BOARD.value
board = BoardShim (board_id, params)
```

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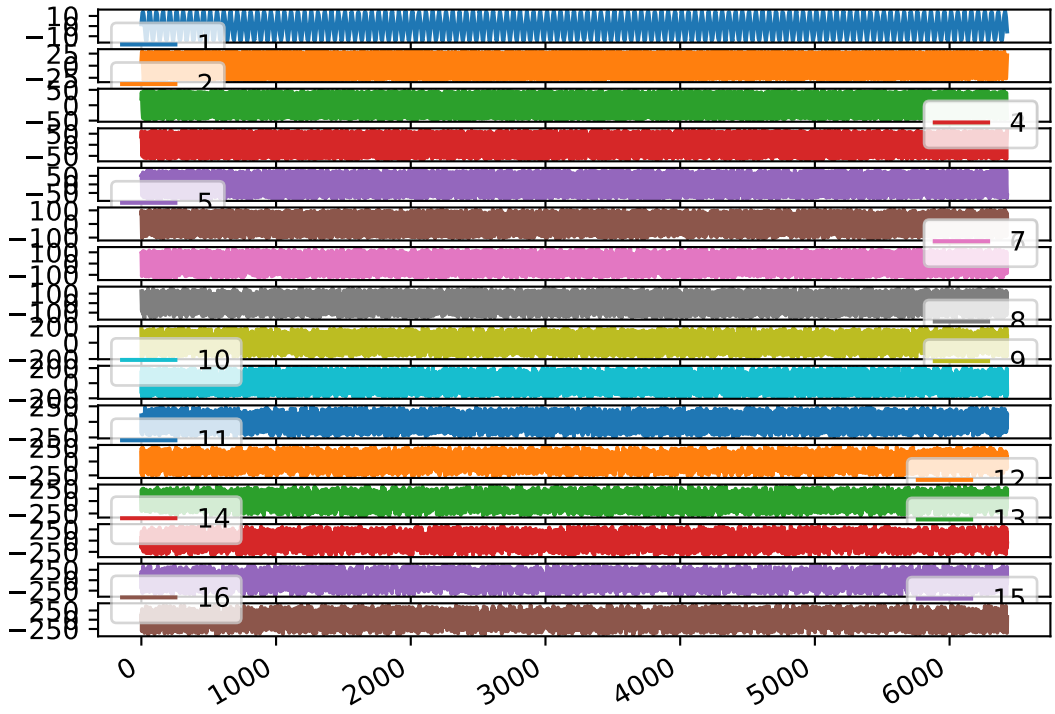
```
board.prepare_session ()
board.start_stream ()
time.sleep (20)
data = board.get_board_data ()
board.stop_stream ()
board.release_session ()
```

In [3]:
```
# plot original data
eeg_channels = BoardShim.get_eeg_channels (board_id)
df = pd.DataFrame (np.transpose (data))
df[eeg_channels].plot (subplots = True)
plt.show()
```



In [4]:
```
# demo for different denoising methods,
# apply different methods to different channels to determine the best one
for count, channel in enumerate (eeg_channels):
    # first of all you can try simple moving median or moving average with different␣
↪window size
    if count == 0:
        DataFilter.perform_rolling_filter (data[channel], 3, AggOperations.MEAN.value)
    elif count == 1:
        DataFilter.perform_rolling_filter (data[channel], 3, AggOperations.MEDIAN.
↪value)
    # methods above should increase signal to noise ratio but we can do even better
    # using wavelet based denoising, feel free to try different wavelet functions and␣
↪decomposition levels
    elif count == 2:
        DataFilter.perform_wavelet_denoising (data[channel], 'db6', 5)
    elif count == 3:
        DataFilter.perform_wavelet_denoising (data[channel], 'bior3.9', 5)
```

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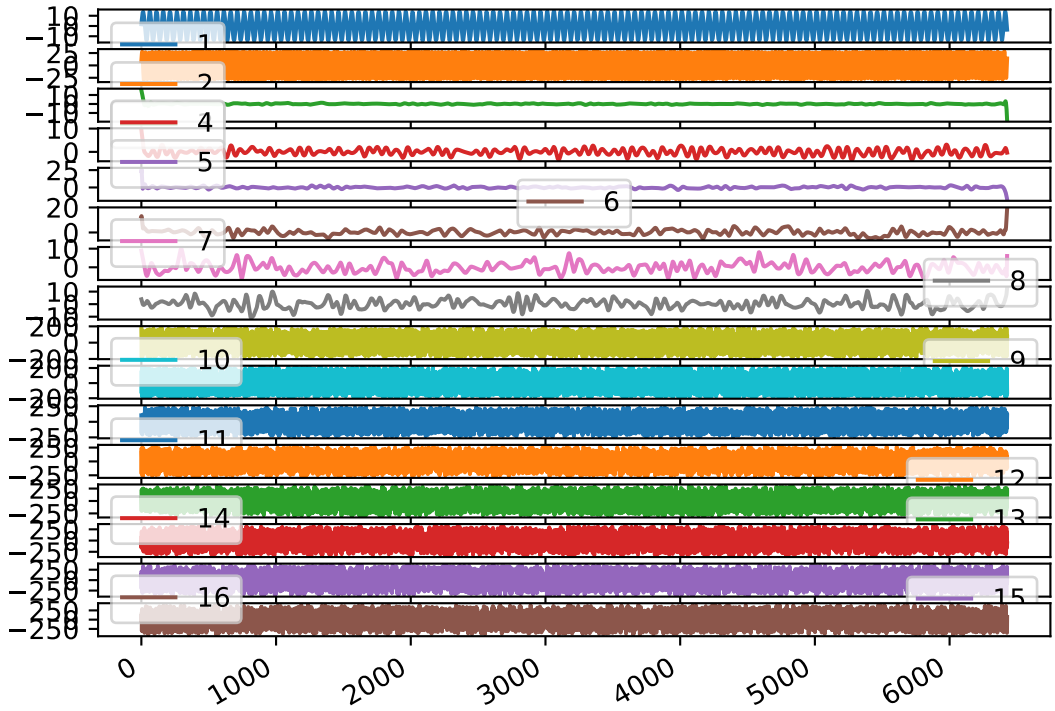
```
    elif count == 4:
        DataFilter.perform_wavelet_denoising (data[channel], 'sym7', 5)
    elif count == 5:
        DataFilter.perform_wavelet_denoising (data[channel], 'coif3', 5)
    elif count == 6:
        DataFilter.perform_wavelet_denoising (data[channel], 'bior6.8', 5)
    elif count == 7:
        DataFilter.perform_wavelet_denoising (data[channel], 'db4', 5)
```

In [5]:
```
# plot denoised data
df = pd.DataFrame (np.transpose (data))
df[eeg_channels].plot (subplots = True)
plt.show()
# as you can see wavelet based denoising works much better and increases signal to␣
↪noise ratio significantly!
```



5.8.3 BrainFlow Band Power Notebook

In [1]:
```
import argparse
import time
import brainflow
import numpy as np

import pandas as pd
import matplotlib
import matplotlib.pyplot as plt

from brainflow.board_shim import BoardShim, BrainFlowInputParams, LogLevels, BoardIds
```

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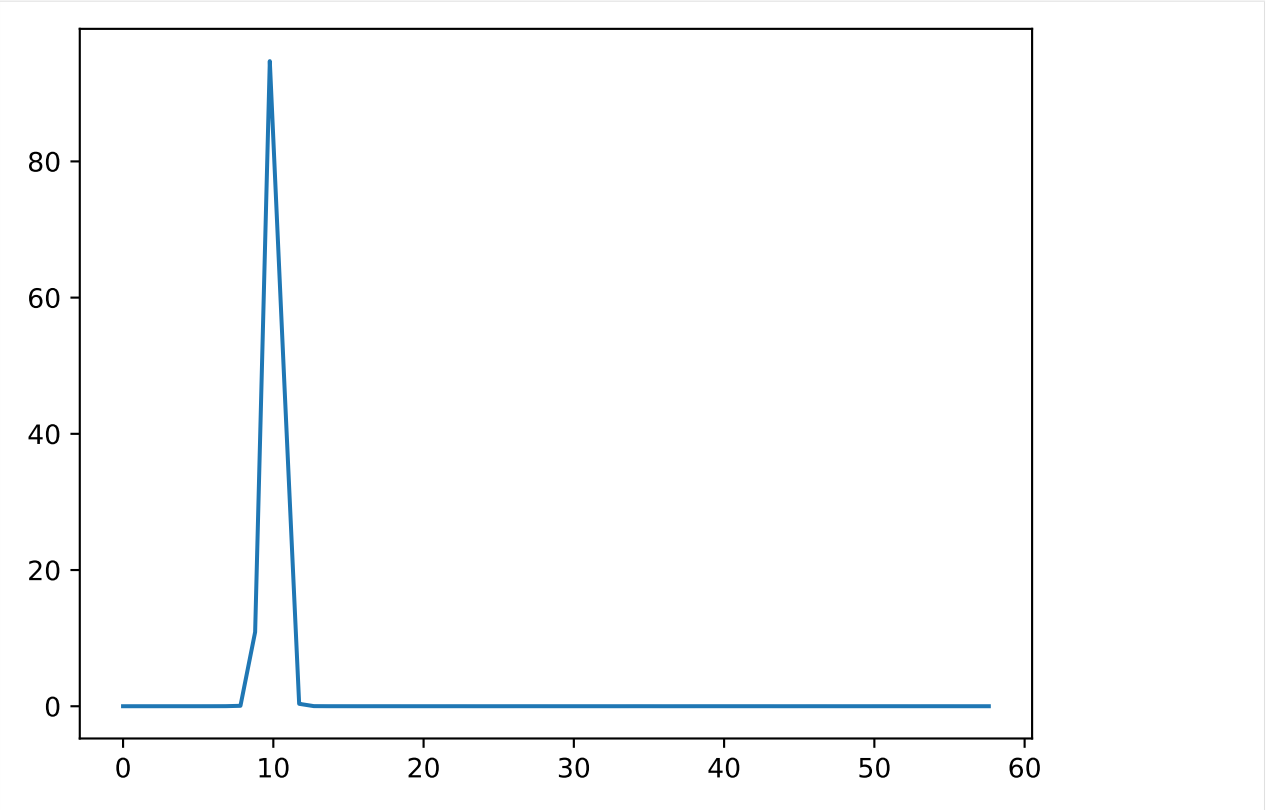
```
from brainflow.data_filter import DataFilter, FilterTypes, AggOperations,␣
↪WindowFunctions, DetrendOperations
```

```
/home/docs/checkouts/readthedocs.org/user_builds/brainflow-openbci/envs/stable/lib/
↪python3.7/site-packages/traitlets/traitlets.py:3036: FutureWarning: --rc={'figure.
↪dpi': 96} for dict-traits is deprecated in traitlets 5.0. You can pass --rc
↪<key=value> ... multiple times to add items to a dict.
  FutureWarning,
```

In [2]:
```
# use synthetic board for demo
params = BrainFlowInputParams ()
board_id = BoardIds.SYNTHETIC_BOARD.value
sampling_rate = BoardShim.get_sampling_rate (board_id)
nfft = DataFilter.get_nearest_power_of_two (sampling_rate)
board = BoardShim (board_id, params)
board.prepare_session ()
board.start_stream ()
time.sleep (10)
data = board.get_board_data ()
board.stop_stream ()
board.release_session ()
eeg_channels = BoardShim.get_eeg_channels (board_id)
# use first eeg channel for demo
# second channel of synthetic board is a sine wave at 10 Hz, should see big 'alpha'
eeg_channel = eeg_channels[1]
```

In [3]:
```
# optional: detrend
DataFilter.detrend (data[eeg_channel], DetrendOperations.LINEAR.value)
```

In [4]:
```
psd = DataFilter.get_psd_welch (data[eeg_channel], nfft, nfft // 2, sampling_rate,␣
↪WindowFunctions.HANNING.value)
plt.plot (psd[1][:60], psd[0][:60])
plt.show ()
```



In [5]:
```
# calc band power
alpha = DataFilter.get_band_power (psd, 7.0, 13.0)
beta = DataFilter.get_band_power (psd, 14.0, 30.0)
print ("Alpha/Beta Ratio is: %f" % (alpha / beta))
```

```
Alpha/Beta Ratio is: 2316.283381
```

CHAPTER

SIX

INTEGRATION WITH GAME ENGINES

6.1 Unity

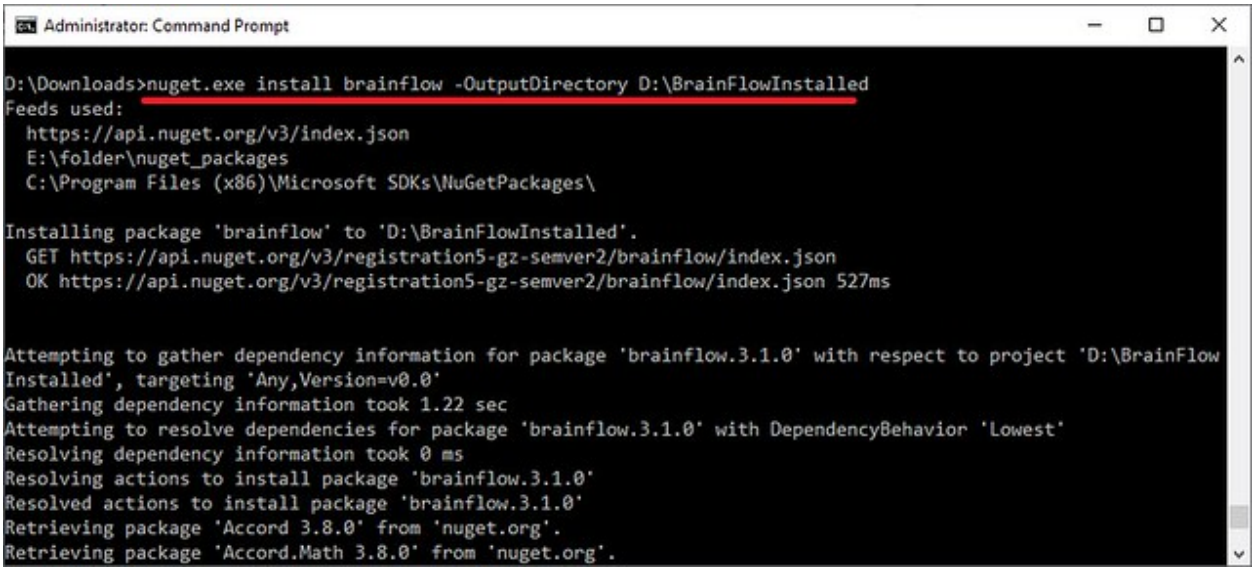
Integration with Unity can be done only using C# binding. And currently it works only for Windows.

You can build C# binding from source or download compiled package directly from Nuget.

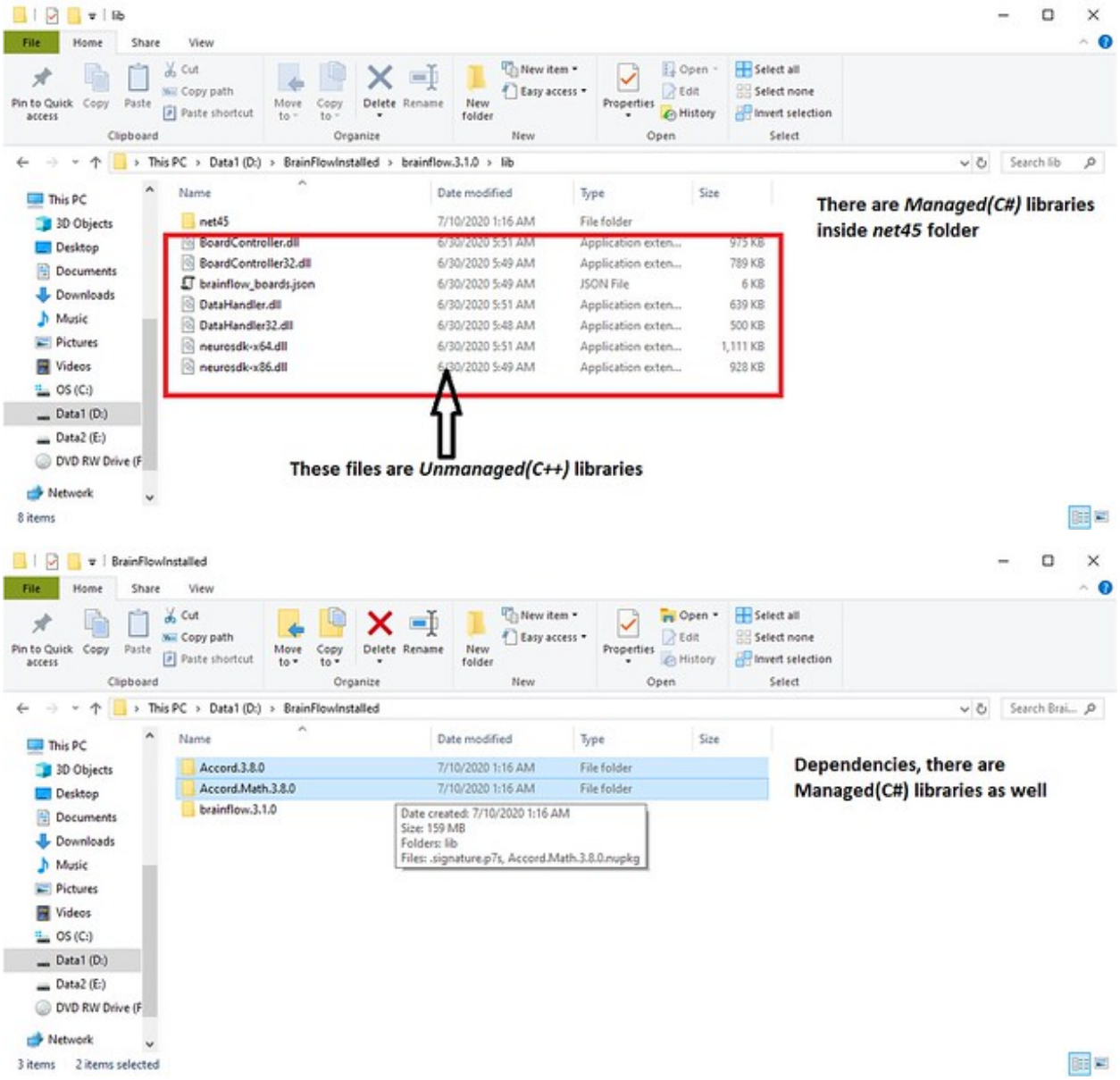
Here we will use Nuget to download and install BrainFlow with dependencies.

Download nuget.exe and run

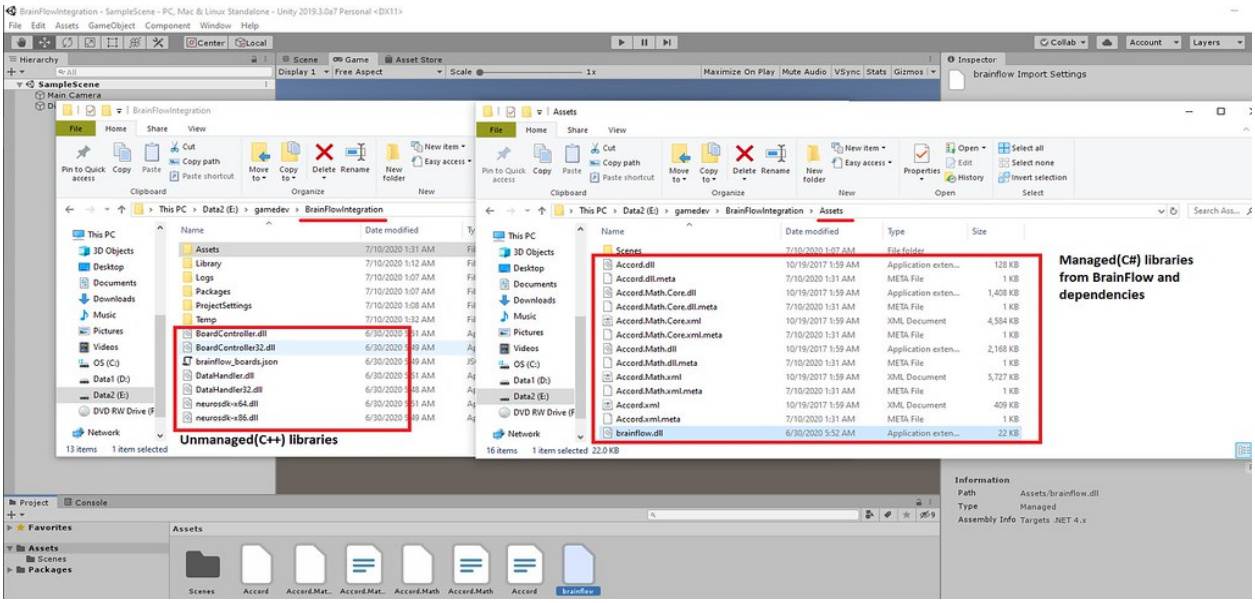
```
nuget.exe install brainflow -OutputDirectory <OUTPUTDIR>
```



Open OUTPUTDIR, you will see BrainFlow library and dependencies. For BrainFlow there are *Managed(C#)* and *Unmanaged(C++)* files. For dependencies like Accord there are only *Managed(C#)* libraries.



Open your Unity project and copy **Managed(C#)** libraries from BrainFlow and **all dependencies** to the Assets folder, after that copy **Unmanaged(C++)** libraries from BrainFlow to the root folder of your project.



Now, you are able to use BrainFlow API in your C# scripts!

For demo we will create a simple script to read data and calculate concentration level.

Add a Sphere object to the Scene and attach script below.

```
using System;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

using Accord;
using Accord.Math;
using brainflow;

public class Sphere : MonoBehaviour
{
    private BoardShim board_shim = null;
    private MLModel concentration = null;
    private int sampling_rate = 0;
    private int[] eeg_channels = null;

    // Start is called before the first frame update
    void Start()
    {
        try
        {
            BoardShim.set_log_file("brainflow_log.txt");
            BoardShim.enable_dev_board_logger();

            BrainFlowInputParams input_params = new BrainFlowInputParams();
            int board_id = (int)BoardIds.SYNTHETIC_BOARD;
            board_shim = new BoardShim(board_id, input_params);
            board_shim.prepare_session();
            board_shim.start_stream(450000, "file://brainflow_data.csv:w");
            BrainFlowModelParams concentration_params = new␣
↪BrainFlowModelParams((int)BrainFlowMetrics.CONCENTRATION, (int)BrainFlowClassifiers.
↪REGRESSION);
```

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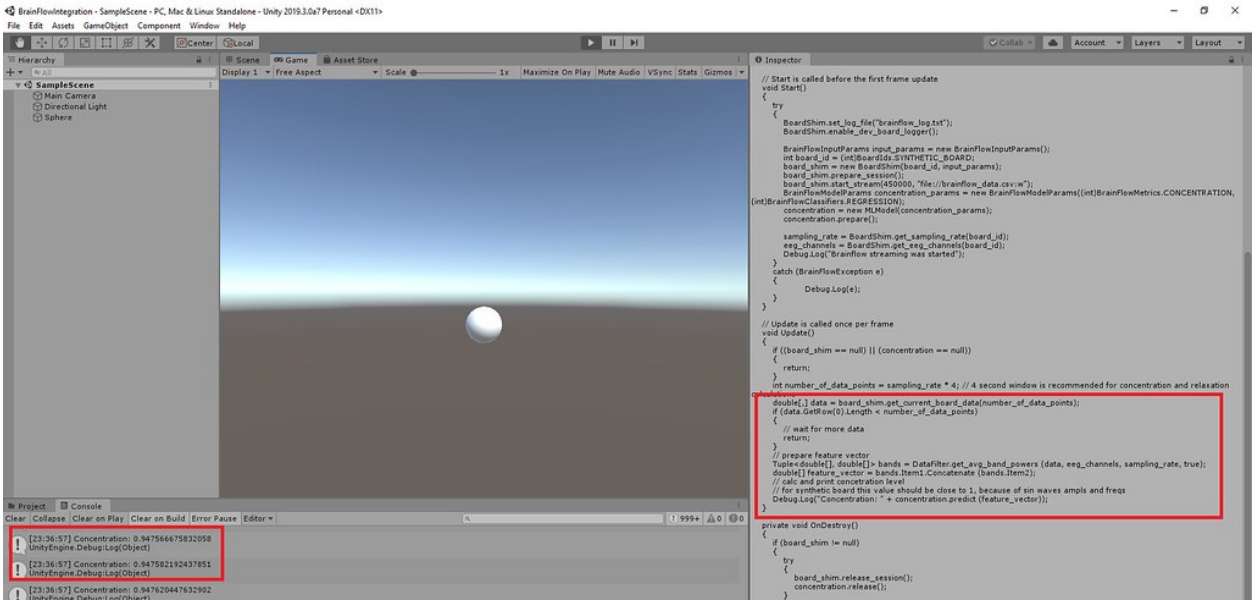
```
            concentration = new MLModel(concentration_params);
            concentration.prepare();

            sampling_rate = BoardShim.get_sampling_rate(board_id);
            eeg_channels = BoardShim.get_eeg_channels(board_id);
            Debug.Log("Brainflow streaming was started");
        }
        catch (BrainFlowException e)
        {
            Debug.Log(e);
        }
    }

    // Update is called once per frame
    void Update()
    {
        if ((board_shim == null) || (concentration == null))
        {
            return;
        }
        int number_of_data_points = sampling_rate * 4; // 4 second window is␣
↪recommended for concentration and relaxation calculations
        double[,] data = board_shim.get_current_board_data(number_of_data_points);
        if (data.GetRow(0).Length < number_of_data_points)
        {
            // wait for more data
            return;
        }
        // prepare feature vector
        Tuple<double[], double[]> bands = DataFilter.get_avg_band_powers (data, eeg_
↪channels, sampling_rate, true);
        double[] feature_vector = bands.Item1.Concatenate (bands.Item2);
        // calc and print concetration level
        // for synthetic board this value should be close to 1, because of sin waves␣
↪ampls and freqs
        Debug.Log("Concentration: " + concentration.predict (feature_vector));
    }

    private void OnDestroy()
    {
        if (board_shim != null)
        {
            try
            {
                board_shim.release_session();
                concentration.release();
            }
            catch (BrainFlowException e)
            {
                Debug.Log(e);
            }
            Debug.Log("Brainflow streaming was stopped");
        }
    }
}
```

If everything is fine, you will see Concentration Score in Console.



After building your game you need to copy *Unmanaged(C++)* libraries to a folder where executable is located.

6.2 Unreal Engine

First of all you need to compile BrainFlow from source. For Windows you need to specify an option to link MSVC Runtime *dynamically*. And you need to use the same version of Visual Studio as in your Unreal Project.

Command line example for Windows and MSVC 2017:

```
# install cmake, clone repo and run commands below
cd brainflow
mkdir build_dyn
cd build_dyn
cmake -G "Visual Studio 15 2017 Win64" -DMSVC_RUNTIME=dynamic -DCMAKE_SYSTEM_
↪VERSION=10.0 -DCMAKE_INSTALL_PREFIX=FULL_PATH_TO_FOLDER_FOR_INSTALLATION ..
# e.g. cmake -G "Visual Studio 15 2017 Win64" -DMSVC_RUNTIME=dynamic -DCMAKE_SYSTEM_
↪VERSION=10.0 -DCMAKE_INSTALL_PREFIX=E:\folder\brainflow\installed_temp ..
cmake --build . --target install --config Release -j 2 --parallel 2
```

Add new entry to your *PATH* environemnt variable to point to a folder *FULL_PATH_TO_FOLDER_FOR_INSTALLATION\lib* in example above it's *E:\folder\brainflow\installed_temp\lib*. If you have Unreal Engine Editor or Visual Studio running at this point you need to restart these processes.

Open your Visual Studio Solution for your Unreal Engine project, here we created a project called *BrainFlowUnreal*.

Edit file named *ProjectName.Build.cs*, in our example this file is called *BrainFlowUnreal.Build.cs*

```
using UnrealBuildTool;
using System.IO;

public class BrainFlowUnreal : ModuleRules
```

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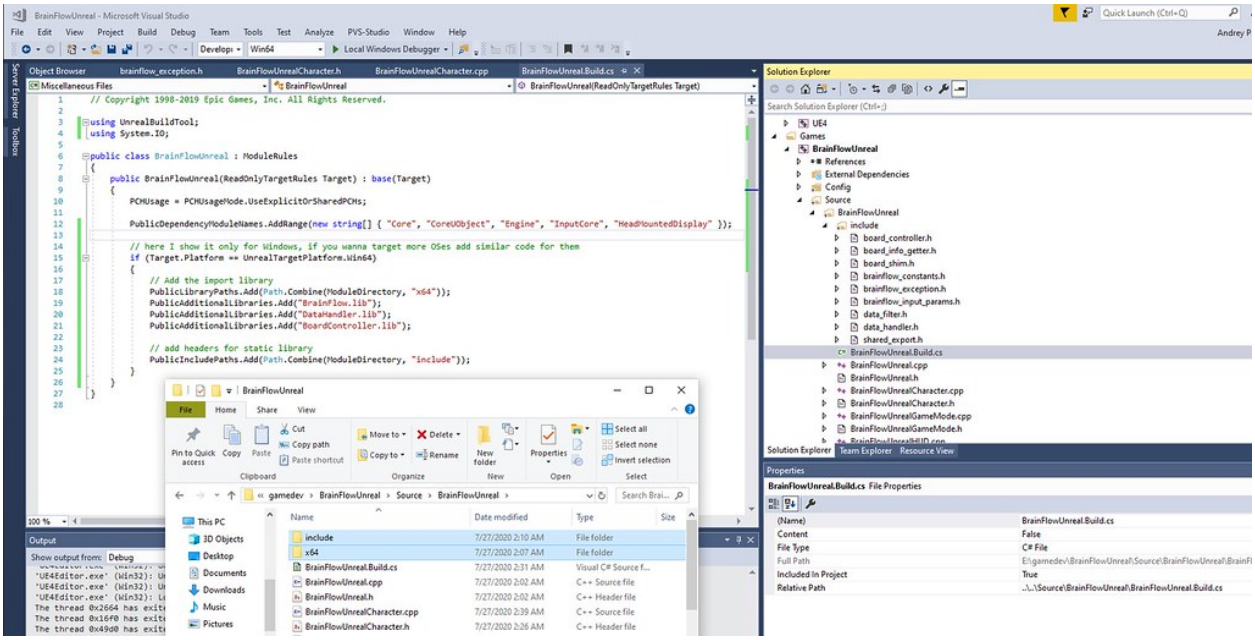
```
{
    public BrainFlowUnreal(ReadOnlyTargetRules Target) : base(Target)
    {
        PCHUsage = PCHUsageMode.UseExplicitOrSharedPCHs;

        PublicDependencyModuleNames.AddRange(new string[] { "Core", "CoreUObject",
↪"Engine", "InputCore", "HeadMountedDisplay" });

        // here I show it only for Windows, if you wanna target more OSes add similar␣
↪code for them
        if (Target.Platform == UnrealTargetPlatform.Win64)
        {
            // Add the import library
            PublicLibraryPaths.Add(Path.Combine(ModuleDirectory, "x64"));
            PublicAdditionalLibraries.Add("BrainFlow.lib");
            PublicAdditionalLibraries.Add("DataHandler.lib");
            PublicAdditionalLibraries.Add("BoardController.lib");

            // add headers for static library
            PublicIncludePaths.Add(Path.Combine(ModuleDirectory, "include"));
        }
    }
}
```

After that you need to copy headers and libraries from BrainFlow installation folder to your Unreal Engine project. Here we copied a content of *E:\folder\brainflow\installed_temp\inc* to a folder *E:\gamedev\BrainFlowUnreal\Source\BrainFlowUnreal\include*. Also, you need to copy compiled libraries from *E:\folderbrainflow\installed_temp\lib* to *E:\gamedev\BrainFlowUnreal\Source\BrainFlowUnreal\x64*



Note: in this example we didn't create a new plugin as described here. *Also we linked only static libraries and didn't link or load dynamic libraries manually. And we don't recommend to configure it as a plugin.*

Finally, you are able to use BrainFlow in your Unreal Engine project.

When you will build a project for production put C++ libraries for BrainFlow in the folder with executable.

CHAPTER

SEVEN

BRAINFLOW DEV

7.1 Code style

We use clang-format tool to keep the same code style for all cpp files. You can download clang-format binary from LLVM Download Page We recommend installing a plugin for your text editor or IDE which will apply clang-format tool during saving. You will need to set code style option to "FILE"

Plugins for text editors and IDEs:

- Sublime
- VSCode
- clang-format tool is preinstalled for Visual Studio

Unfortunately clang-format cannot handle naming, so some additional rules are: - methods and variables should be in lower case with underscore - class names should be in camel case - use brackets even for single line if and for statements

We try to keep the same code style for all bindings as well, even if it doesn't match PEP or other standards. For example we add spaces before and after assignment operator to specify default value for method's params and add spaces before brackets.

7.2 CI and tests

If you want to commit to core module of brainflow project please check that all tests are passed, you can enable Travis CI and AppVeyour for your fork of BrainFlow to run tests automatically, or check CI status directly in your PR.

Also you can run integration tests manually for any board even if you dont have real hardware using BrainFlow Emulator.

7.3 Pull Requests

Just try to briefly explain a goal of this PR.

7.4 Instructions to add new boards to BrainFlow

- add new board Id to BoardIds enum in C code and to the same enum in all bindings
- add new object creation to board controller C interface
- inherit your board from Board class and implement all pure virtual methods, store data in DataBuffer object, use synthetic board as a reference, try to reuse code from utils folder
- add information about your board to brainflow_boards.h
- add new files to BOARD_CONTROLLER_SRC variable in CmakeLists.txt, you may also need to add new directory to *target_include_directories* for BOARD_CONTROLLER_NAME variable

You've just written Python, Java, C#, R, C++ ... SDKs for your board! Also now you can use your new board with applications and frameworks which use BrainFlow API.

Optional: We use CI to run tests automatically, to add your board to CI pipelines you can develop a simple emulator for your device. Use emulators for existing boards as a reference and add tests for your device to *Travis* and *Appveyour*.

7.5 Instructions to build docs locally

Don't push changes to Docs without local verification.

- install pandoc
- optional: install Doxygen, skip it if you dont understand what it is or don't need to publish your local build

Install requirements:

```
cd docs
python -m pip install -r requirements.txt
```

Build docs:

```
make html
```

7.6 Debug BrainFlow's errors

Since bindings just call methods from dynamic libraries, more likely errors occur in C++ code, it means that you need to use C++ debuger like gdb. If there is an error in binding, it should be simple to figure out and resolve the issue using language specific tools.

Steps to get more information about errors in C++ code:

- build BrainFlow's core module and C++ binding in debug mode. In files like tools/build_linux.sh default config is Release, so you need to change it to Debug
- reproduce your issue using C++ binding
- run it with debuger and memory checker

Example for Linux(for MacOS it's the same):

```
vim tools/build_linux.sh
# Change build type to Debug
bash tools/build_linux.sh
# Create a test to reproduce your issue in C++, here we will use get_data_demo
cd tests/cpp/get_data_demo
mkdir build
cd build
cmake -DCMAKE_PREFIX_PATH=TYPE_FULL_PATH_TO_BRAINFLOW_INSTALLED_FOLDER -DCMAKE_BUILD_
↪TYPE=Debug ..
# e.g. cmake -DCMAKE_PREFIX_PATH=/home/andrey/brainflow/installed_linux -DCMAKE_BUILD_
↪TYPE=Debug ..
make
# Run Valgrind to check memory errors
# Here we use command line for Ganglion
sudo valgrind --error-exitcode=1 --leak-check=full ./brainflow_get_data --board-id 1 -
↪-serial-port /dev/ttyACM0 --mac-address e6:73:73:18:09:b1
# Valgrind will print Error Summary and exact line numbers
# Run gdb and get backtrace
sudo gdb --args ./brainflow_get_data --board-id 1 --serial-port /dev/ttyACM0 --mac-
↪address e6:73:73:18:09:b1
# In gdb terminal type 'r' to run the program and as soon as error occurs, type 'bt'␣
↪to see backtrace with exact lines of code and call stack
```

7.7 BrainFlow Emulator

BrainFlow Emulator allows you to run all integration tests for all supported boards without real hardware. Our CI uses it for test automation. Also, you can run it on your own PC!

7.7.1 Streaming Board

Streaming Board emulator works using Python binding for BrainFlow, so **you need to install Python binding first.**

Install emulator package:

```
cd emulator
python -m pip install -U .
```

Run tests

```
python emulator\brainflow_emulator\streaming_board_emulator.py python tests\python\
↪brainflow_get_data.py --log --board-id -2 --ip-address 225.1.1.1 --ip-port 6677 --
↪other-info -1
```

This emulator uses synthetic board as a master board and the IP address and port are hardcoded.

7.7.2 OpenBCI Cyton

Cyton emulator simulate COM port using:

- com0com for Windows
- pty for Linux and MacOS

You should pass test command line directly to cyton_linux.py or to cyton_windows.py. The script will add the port automatically to provided command line and will start an application.

Install emulator package:

```
cd emulator
python -m pip install -U .
```

Run tests for LinuxMacOS and Windows (port argument will be added by Emulator!)

```
python brainflow_emulator/cyton_linux.py python ../tests/python/brainflow_get_data.py␣
↪--log --board-id 0 --serial-port
python brainflow_emulator\cyton_windows.py python ..\tests\python\brainflow_get_data.
↪py --log --board-id 0 --serial-port
```

7.7.3 OpenBCI NovaXR

NovaXR emulator creates socket server and streams data to BrainFlow like it's a real board, but with much lower sampling rate.

Install emulator package:

```
cd emulator
python -m pip install -U .
```

Run tests:

```
python brainflow_emulator/novaxr_udp.py python ../tests/python/brainflow_get_data.py -
↪log --ip-address 127.0.0.1 --board-id 3
```

7.7.4 OpenBCI Wifi Shield based boards

Wifi shield emulator starts http server to read commands and creates client socket to stream data.

Install emulator package:

```
cd emulator
python -m pip install -U .
```

Run tests for Ganglion, Cyton and Daisy with Wifi Shield:

```
python brainflow_emulator/wifi_shield_emulator.py python ../tests/python/brainflow_
↪get_data.py --log --ip-address 127.0.0.1 --board-id 4 --ip-protocol 2 --ip-port␣
↪17982
python brainflow_emulator/wifi_shield_emulator.py python ../tests/python/brainflow_
↪get_data.py --log --ip-address 127.0.0.1 --board-id 5 --ip-protocol 2 --ip-port␣
↪17982
python brainflow_emulator/wifi_shield_emulator.py python ../tests/python/brainflow_
↪get_data.py --log --ip-address 127.0.0.1 --board-id 6 --ip-protocol 2 --ip-port␣
↪17982
```

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CHAPTER

EIGHT

ASK HELP

8.1 Contact Info, Feature Request, Report an Issue

- Join our slack workspace using self-invite page
- To report bugs or request features create an issue in our GitHub Page
- For hardware related questions and issues contact board manufacturer

8.2 Issue format

First of all you need to run your code with:

```
enable_dev_board_logger ()
```

After that, make sure:

- you've specified BrainFlow version and OS version
- you've attached all logs to your issue description
- you've provided steps or a simple example to reproduce your issue

8.3 Contributors

- Andrey1994 - 693 contributions
- daniellasry - 26 contributions
- shirleyzhang867 - 5 contributions
- mesca - 5 contributions
- Fan1117 - 5 contributions
- John42506176Linux - 4 contributions
- retiutut - 3 contributions
- alexcastillo - 1 contribution
- stellarpower - 1 contribution

CHAPTER

NINE

PARTNERS AND SPONSORS

9.1 OpenBCI

OpenBCI specializes in creating low-cost, high-quality biosensing hardware for brain computer interfacing. Their arduino compatible biosensing boards provide high resolution imaging and recording of EMG, ECG, and EEG signals. Their devices have been used by researchers, makers, and hobbyists in over 60+ countries as brain computer interfaces to power machines and map brain activity. OpenBCI headsets, boards, sensors and electrodes allow anyone interested in biosensing and neurofeedback to purchase high quality equipment at affordable prices.

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