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The Utility of Electroencephalography for User Input

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**Starting Use of
Electroencephalography
as a Computer Interface**

Caleb Maurice

5/5/2022

ABSTRACT

The goal of this paper is to introduce the use of noninvasive brain-computer interfaces to prospective computer scientists. Electroencephalography is explained starting with how a user's brain waves are measured and ending with how the data is parsed to software programs.

To further expand on the ability to implement electroencephalography into software code, an example of a simple game is given. This game is an endless runner, meaning that it has no end and stops once the player's game piece collides with an object. It is coded in the Python computer language.

TABLE OF CONTENTS

| | Page |
|--------------------------|------|
| LIST OF FIGURES..... | iv |
| CHAPTERS | |
| I. INTRODUCTION..... | 1 |
| II. THE BRAIN..... | 2 |
| III. HARDWARE..... | 3 |
| IV. SOFTWARE & DEMO..... | 6 |
| V. FUTURE WORK..... | 9 |
| BIBLIOGRAPHY..... | 10 |

LIST OF FIGURES

| Figure | | Page |
|--------|--|------|
| 1 | Electrode Placements for 10-20 Standard..... | 5 |
| 2 | Electrode Placements on Muse 2..... | 6 |
| 3 | Game Screenshot..... | 8 |

INTRODUCTION

Electroencephalography (also known as EEG) is a method to measure and record data on electrical fields within the brain. It is most common in the medical fields to diagnose and detect problems that affect the brainwaves, such as epilepsy. However, there are also wide non-medical uses for this technology (Roy et al., 2019). Because brain waves can be read through EEG sensors, they could be used as a computer interface for interactive input rather than merely recording data.

Using electroencephalography as a brain computer interface has already proven itself feasible by various groups. The University of Minnesota had demonstrated the use of this noninvasive sensor array to control a robotic arm (Meng et al., 2016). Jack Stewart (2016), a reporter with no flight experience who works for the company Wired, got the opportunity to control a plane with EEG created by Honeywell Aerospace. Mercedes-Benz has also revealed a mind-controlled car concept at the 2021 International Motor Show in Germany (Humphries, 2021).

This paper intends to introduce programmers on how to start using EEG for their own software development. It will start with an explanation of the types of brain waves that will be detected. Then there will be an explanation of the hardware for EEG-sensing headsets. This will include the use of the specific model that is in the example. After the hardware is explained, the general workflow that comes from processing the raw data will be walked through. Finally, the audience will be introduced to useful tools to stream the data to Python 3.9 software from the headset introduced prior.

The choice of headwear used for this is the Muse 2 headband. This headband was selected because it is a commercially available headband that does not need any assistance to place on the user's head.

The programming example and demonstration will be a simple endless runner video game. The code will walk through each stage starting with connecting the headset. There it will then need to initiate the stream of the raw data into a buffer. It will then process the data and remove outliers that may come from external interference. Finally, the data will be able to be read by the software to interact with the game.

THE BRAIN

EEG devices are designed with the focus of reading only a specific type of brain wave. These brain waves, known as spontaneous EEG, then help determine the optimal placement of electrodes on the scalp of the user. The device then measures the difference of voltage between two electrodes to get its final readings (Müller-Putz et al., 2015).

Spontaneous EEG brain waves are measurable brain waves that are permanently active. These brain waves fluctuate and are typically measured between two electrodes compared between each other. The frequencies of these brain waves measurements are taken as changes over a given range of time instead of being read in a single instant. The fluctuation is often categorized by its frequency into five different subgroups.

Delta waves have the lowest frequency at 1-4 HZ. They typically indicate deep sleep or unconsciousness.

Theta waves are the second least active. These waves are 4-8 HZ and can indicate lighter levels of sleep or a drowsy state while conscious.

Alpha waves are 8-13 HZ. These waves can indicate that someone is relaxed. There are also studies that propose that these don't necessarily imply relaxed brain activity, but merely a difference in what information the brain is processing.

Beta waves, the second highest in frequency, range from 13-25 HZ. These waves can come from excited brain activity, such as focus or anxiousness.

The most active brain waves are Gamma waves, which are when the user is in peak performance. They are between 20 – 200 HZ, but they typically don't go over 40. (Müller-Putz et al., 2015).

HARDWARE

EEG sensing headsets demand multiple electrodes placed on multiple locations on the head. These electrodes are often made from a conductive metal and often applied with a conductive gel between the scalp and the electrodes. The conductive gel is necessary to detect brain waves whenever an electrode is placed over hair. These “wet” EEG caps typically require a second person trained on how to apply the device to the user's head (Fiedler, 2015). Two of these electrodes are then used together to read the brain waves. The active electrode relies on the second electrode, known as the reference electrode, to find differences in the brainwaves. Because no reference electrode is completely absent of activity, choosing which electrode to use will impact the results (Müller-Putz et al., 2015).

Alternatives to wet EEG caps do exist. Dry multipin electrodes are electrodes with 24 pins which are rounded off at the ends (Fiedler, 2015). These pins allow for the electrodes to reach the skin passed the hair layer, something that a flat electrode disk would not be able to do. By reaching the hair layer, it removes the necessity to apply a gel, reducing setup time and removing a cleanup time from user operation of the headset.

The Muse 2 headband uses flat electrodes but avoids the need of a conductive gel by other means. The headband focuses on using parts of the head that have no hair. This is primarily focused on the middle of the wearer's forehead and the back of their ears. The company does encourage dampening the locations if it is a notably dry day in order to assist the electrodes in reading the brainwaves.

The increase in the number of electrodes for an EEG device will also increase its accuracy but has a trade-off with cost and computer's hardware to keep up with the device's readings. Because of this, various standards have been implemented to make the most efficient use out of a limited number of electrodes. The earliest standard is a 10-20 system published by Jasper in 1958. This system uses only 21 electrode channels. There have been more advanced standards to gather more complex readings, such as the 128 electrode channel locations (Müller-Putz et al., 2015).

The Muse 2 follows a simplified version of the 10-20 standard. There are 5 electrodes in total. The frontal electrodes, which rests on opposite sides of the forehead, are positioned at AF7 and AF8. The temporal electrodes, which rests behind the ears, are

positioned at TP9 and TP10. The reference electrode for all the active electrodes is positioned center of the forehead, which is marked as FPZ (Chaudhary et al., 2020).

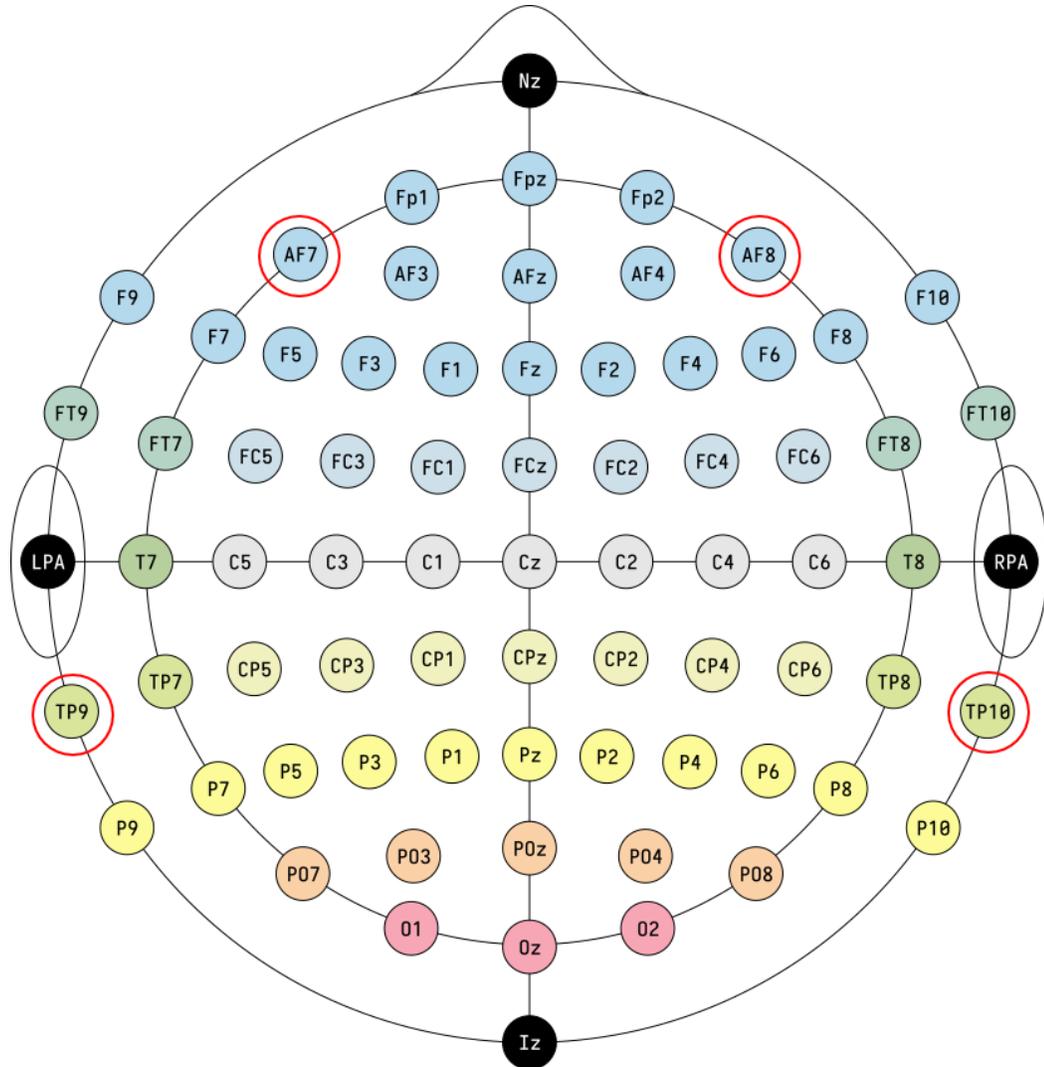


Figure 1: Electrode Placements for 10-20 Standard (Wikimedia Commons)



Figure 2: Electrode Placements on the Muse 2 (choose muse.com)

SOFTWARE & DEMO

The demonstration software remains simple because of the challenges with more complex brain readings. Daly and Wolpaw describes the beginning of using an EEG device as a ‘conventional learning process’ (Meng et al., 2016). This means that it will take some time for a consumer to get used to controlling, like learning how to ride a bike. Unlike learning how to ride a bike however, the computer still must process and understand the data that it’s taking in. Advanced use of EEG is very complex and requires several years of training, advanced signal processing, and feature extraction methodologies to correctly interpret the data (Roy et al., 2019) A portion of this work is necessary because of noise that electrodes may still pick up, interfering with the computer’s ability to understand what the user wants.

The demonstration is run on the Windows 10 operating system with a Bluetooth card installed on a PCI Express slot of a motherboard. This is because the Muse 2 is meant to connect to a partner application developed by the same company through Bluetooth. However, this partner application is specifically for mobile devices and does not allow the headset to pair with any other Bluetooth device freely.

For the Muse 2 headband, the first essential part is to connect it to the computer and begin the stream. This requires the participating computer to have a Bluetooth transceiver to communicate with the Muse 2 headband. To then connect to the headset and pull its stream, the application BlueMuse (Kowaleski, 2022) is used. The library Muse-IsI (Kothe, 2016) is then used within Python 3.9 to search for the data stream the computer is already receiving.

The rest of the workflow is then within a loop. The first stage of the loop is to acquire the raw data being received from the stream. This data is recorded over a length of time and placed within buffers.

The second stage of the cycle is the processing of the data. This is done by taking the raw data and separating the brainwaves into Delta, Theta, Alpha, and Beta waves. Each wave is then averaged over a certain period of time to make the signal smoother and easier to read.

Finally, the program is able to take the readings and apply it as input for any given program.

The input is used in the endless runner example and runs by the library Pygame. The target of the game is to travel the furthest distance a player can manage without their game piece (Figure 3, yellow object) colliding with any randomly generated objects (Figure 3, red objects). If a game piece collides with these objects, the game ends and could be reset from the beginning.

The game is controlled by the Alpha waves of the player. The game piece controlled by the user is then lowered if their concentration is below a lower limit, and the game piece rises if the frequency of the Alpha waves is above a higher limit. The lower limit and upper limit are different values so that there is a dead zone where the game piece will not raise nor lower to avoid the obstacles.

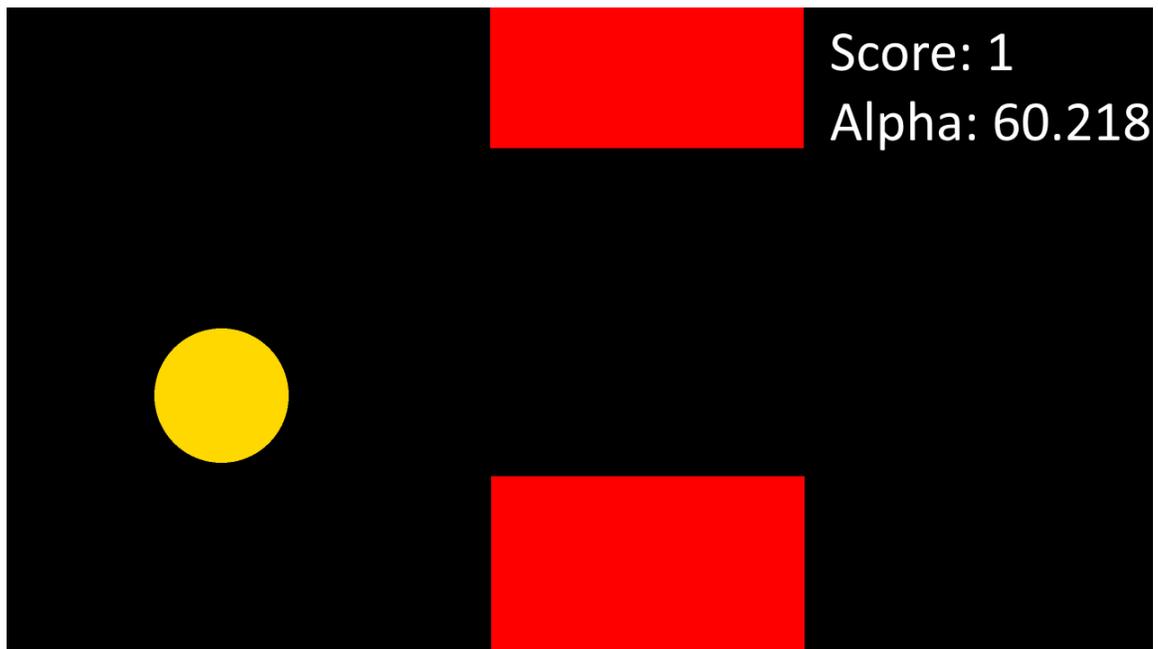


Figure 3: Game Screenshot

FUTURE WORK & APPLICATION

In the near future, the goal is for this to be used as a guide for future readers to learn how to achieve easily accessible and comprehensible brain-computer interfaces without reinventing the wheel. This should allow more computer programmers to experiment with controls placed in their games to allow more exposure and general demand for controls that involve brain-computer interfaces.

This is first achieved by introducing computer programmers to the brain waves involved. Therefore, the programmers understand what the sensors are reading as well as the difference between the five brainwave categories.

The next important thing that programmers are introduced to is the understanding of how the sensors operate. This will help them to easily apply headsets and connect them for easy and useful readings.

The final important note is the code. The software code will always follow a similar pattern, but it will change in appearance with each program. In the long term, fostering a larger community interested in brain-computer interfaces will help with making more complex control schemes for software with cheaper headsets and sensors.

BIBLIOGRAPHY

Chaudhary, Mahima & Mukhopadhyay, Sumona & Litoiu, Marin & Sergio, Lauren &

Adams, Meaghan. (2020). Understanding Brain Dynamics for Color Perception using Wearable EEG headband.

Delijorge, J., Mendoza-Montoya, O., Gordillo, J. L., Caraza, R., Martinez, H. R., &

Antelis, J. M. (2020). Evaluation of a P300-Based Brain-Machine Interface for a Robotic Hand-Orthosis Control. *Frontiers in Neuroscience*, 14. <https://doi.org/10.3389/fnins.2020.589659>

Fiedler, P., Pedrosa, P., Griebel, S., Fonseca, C., Vaz, F., Supriyanto, E., Zanow, F., &

Haueisen, J. (2015). Novel Multipin Electrode Cap System for Dry Electroencephalography. *Brain topography*, 28(5), 647–656. <https://doi.org/10.1007/s10548-015-0435-5>

Humphries, M. (2021, September 7). Mercedes-benz is experimenting with mind control

in vehicles. PCMag. <https://www.pcmag.com/news/mercedes-benz-is-experimenting-with-mind-control-in-vehicles>

Kothe, C. (2016) pylsl [Computer Software]. Retrieved from

<https://github.com/chkothe/pylsl>

Kowaleski, J. (2022) BlueMuse [Computer Software]. Retrieved from

<https://github.com/kowalej/BlueMuse>

- Meng, J., Zhang, S., Bekyo, A., Olsoe, J., Baxter, B., & He, B. (2016). Noninvasive Electroencephalogram Based Control of a Robotic Arm for Reach and Grasp Tasks. *Sci Repm* 6. <https://doi.org/10.1038/srep38565>
- Müller-Putz, G. R., Riedl, R., & Wriessnegger, S. C. (2015). Electroencephalography (EEG) as a Research Tool in the Information Systems Discipline: Foundations, Measurement, and Applications. *Communications of the Association for Information Systems*, 37(46), 911-948. <https://dx.doi.org/10.17705/1CAIS.03746>
- Roy, Y., Banville, H., Albuquerque, I., Gramfort, A., Falk, T. H., & Faubert, J. (2019). Deep learning-based electroencephalography analysis: a systematic review. *Journal of Neural Engineering*, 16. <https://doi.org/10.1088/1741-2552/ab260c>
- Stewart, J. (2016, November 15). I used only my mind to fly a plane around seattle. *Wired*. <https://www.wired.com/2016/11/used-mind-fly-plane-around-seattle/>