Measuring Brainwaves

Nikhil D'Souza[1], Matthew Yun[2]
Gunn High School[1] , Lockheed Martin Aeronautics Company[2]

INTRODUCTION

The human brain is the most advanced biological part in nature. It is so advanced that even humans are not able to understand it to our full capacity. However recently, scientists have been able to recognize that there is energy being emitted from the brain. All of our brains are made up of billions of neurons or, specialized cells transmitting nerve impulses. These neurons use electricity to communicate. When millions of these neurons communicate at once, this generates a significant amount energy. Scientists say that the brain can produce as much as 10 watts of electricity. This energy is in the form of waves, also known as "brain waves" or "neural oscillations". Brain waves are important because they represent the activity inside our brain. All our thoughts, emotions, and behaviors are results of our neurons communicating with each other.

The significance of measuring energy emitted from the brain is to associate brain waves with their patterns. Each person has a different brain wave pattern. Through a thorough analysis of brain wave readings, we have learned that these patterns can be used to learn more about the brain. Different feelings, emotions, and actions are represented by the speed of these brain waves.

RESEARCH QUESTION

How can an application that measures emitted brain waves give feedback based on a person's behavior?

BACKGROUND

Background and Significance

Brain waves, or neural oscillations, were first observed by German psychiatrist Hans Berger in 1924. Brain waves are vibrations emitted from the brain when neurons communicate with each other.

There are several types of brain waves, and each type of wave is used in different circumstances. When we are tired, slow, sleeping, or dreaming, we are emitting oscillations with low frequencies. When we are awake or alert, we emit oscillations with higher frequencies. According to Brainworks Neurotherapy, the different types of brain waves can be categorized according to their frequencies into four groups: delta (.5 to 3 Hz), theta (3 to 8 Hz), alpha (8 to 12 Hz), beta (12 to 38 Hz), and gamma waves (38 to 42 Hz).

According to Brainwave College, these waves are very important because they represent the activity that is occurring in the brain. But the waves don't only represent brain activity, they can also determine the brain's behavior. Brain stimulation can alter the patterns of brain waves thus changing the state of mind. An alarm clock is an example of brain stimulation because it is changing delta waves into beta waves (an asleep to awake state). Medications or recreational drugs are the most common methods to alter brain function. Developed by Hans Berger, Electroencephalography (EEG) is a human-made method to track brain activity without affecting the subject. By placing several electrodes nodes on the scalp of a person, the EEG is able to detect voltage fluctuations of the person's brain. According to WebMD, this is commonly used by medical professionals to monitor the depth of anesthesia and diagnose epilepsy, catatonia, and seizures. This method of detecting brain waves is not invasive unlike Electrocorticography, which requires electrodes to be placed on the surface of the brain instead of the scalp. The device that I will be using to measure brain waves is the Emotiv EPOC. According to Emotiv EPOC Product Specifications, the device is a scientific contextual wireless EEG system that has 14 EEG channels and 2 references. Using this device, I will be able to receive brain wave data from the Emotiv which can then be parsed through the server.

Research Methodology

The first step of the research will be to establish a way to attain access to the raw stream data from the Emotiv EPOC headset. For this task, I will be using "emokit", which is an open source driver created by the OpenYou Organization. Next, I will need to create a mechanism that can parse the data received from the Emotiv to the server. For this I will use Node.js, which is a JavaScript Runtime for developing server-side web applications. With Node.js I will be able to receive data on any device, whether it is a browser on a computer, or an app on an iPhone. Finally, this project will be open-sourced.

RESULTS

In order to measure brainwaves the following steps were used and perfected as the project progressed. The first step was to configure the Emotiv. The headset has 14 electrodes that have felt pads. Because brainwaves are electrical, a saline solution is required to moisten the felt pads to increase conductivity. After that, the Emotiv is configured but there is still no data being received.

Emokit, or an open source driver, was used for accessing the raw stream of data from the Emotiv. Using the programming languages C and Python, I was able to parse the information from the Emotiv and send it to a local server.

To extract the raw data, the first task was to return the hidraw device path and headset serial number. This is important so that the Bluetooth device can be found and accessed using the hidapi. With the key values returned from the hid device found by the hidapi (Emotiv), the Emopacket class was created. The purpose of the Emopacket class is to initialize packet data and set a variable for the global battery value.

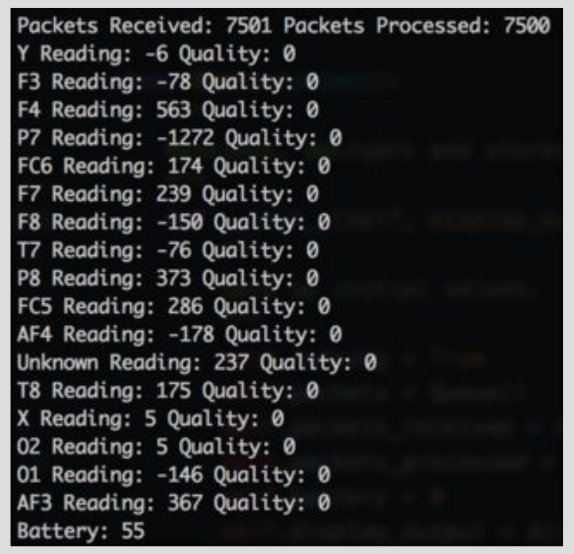
Unfortunately an obstacle I faced while receiving the data was the encryption. So a crypto function was used to perform a decryption of the packets received by the Emotiv. Then an Emotiv class stored the decrypted packets in a queue for later use.

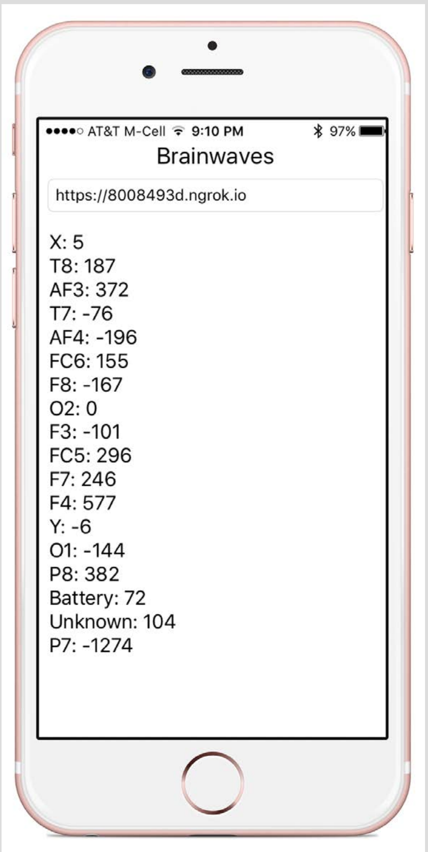
Finally, an update console function outputted the sensor, gyro, and battery values once per second to the console. An additional function was used to return sensor level values from data using a sensor bit mask in microvolts (uV).

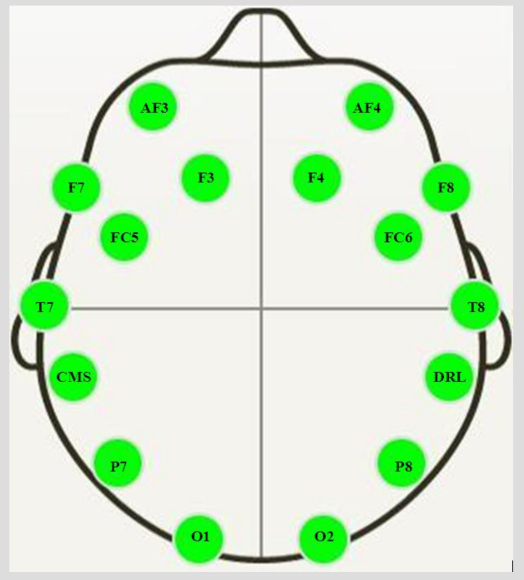
The Emotiv data was being outputted on the computer, but still nothing will appear on the iOS Device. To send the information from the computer to the iOS Device, I used ngrok, or a service that creates secure tunnels to local host. This creates a way to send information from your local machine to the Internet in a public URL.

Lastly, an iOS app was created so that the user could open it and view the information. However, the information still needed to be received from the ngrok server and sent to the iOS device. To do this a get request function that uses Alamofire, or an HTTP Networking service, to get the information in the ngrok server. This receives it as a JSON file. Also, this function parses the information out of the JSON file and displays in the app. One problem that this creates is that there is only one get request. The Emotiv is supposed to output information continuously. So a repeat request function was created to use an NSTimer to send get requests in intervals, once per second.

DATA / PICTURES







CONCLUSION

The focus of this project was to find a way to measure the brainwaves of a human and output the data on an iOS device. I was very successful to decrypt the raw data from the Emotiv and output it in microvolts.

A question that I had throughout my project was: Why were the electrodes positioned on the Emotiv in fixed locations? It turns out, these electrodes are reading emitted electrical energy from various different parts of the brain. The human brain has specific areas that emit more energy than others. In other words, these are the most optimal electrode positions for the purpose of this project. However a more powerful EEG headset would have many more electrodes for measuring brainwaves emitted from more parts of the brain.

Another conundrum that I did not immediately understand was why the Emotiv data encrypted. After doing some research, I realized that brainwaves are very unique to each person and if a hacker were to get their hands on the data, they could potentially reveal information about the user.

A few complications that I had while doing the project include not being able to connect to the Emotiv, not being able to gain access to the raw stream of data, not being able to send the data to a public server, and not being able to parse the data from a JSON file. Eventually, I was able to solve the problems and get closer to my goal.

In the beginning of the project, I expected to see data similar to my final results because of the way the brain functions. However what I failed to see was the correlation between brain function and human behavior. The Emotiv's data was not very helpful as to understanding what a person is actually doing. Occasionally, I was receiving misleading results which did not serve any purpose at all. I believe there is still a long way to go until we perfect this technology. The brain is one of the most mysterious biological organs on our planet, but more projects like this could completely change our understanding of neurology.

In the end, this project has educated me on basic neurology, data extraction, cybersecurity with data encryption/decryption, data parsing, sending data through the web, and HTTP requests.

NEXT STEPS

Neurotechnology is the next dimension of technology. Although this technology is still not very reliable, the possibilities for invention and discovery are endless. Neural Entrainment is when one of the senses is given a stimulus. Recording neural activity during entrainment shows a Cortical Evoked Response in the brain.

This can be setup in a scientific experiment by making a person listen closely to small, rapid pulses of sound. As the sounds progresses, the frequency rate of these pulses can change slowly, and the brainwave patterns of the person will change guiding their mind to various useful mental states. Brainwave Entrainment is a very precise way to control your brainwaves, and reproduce the exact frequencies required for the states of mind. Another example is staring at a campfire or the flickering of a burning candle. This can ease your mind into a state of calmness.

Another possibility to take this project to the next level is by using the brainwave data to control objects. An algorithm could be deduced to control a drone, for example, and hover it in a direction depending on the frequency of a person's neural oscillations.

Today, scientists have not discovered all of the types of brain cells that exist. They also do not fully understand how electrical and chemical signals from neurons produce thoughts. With this gap in knowledge, scientists are not able to explain how major traumatic injuries and neurodegenerative diseases affect brain function. There are over 1.4 million people annually in the United States that suffer a traumatic brain injuries and over 50,000 of those people die. By improving Neurotechnology, doctors will be able to save thousands of lives each year.

ACKNOWLEDGEMENTS

I would like to thank my mentor Matthew Yun for assisting me throughout my whole project even when I had encountered several obstacles. I would also like to thank Kevin Frans, for helping me send the Emotiv data from the computer to the iOS device.

This project is open-source. See the project at: https://github.com/nikhiljay/brainwaves.

Sources include: Brainworks Neurotherapy, Brainwave College, WebMD, Scientific American, Transparent Corporation, Huffington Post, and BrainandSpinalCord.com.