CSE396-COMPUTER ENGINEERING PROJECT

Spring 2022

Final Report

REDSTONE

- EMPLOYEES -

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Company Goal

- Making suggestions and determinations by monitoring the psychological symptoms of the users by making use of the opportunities provided by fNIRS technology.

Our Project

- People want to listen to different types of music according to their moods, but there may be situations where they have difficulty deciding. The project, which we aim to develop as a company, aims to find the best type of music suitable for the instant moods of the users.
- In our project, there is a music piece prepared by us, the type of which cannot be easily detected by the users, and a headband containing the fNIRS technology that we will use to measure the reaction of the user while listening to the music. It aims to show the user which music genre their current mood is more inclined to by making comparisons with the data when the user is listening to the music through the data we have obtained before.

RoadMap

➢ Ordering

A few companies supplying parts were contacted and the necessary materials were ordered.

➢ Building Hardware

- Control and Sensing Electronics

  The control and sensing electronics require of four small circuits:

  - Data acquisition and Bluetooth® broadcasting board
  - LED Intensity control board
  - Detachable Sparkfun® LiPo Charger with 400 mAh LiPo battery
  - fNIRS sensing electronics.

  We will print electronic circuits and assemble them according to instruction manual.

- Headband and Casing

  Headband will be designed to be suitable for control and sensing electronics in a way that is easy for the user to use.

- System Consolidation

  We will install control and sensing electronics into our headband.

➢ Developing

We will create website for the customers to inform users about our project. Also, we will make mobile application. In mobile application we will gather current emotional values to user and add our database that will be the source for making decisions about which music type the user likes most at that time. We will show our estimation to user inside mobile application.

➢ Data Collection

Create music with small parts from different kind of music. In line with the purpose of the project, a music piece of 2 minutes is prepared. For creating a database, the data collected from the sensor is recorded by listening to music to the volunteers while the device is plugged in.

➢ Testing

The tests are carried out by means of the sensor on the equipment and the communication device on the equipment. Testing our device in different situations and environment to improve its music taste detection ability and advancing its calibration process even further from acquired data from tests.

Task Sharing

<table>
<tr><td></td><td>What is to be done?</td><td>Group Members</td></tr>
<tr><td>Software Development</td><td>Creating a website where our customers can reach us and learn general information about our product. (Using React)
Create a mobile app which detects and shows music type the user likes most according to the current mood. (Using flutter/java)</td><td>Hüseyin Ömer Güray
Muhammed Bedir Uluçay
Mithat Enes Özdemir
Muhammed Alperen Karaçete</td></tr>
<tr><td>Hardware Development</td><td>Follow given instructions at manual as follows:
Prepare control and sensing electronics.
Making Headband and casing.
System consolidation.</td><td>Ozan Şelte
Burak Ceylan
Zeynep Çiğdem Parlatan
Rian Ryzhov</td></tr>
<tr><td>Data Analysis</td><td>➢ By using machine learning, the most appropriate classification algorithm will be determined and applied to the data taken from data collection.</td><td>Anıl Mert Ulaşan
Yusuf Boy
Selimhan Meral
Mustafa Gürler</td></tr>
</table>

The Final Product We Aim For

In the final version of our product, we aim to design a headband like the one above, and make the users listen to the special song we have prepared, make the necessary measurements thanks to the headband we have designed, and estimate music type that user likes most at that time according to the headband data.

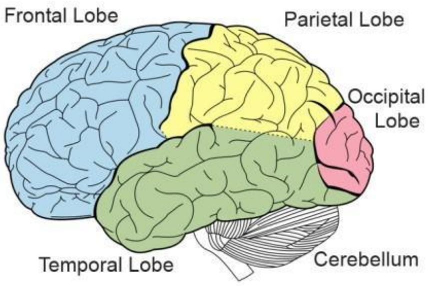
Theoretical Framework

As we mentioned in the introduction, this project is based on observing the effects on the brain by making people listen to a piece of different music genres.

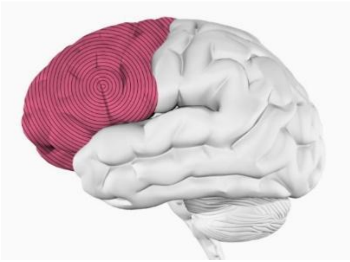
➢ Brain Structure and Response to Music

Music, which exists as a part of people's life, begins to take shape on the basis of sound and hearing. Vibration waves produced by a source are carried to the ear through the air. Here, too, it is converted into electrical signals transmitted to the brain via auditory nerves, and these signals are transmitted to the auditory canals in our brain. By interpreting these signals in the relevant areas of the brain, the perception and meaning of music emerges. That is, music is perceived as music only after it has been combined and interpreted in the brain. New signals, organized according to the characteristics of the perceived music, are sent to many more brain regions. As you can see, when we start listening to music, almost all parts of our brain are affected.

If we look at the structure of our brain, the cerebral cortex is divided into four lobes. These are frontal, temporal, parietal and occipital. Each of these lobes is responsible for different functions.



The frontal lobe is the lobe with the most space in the brain and performs functions such as thinking, decision making and planning. It is one of the most affected areas when we listen to music.

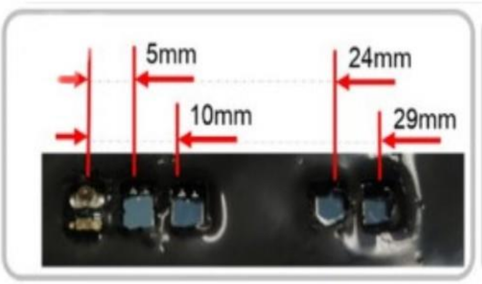


This lobe is the area we focus on in our project, as it is one of the most affected areas and occupies a large area by being located in the front of our head. Therefore, while we designing our headband, we positioned the photodiodes to be in front of our head.

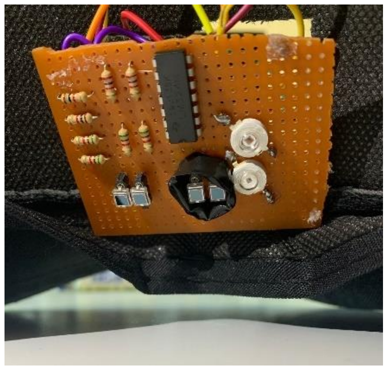
Hardware Details

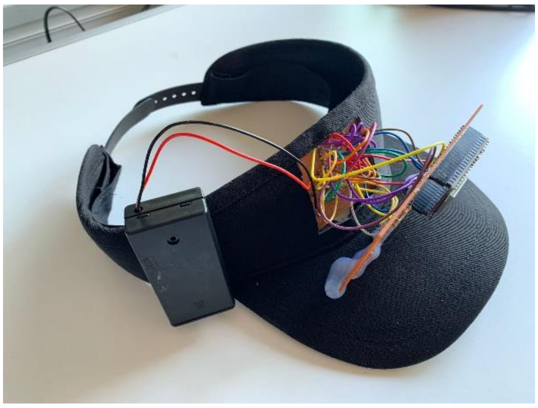
➢ Hardware Description

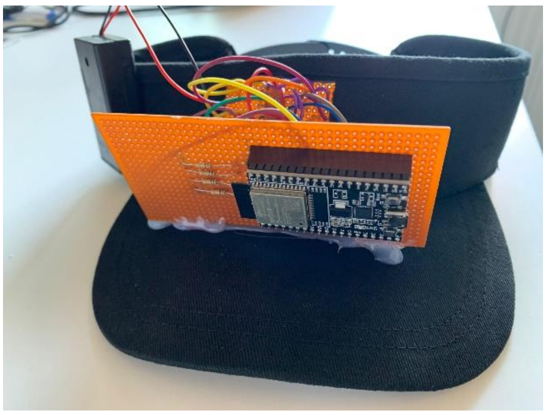
Analogue data reading was performed with the help of ESP32-WROOM-32D Wi-Fi Bluetooth Development Module from the diodes on the hardware. The read analog data is transferred to the phone with the help of the mobile application we developed using the BLE technology provided by the ESP32-WROOM-32D Wi-Fi Bluetooth Development module. The data transferred from ESP32 to the phone takes place from the beginning to the end of the piece of music that the user listens while using our product. After the data collection over the phone is completed, the collected dataset is transferred to the database we have set up on a remote server.



Placement of photodiodes







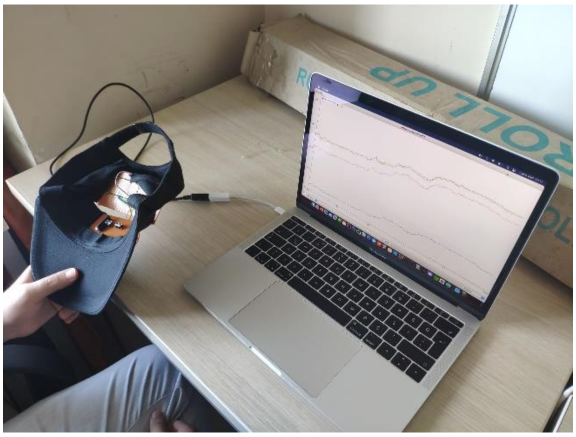
➢ Bill of materials

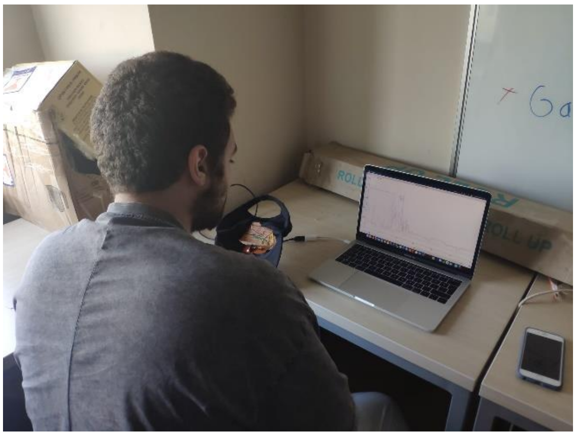
Product	Description	Manufacturer	Cost
	ESP32-WROOM-32D	MINGYUANDINGYE	118.84₺
	BPW34 Photodiode (4)	CHINA	100.84₺
	3W IR Power Led 730nm 740nm	EPILEDS	21.24₺
	3W IR Power Led 840 - 850nm	EPILEDS	20.36₺
	Perforated Plaque	CHINA	14,58₺
	Jumper Cable	ETERNALFAR	15₺
	Lithium-Ion Battery Holder	CHINA	7,78₺
	LM324N OpAmp	TEXAS	4,91₺

Total Cost: 303.55₺

➢ Validation and Characterization

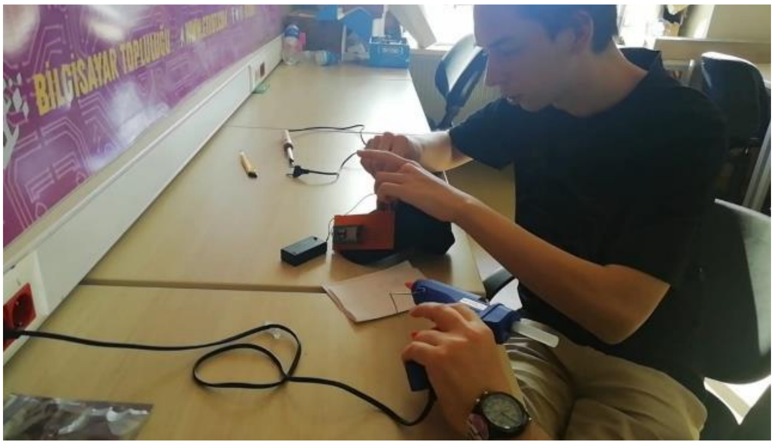
The sensor data coming from the plotter as serial data from the ESP32-WROOM-32D module was checked according to behavior of the photodiode.

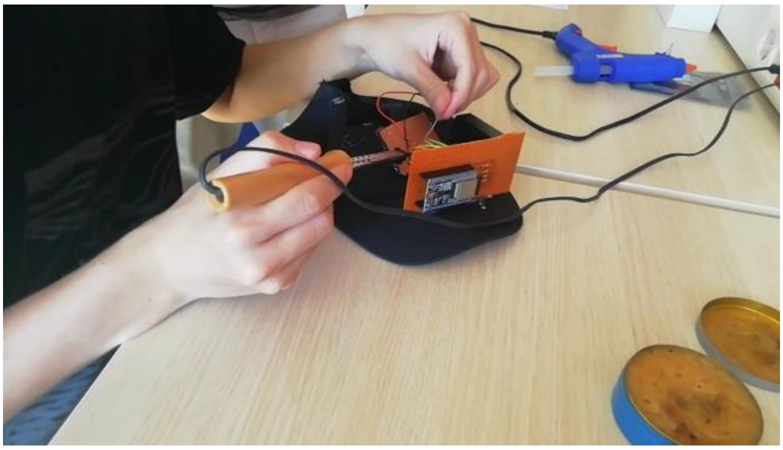




Methods

➢ Building





➢ Participants

A total of 100+ participants between the ages of 19-27 participated in our project voluntarily. Before starting the test, the whole process was explained to the participants. (After adding the opamp to the hardware and applying the FFT, we were able to get 32 new data.)

Participants were selected from Gebze Technical University library, Gebze Technical University Kelebek cafeteria and Gebze KYK dormitory

➢ Project Design

For the music to be played to the participants, 6 different genres and 2 songs of each genre were selected. These musical stimuli were selected according to certain characteristics by examining previous studies and articles.

Selected genres are listed below.

- **Classical Music:**
  The most important feature is that it is polyphonic or very melodic (polyphonic) and polyrhythmic (polyrhythmic). It usually contains the most violin family (string instruments).

- **Electronic Music:**
  It is the name given to the type of music made with the help of electronic hardware and software suitable for this hardware.

- **Jazz Music:**
  Jazz music is created using blue notes, syncopation, swing, multiple rhythm, bickering, and improvisation techniques.

- **Rock Music:**
  Musically, rock is based on the electric guitar and is usually achieved by incorporating electric bass guitar and drums.

- **Pop Music:**
  Pop songs are typically short to medium length with repeated choruses, melodic tunes, and hooks.

- **Hip Hop Music:**

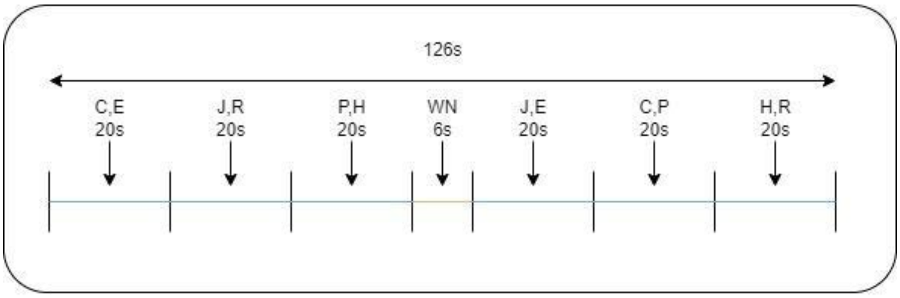
  Hip hop music consists of stylized rhythmic music that commonly accompanies rhythmic and rhyming speech ("rapping").

Genre and Stimuli No.	**Music Stimulus Name**
Classical 1	“Canon In D Major” by Pachelbel
Classical 2	“Four Seasons” by Vivaldi
Electronic 1	“Dancin” by Aaron Smith
Electronic 2	“Bad” by David Guetta
Jazz 1	“Feeling Good” by Michael Bublé
Jazz 2	“Sing, Sing, Sing” by Benny Goodman
Rock 1	“Iron Man” by Black Sabbath
Rock 2	“Smoke On the Water” by Deep Purple
Hip hop 1	“In Da Club” by 50 Cent
Hip hop 2	“Empire State of Mind” by Jay-Z
Pop 1	“Uptown Funk” by Bruno Mars
Pop 2	“Happy” by Pharrell Williams

Table1: Music Stimuli used in the project

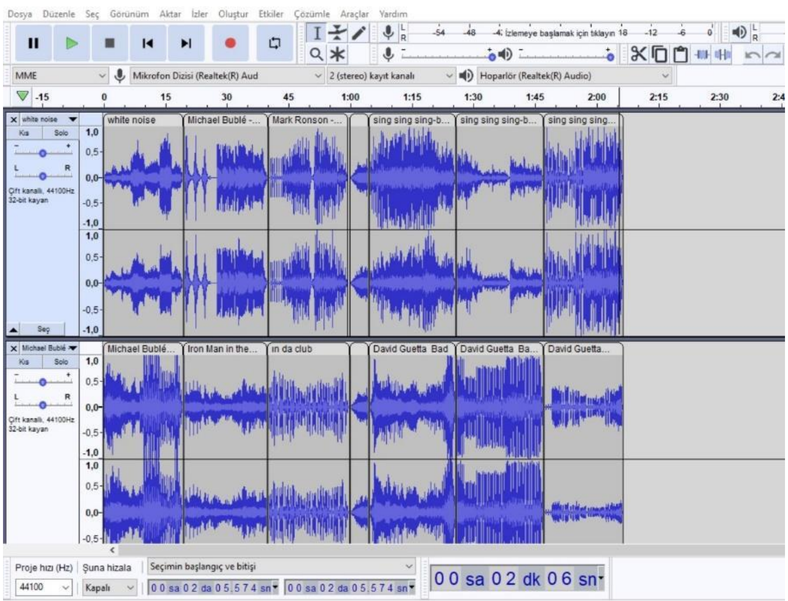
We superimposed the genres in pairs using Audacity software. Our aim in doing this is not to make the participant listen to a single specific genre, as we stated in the introduction to our project, but to listen to different genres in a complex way and to observe the effects on their brain according to their instant mood.

Since the brain cannot perceive many different species in a short time at the same time, we found it correct to reduce it in pairs. To interpret the data, we received in a meaningful way, we matched the same species with each other differently and obtained two different cross sections. We did it using the Latin square method to eliminate any sorting bias when matching.



Audio sample pattern. Classical(C), Elektronic(E), Jazz(J), Rock(R), Pop(P), Hip Hop(H), White Noise(WN)

We added white noise generated by the audacity software between the two slices created. Technically speaking, white noise can be defined as noise whose amplitude is constant throughout the audible frequency range. After the first slice, a short-term white noise was added to allow the brain to return to basic values and resting state. Thus, when we moved to the second section, we aimed to obtain more accurate values.

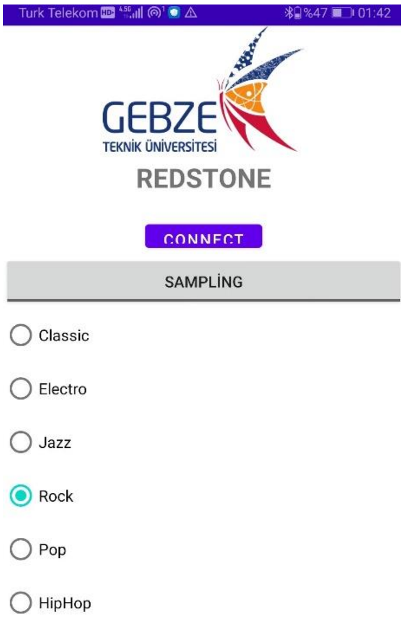


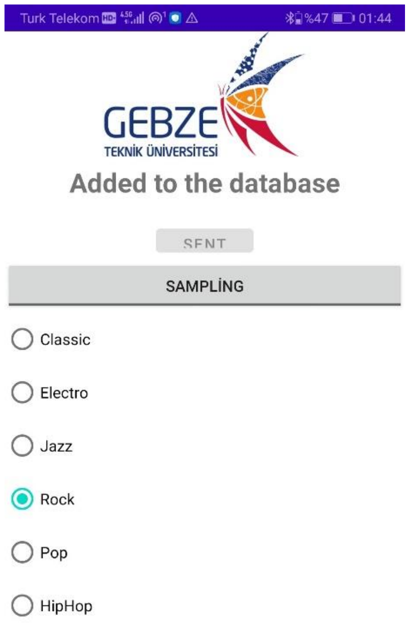
Audacity Software with selected songs

When we got to the testing phase, we first explained the purpose of our project to the volunteers and started the testing process when they agreed to participate. In order to prevent the effect of the movement, we put the participants on the chair and put on our headband and on-ear headphones. Since we will be playing songs, we tried to create an isolated environment and used noise canceling headphones, since the noise coming from outside could affect the flow of the project.

In the same way, to avoid the effect of movement in the cerebral blood flow, we wanted them to remain motionless by focusing their eyes on a fixed cross on the computer while playing the song.

Before starting the song, we asked the participants which of the 6 genres they would like to listen to, and after their answer, they started to listen to our test song. During this process, which took about two minutes, we received the data from the user with the help of photodiodes.





Screenshot of data collection via mobile application.

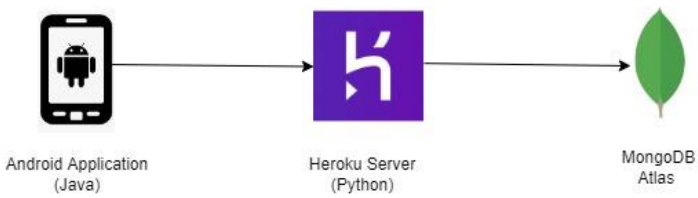
Screenshot of user side at mobile application.

➢ System Design

In the application we are using Java. Our app is firstly scanning available Bluetooth devices to find the one which we build as a hardware. After the app find the device, our test music start playing, and we start to read all data from device then push all data to an array which we read from device. When the song stops playing, we are sending a post request to our backend service which we deployed on Heroku. We are using POST requests to gather our data. Our backend is written in Python and our database is MongoDB on MongoDB Atlas platform.

If our data is a test data, we switch to the "Test" mode by pressing the box with the title "Sampling" and which type of music will he or she like and if its test data we are also sending array as a result which song liked from tester and don’t getting any response.

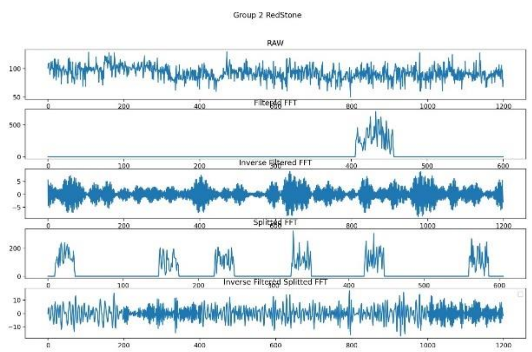
If it’s not a test data, we are just sending values and waiting response from our backend service to which song is proper for the person.

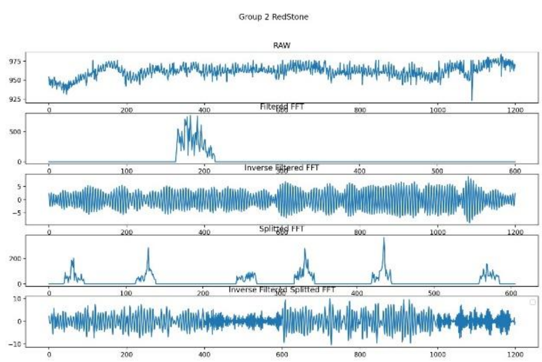


➢ Data Processing

Data processing phase, we ended up with a model that trains itself to suggest a song kind in six different songs.

We receive 4 different columns of data from 4 different sensor which is attached to user frontal lobe. We put the raw data to FFT to filter and get a meaningful data for data analysis part.





We used two different FFT results to use in data analysis and machine learning part. We calculate FFT’s and then found the best part of the FFT to filter. We removed the zero parts to obtain meaningful data. Inverse FFT filtering applied for the meaningful data obtained from FFT filter. Then the raw data divided into 6 parts and we applied the same procedure to all of them, finally merged into one.

Since we have 6 different kinds of mix in our test song, we separated the values into 6 equal columns. Each part of data column obtained from dividing into 6 different ranges mean of the dataset. In the end of this part our dataset has 12 columns (6 columns of first FFT, 6 columns for second FFT result) and the label. Label represents the song kind that chosen by user.

Selecting the best data manipulation algorithm, we depend on KNN (K-Nearest Neighbors). Because we have 6 kinds of songs and to achieve a successful model, we need nonlinear algorithms. After we need classification because as we mentioned sensor data should present one type of genres.

10	113.777778	114.222222	110.240741	99.111111	98.592593	101.592593	4
11	113.777778	114.222222	110.240741	99.111111	98.592593	101.592593	4
12	58.037037	58.055556	57.907407	56.962963	56.333333	57.092593	3
13	824.166667	815.296296	810.481481	814.981481	3458.518519	1647.722222	1
14	219.388889	225.870370	229.092593	231.962963	232.759259	234.129630	3
15	219.388889	225.870370	229.092593	231.962963	232.759259	234.129630	3
16	1655.000000	1655.555556	1667.462963	1657.407407	1667.870370	1669.000000	0
17	1978.370370	1995.666667	2489.222222	2230.222222	2085.537037	2046.074074	0
18	2110.388889	2144.759259	2148.870370	2163.370370	2165.444444	2146.481481	4
19	2486.481481	2501.074074	2504.518519	2505.240741	2502.018519	2504.851852	3
20	2486.481481	2501.074074	2504.518519	2505.240741	2502.018519	2504.851852	3
21	2223.592593	2370.944444	2371.796296	2400.925926	2414.759259	2424.814815	2
22	991.203704	996.203704	1000.759259	1002.444444	986.740741	969.611111	1
23	991.203704	996.203704	1000.759259	1002.444444	986.740741	969.611111	1
24	365.814815	355.574074	336.111111	365.351852	400.074074	390.574074	5
25	365.814815	355.574074	336.111111	365.351852	400.074074	390.574074	5
26	1676.388889	1686.129630	1688.500000	1687.481481	1699.925926	1708.166667	4

Post process dataset.

- **Selecting Classification Algorithm**

Since we must predict a song type, we must apply classification algorithm to the model. We applied KNN (K-Nearest Neighbors), SVC (Support Vector Machine), DT (Decision Tree), Random Forest and Naïve Bayes algorithms to train the model. Then we tested each algorithm by applying k-fold cross validation. We checked confusion matrices, precision/recall values, execution time and overall accuracies to decide on the best classification algorithm.

We got the best results with Random Forest Classifier. Other algorithms produced really bad results. These are the results of the Random Forest Classication;

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Maximum Accuracy That can be obtained from this model is: 31.25 %

Minimum Accuracy: 12.5 %

Overall Accuracy: 21.875 %
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- **Result and Discussion**

While testing the headband with the song, we receive data from the user every 100 millisecond which is enough to label. Since our device has a Bluetooth connection, sending data every 100 millisecond can be fast for Bluetooth. Therefore, some data loss may occur (negligible). Since the amount of data that we collect is too low to train a machine learning model, all the algorithms we test, did not perform very well. However, the accuracy we achieved is acceptable depending on our dataset size. If we could collect ten thousand more data and train our model with it, we could comment on failures of the project better.

Our Project Sources and Official Site

- Website Source Code: https://github.com/RedstoneGtu/redstonegtu
- Heroku Source Code: https://github.com/RedstoneGtu/redStoneHeroku
- Firmware Source Code: https://github.com/RedstoneGtu/redStoneFirmware
- Mobile Application Source Code: https://github.com/RedstoneGtu/Android_Java_App
- Realtime Raw input monitor(serial): https://github.com/RedstoneGtu/Serial_Plotter
- Website: https://redstonegtu.github.io/redstonegtu/
- YouTube Video: https://www.youtube.com/watch?v=7K6aRm8lHxc
- Music:https://drive.google.com/file/d/1svFXuHczr8yqmkgar_2cMnrQf41lsp7p/view
- Mobile Application APK Document: https://drive.google.com/file/d/17s4xj84wTbnK8vjEabNVGoG9_XAGbX8d/view?usp=sharing

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