Developing a set of applications for music creation using low-cost brain-computer interfaces

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Abstract

In this paper we present a set of applications to use low-cost brain-computer interfaces for music creation and performance in the form of a PureData (Pd) External Library. This set of Pd objects allows artists and other potentially interested users to access both raw EEG signals and derived features and to include them in their own implementations.

1. Introduction

Brain-Computer Interfaces emerged in the medical field as a way to help patients with severe motor disabilities to communicate with their surroundings using only their brain activity [1]. Nowadays, focused in the general public, companies such as Neurosky and Emotiv started to develop more affordable interfaces for applications in entertainment and the arts.

Still in the BCI popularization context, Do-It-Yourself interfaces from hacked toys like MindFlex game appear as accessible alternatives to EPOC or Mindwave interfaces. The website Instructables[1] has lots of interesting tutorials, including one showing how to change the MindFlex operation mode and send its data via Bluetooth to a computer or smartphone [2].

2. The Application Set

To make it easier to use Brain-Computer Interfaces for interactive music and multimedia creation, we have developed a PureData[2] (Pd) External Library to work with the hacked MindFlex interface.

In the following, externals are divided in three groups: The main object, Feature Extraction and Auxiliary Functions. The source code and documentation for all the externals can be downloaded here[3]

2.1. The Main Object

The `mindflex` object is responsible for establishing the Bluetooth connection between interface and computer and for parsing incoming packets. To connect to an interface the user can either use the search function present in the `mindflex` object, and select the interface from a list of all Bluetooth devices available, or connect directly to the interface by informing the corresponding Bluetooth address.

After start receiving data, the `mindflex` object sends through different outlets all the information provided by the interface: the 12-bit signed integer raw signal sampled at 512 Hz and several signal features computed once every second: attention and meditation percentage levels, and energy levels for the 8 principal EEG bands (each as a 24-bit unsigned integer).

2.2. Feature Extraction

The feature extraction step is very important within the Brain-Computer Interface workflow, since it is based on the extracted features that we can infer the user's mental state and perform some associated action. Spectral-content-related features were chosen due to the MindFlex interface characteristic of having only one electrode located on the forehead.

The `mind_fft` object calculates the Fast Fourier Transform (FFT) of the EEG signal for

[1]http://www.instructables.com
[2]https://puredata.info/
[3]https://github.com/Feulo/pd_mindflex

a given window size (a power-of-2 passed as a creation argument). The FFT is calculated by the Cooley-Tukey Radix-2 algorithm, and the outputs are the spectrum real and imaginary components, respectively.

One of the most used features in BCI applications is the energy (sum of squared amplitude values) of specific frequency bands, which can be related to different mind states [3]. The energy in these bands can be calculated using the `mind_filter` object, which outputs the portion of the signal corresponding to a chosen frequency band, in addition to the `mind_energy` object, which receives a window size as a creation argument and produces a new energy value for each corresponding time window of the incoming signal.

2.3. Auxiliary Functions

A small set of auxiliary functions were developed to help users during patch creation; these functions do not perform BCI-related tasks but can be useful to test and collect data from patches.

When writing a PureData patch it is often necessary to display the data that is being acquired and manipulated. The `mind_tabwrite` object works similarly to Pd's `tabwrite` and `tabwrite~`, writing incoming data in an array passed as argument.

The `mind_sin` object can be use to simulate the raw data outputted by the `mindflex` object, but instead of outputting a complex EEG signal, it generates a sinusoidal wave with the same sample-rate of the MindFlex interface. The desired frequency is passed as argument and can be changed by sending a message with the new desired frequency. The `mind_sin` can be used to test patch response to a specific EEG frequency band without interference from other signal components.

The `mind_rec` and `mind_play` functions are used, respectively, to record and play a session; the first creates `.RAW` file and records all samples outputted by the interface between the start and stop recording messages passed to it, and the `mind_play` loads a recorded session file and outputs it as a compatible EEG signal. The use of these two functions helps testing patches under development using the same fixed session as input.

3. Final Considerations and Future Work

In this work we have presented a PureData External library developed to allow the use of a Do-it-Yourself Brain-Computer Interface for music and multimedia creation. The proposed functions grant access to all EEG data outputted by the interface and provide tools for manipulating this data, allowing new possibilities for composers and performers.

As future work, we aim to explore the usability of this type of interface in different musical and multimedia creation scenarios through existing partnerships with artists using Brain-Computer Interfaces in their works. We also want to investigate the voluntary control level provided by the interface and the extracted features through experiments with volunteers trying to accomplish proposed tasks by actively manipulating their mental states.

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