

Data Representation for Motor Imagery Classification

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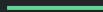
Philip White

Demonstration

OpenBCI Gui

Data stream and trial simulation

Field effect and Hand detection



Key Takeaways

- Classifies images fairly well
 - Too well
 - Undesired feature from environment
 - Offer great promise, but...
 - Progress must be made before usable as real-time BCI
 - Strength of signal images is in interpretability and cross-domain communication
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Abstract

While much progress has been made towards the advancement of brain-controlled interfaces (BCI), there remains an information gap between the various domains involved in progressing this area of research. Thus, this research seeks to address this gap through creation of a method of representing brainwave signals in a manner that is intuitive and easy to interpret for both neuroscientists and computer scientists. This method of data representation was evaluated on the ability of the model to accurately classify motor imagery events in a timely manner.

The proposed data representation of electroencephalographic signals in the form of signal images was found to be able to perform adequately in the task of motor-imagery. However, the amount of time to record enough samples was on the scale of a fifth of a second following the onset of an input from the user. This time delay represents the minimum window size needed to classify the event, meaning that to reduce this delay would require a fundamental shift in the data that is acted upon to perform classification or to generate the signal images. Furthermore, the system performed better than expected, even in the face of random data, suggesting that the system may be relying on some external factor or undesired artifact present in the data in order to perform its task.

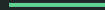
The strength of this approach came from its ability to be understood, visually examined, and altered in near-real-time in order to explore the data captured during a recording session. This was done after data had been recorded and involved altering sets of configuration parameters that affect the computations that go into generating a signal image. Namely, this included the window size, the function used to interpolate between two adjacent data points, and the amount of overlap of the windows. Effectively, this allows a researcher to playback the signal in an intuitive manner, watching for large shifts or edges in the images in order to detect large changes in the underlying data stream. Thus, while this approach may be unsuited for the task of classification, it would be an effective tool for conducting exploratory data analysis.

Motivation

- Unique means of user-control
 - Requires no active muscle control
 - Restore control for disabled
 - Fully-immersive VR
 - Allure of science-fiction
-

Purpose

- Hobbyists and low cost solution
- Cross-domain communication
- Control system
 - Reactivity
 - Accuracy



OpenBCI

Open-Source Software

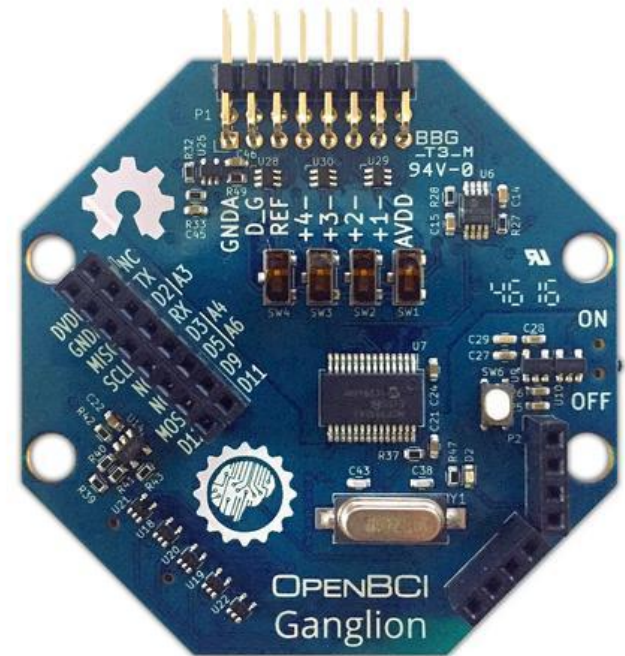
- All tools and software is available on GitHub
- Active community supporting product development
- Blog highlights recent advances made in the field

https://github.com/OpenBCI/OpenBCI_GUI

<https://github.com/OpenBCI>

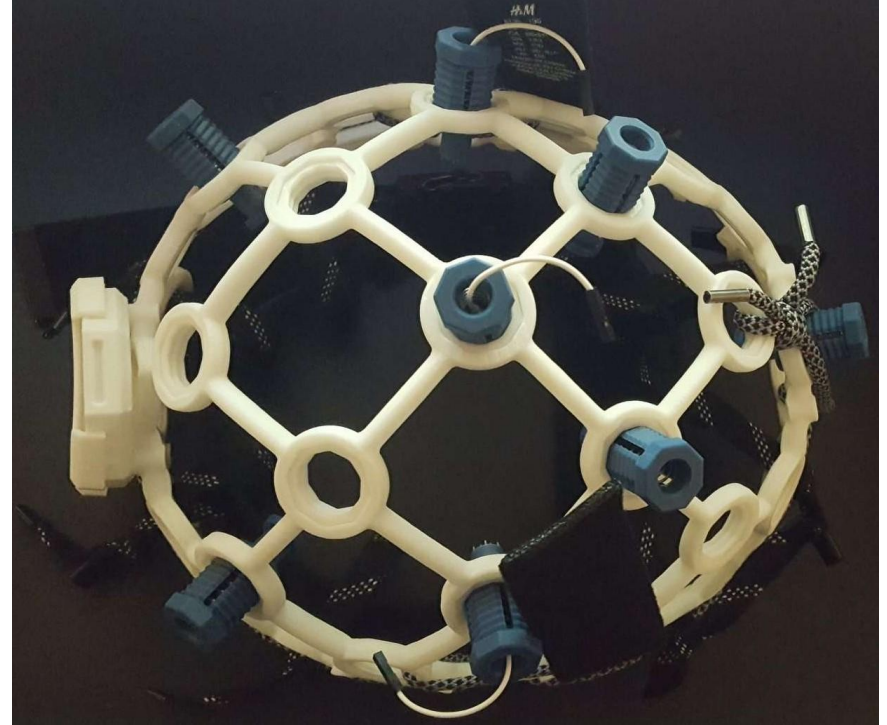
Ganglion

- Differential amplifier
- 4 channels
- Bluetooth connection
- 200 Hz sampling rate
- Simblee on-board microcontroller
- 3 axis accelerometer

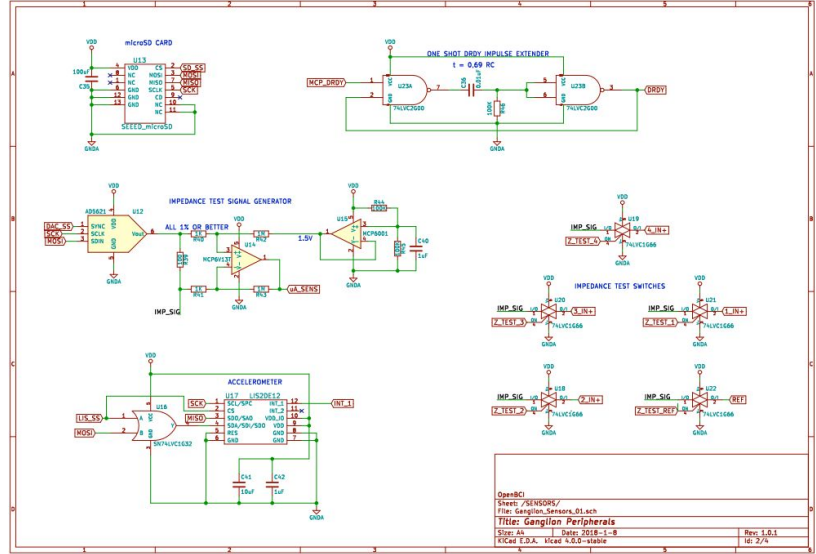
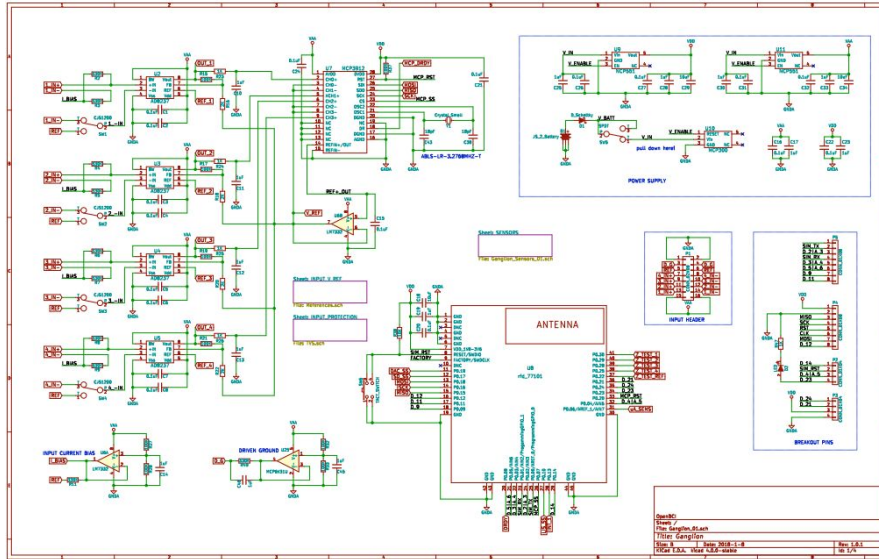


Modified Ultracortex Mark IV

- Supports up to 16 channels
- Electrodes placed based on 10/20 system
 - C3
 - CZ
 - C4
- Dry, spiky electrodes
- Belt restraint on the inside of the base
- Neck strap



Open-Source Hardware



https://github.com/OpenBCI/V3_Hardware_Design_Files

<https://github.com/OpenBCI>

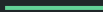
Background

Motor Imagery

- Evoked-potentials
 - User is presented with a stimulus
 - Steady state visually evoked potential
 - Event-related potentials
 - User performs some task
 - Time-locked to an event
 - Multiple ways to record these events
 - EEG
 - MEG
 - fMRI
 - Mu-rhythm suppression
 - Dip in frequency domain around 12 Hz
-

Convolutional Neural Network

- Convolution traditionally comes from signal processing
- Images can be interpreted as a discrete signal
- Operate on unstructured data



Data Acquisition

PhysioNet Dataset

- Build out and test system
 - Verified and widely used
 - Built using the BCI2000 system
 - 64 channels
 - 160 Hz sampling rate
 - 6 trial types
 - Baseline trials - 2 minutes
 - All others - 3 minutes
 - FIR band-pass filter 5 - 50 Hz
 - Implicit trust in subject
 - Subject knows next prompt
 - About 3 seconds between events
-

Manual Dataset

- Similar protocol as PhysioNet
 - No guarantee of rest event between left/right events
 - Next event is always random
 - About 5 seconds between events
 - Slight jitter added to event delay
 - 3 collection methods
 - Main
 - Random
 - Disconnected
-

Signal Images

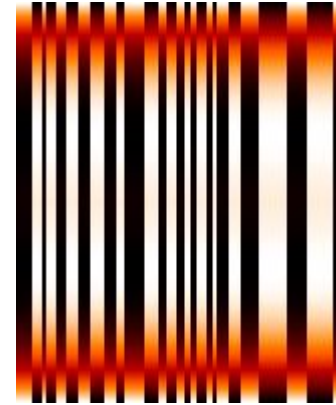
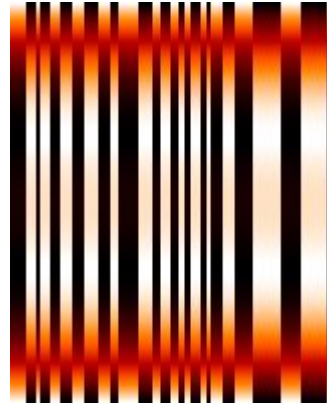
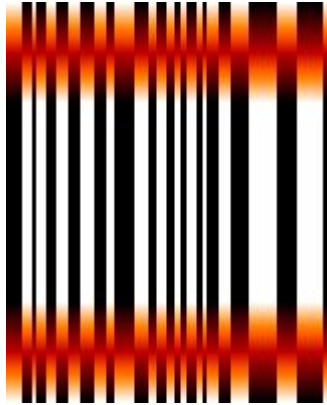
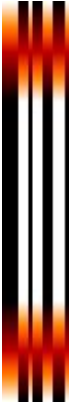
Signal Image

- Define row spacing
 - Provides height
 - Width directly correlates to time
 - Interpolation function
 - Linear
 - Quadratic
 - Cubic
 - `gist_heat` colormap
 - More intuitively understandable
 - Frequency horizontal change from black to white
-

Classification Dataset Construction

- Window length
 - Amount of time of image
 - 0.2, 0.4, 0.6, 0.8, 1.0 seconds
 - Window overlap
 - Number of steps shared between subsequent images
 - 20%
 - Affects dataset size
 - Interested in time per image
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S001



Linear

Quadratic

Cubic

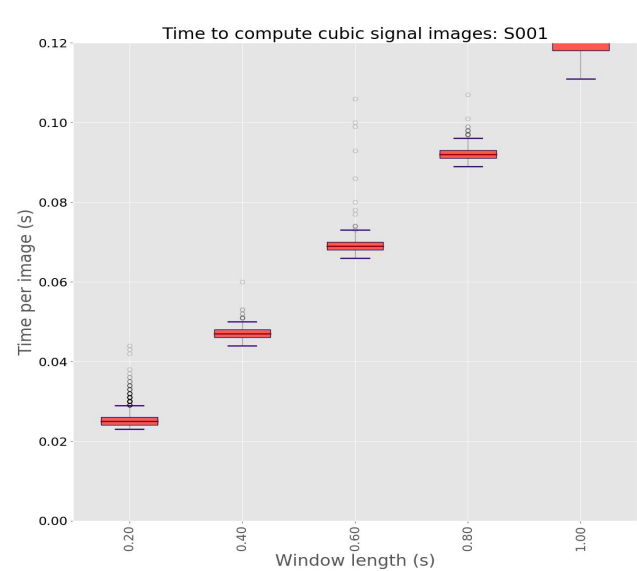
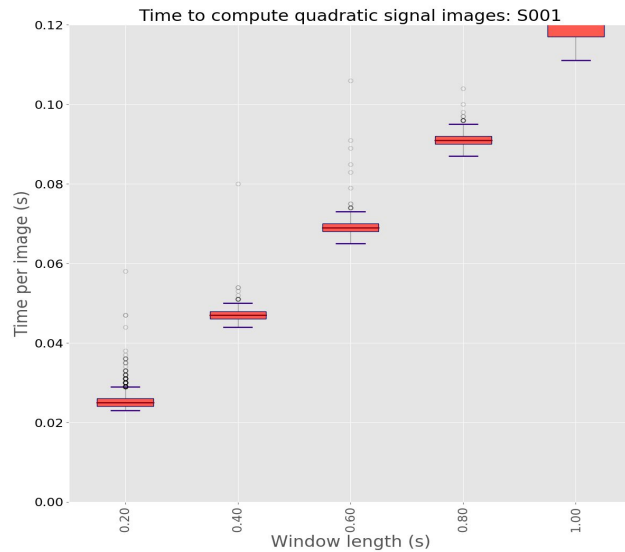
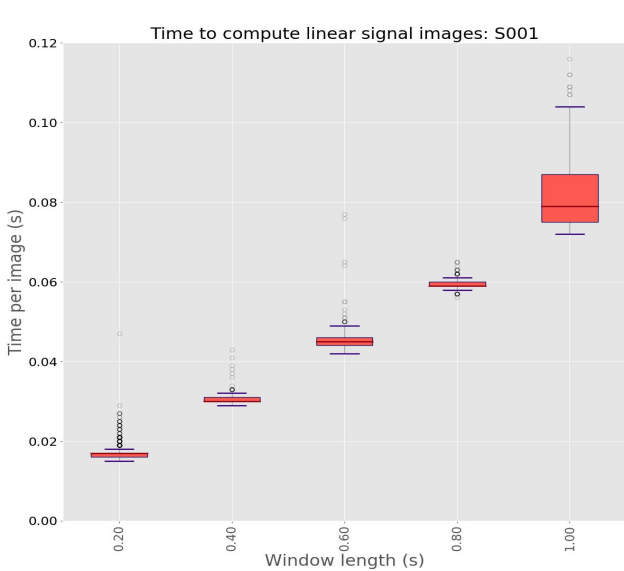
Main

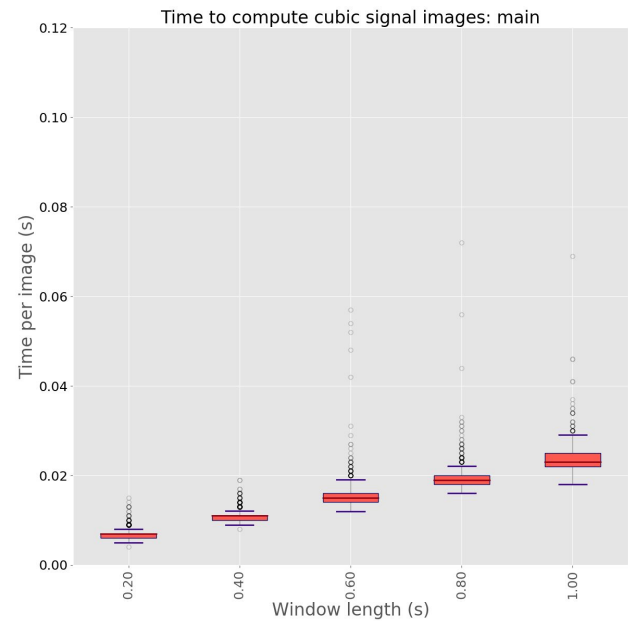
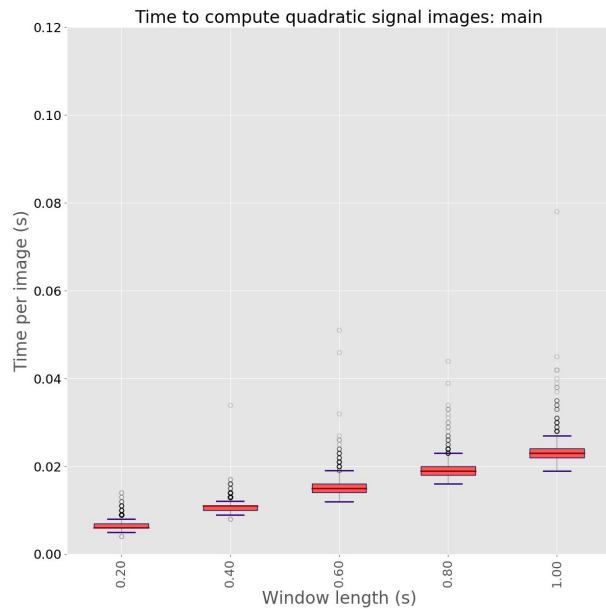
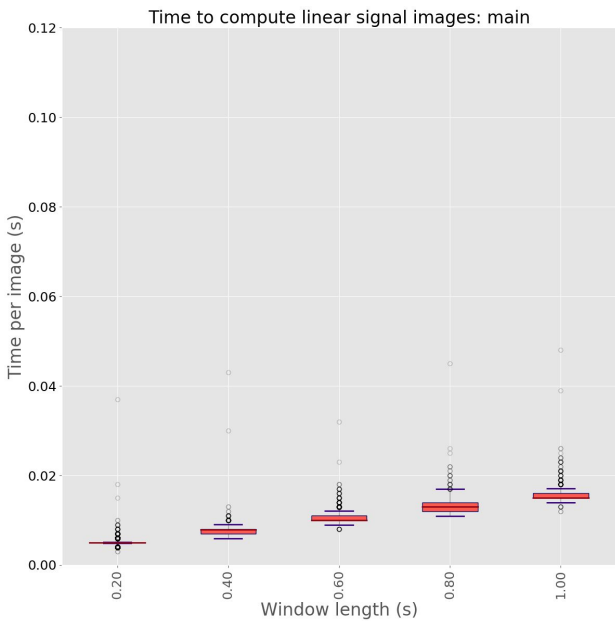


Linear

Quadratic

Cubic





Classification

Model Architecture

- Simple CNN
 - Focus on data representation rather than model tuning
- 3 channel 224x224 image
 - Secondary interpolation
 - Resizing an image scales the image in the frequency domain

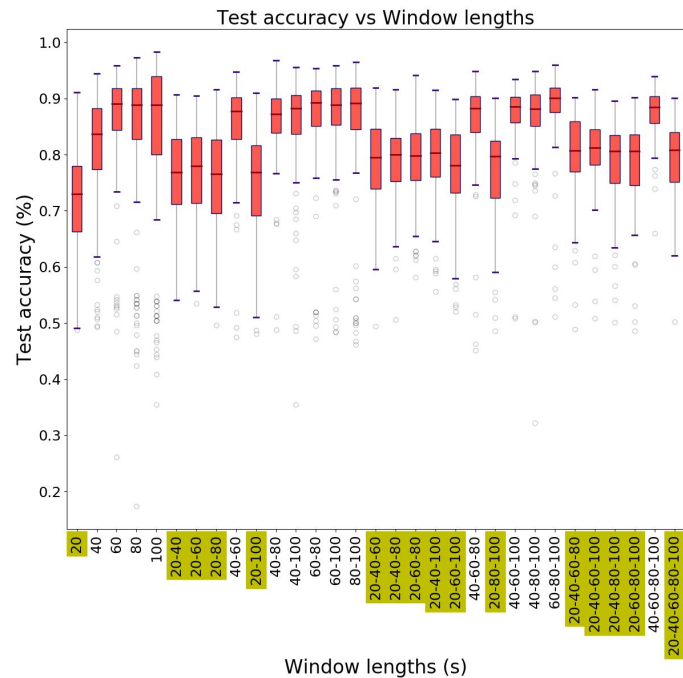


Test Accuracy

- Using '0.20' during training generally lowered accuracy
- High standard deviations
 - Likely an effect of low snr
 - Large number of local minima and maxima
- Performed well where it shouldn't
 - 'Disconnected'
 - 'random'

Subject	0.20	0.40	0.60	0.80	1.00
disconnected_01	83.45	92.17	88.77	92.20	88.39
disconnected_03	78.59	82.44	85.56	86.73	91.37
disconnected_05	51.58	82.41	84.15	85.33	82.50
main	59.99	79.76	83.62	87.46	82.29
random	54.75	73.27	80.73	89.03	89.45

Table 7.4: Recorded Accuracy per Window Lengths



Questions?

Comments?

Future Work

- Custom EEG Board
 - Active Electrodes
 - Non-contact Electrodes

 - Time-sequence Classification
 - 3D Interpolation
 - Transfer Learning
 - User Authentication
-

Implementation Details And Design Patterns

Signal Generator

Trial Recorder
