Mental State Classification By Using Brainwave Sensors

Sukh Sagar Subedi
G19608
Hiraishi Lab

Introduction

- Mental state classification in BCI plays a vital role in different sectors like Medical, Engineering, Robotics, etc.
- The importance of efficient human-machine interaction mechanisms increases with the number of real life scenarios where smart devices, including autonomous robots, can be applied.
- Decoding uses classification/regression models to transform the EEG features into high-level signals such as letters in a speller, directions of motion, affective or cognitive states or clinical markers.

Purpose of research

- Designing a simple BCI game
  - By using a simple brainwave sensor.
  - Concentration and meditation level from the sensor were extracted.
- To develop original commands for an advance BCI game
  - Classifying the mental state of the users.
  - Comparison between three different machine learning classifiers "SVM (Support Vector Machine)", "RandomForest" and " Deep Learning (LSTM)".
  - Comparison between two type of sensors "Neurosky MindWave mobile sensor" and "EMOTIV EPOC+".

Simple BCI Game

Our BCI Game

- Our BCI game is based on concentration, meditation and mixed brain waves.

- In this BCI game we used a battery type IoT device (MaBeee) and single channel sensor.

Devices used in BCI game

- Computer
  - MacBook Air
  - Processor 22GHz intel Core i7
  - Memory 8 GB 1600 MHZ DDr3
  - Graphics Intel HD Graphics 6000 1536 MB
- Neurosky MindWave sensor
- MaBeee (a battery type IoT device)
- Huawei BG2-W09 tablet

Neurosky

- It measure the voltage fluctuation from ionic current flows with in the neurons of the brains.
- Sensor detect the electric activity of the brain using small, metal discs (electrodes) attached to your scalp.

Fig 1. Neurosky MindWave Sensor

Neurosky data layout

- There is 10 parameter data layout.
- Attention and meditation are the original parameter of the Neurosky, which we used in our BCI game.

Table 1. Neurosky data layout

Type	**Frequency (Hz)**
Delta (δ)	0.5-3 Hz
Theta (θ)	3-7 Hz
LowAlpha (α)	7.5-9.25 Hz
HighAlpha (α)	10-11.75 Hz
LowBeta (β)	12-15 Hz
HighBeta (β)	21-30 Hz
LowGamma (γ)	30-39.75 Hz
MidGamma (γ)	41-49.75
attention	original parameter concentration
meditation	original parameter relaxation

MaBeee

- MaBeee is an AA battery-shaped IoT device.
- By installing it into a dry cell-powered item, users can take a full control of the item using mobile via Bluetooth Low Energy (BLE).

Fig 2. MaBeee Device

Simple BCI Game

1. The train with MaBeee will run by using the mind wave signals of a player.
2. The player will get the points by moving the train through the line in the determined time.
3. The game will be played thrice and counted the total score. The player with the highest score will win the game.

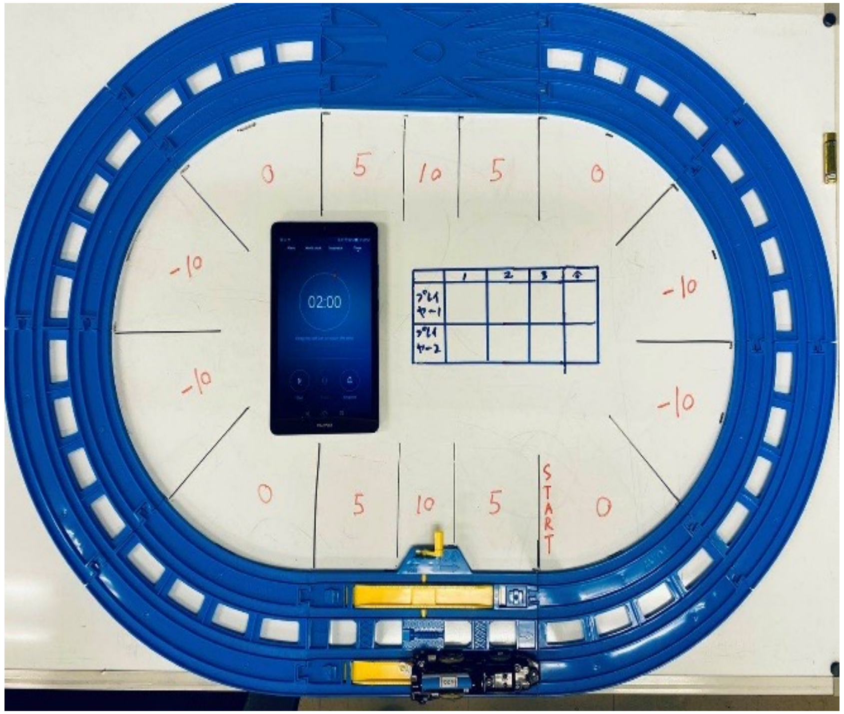

Fig 3. BCI game

BCI Game application

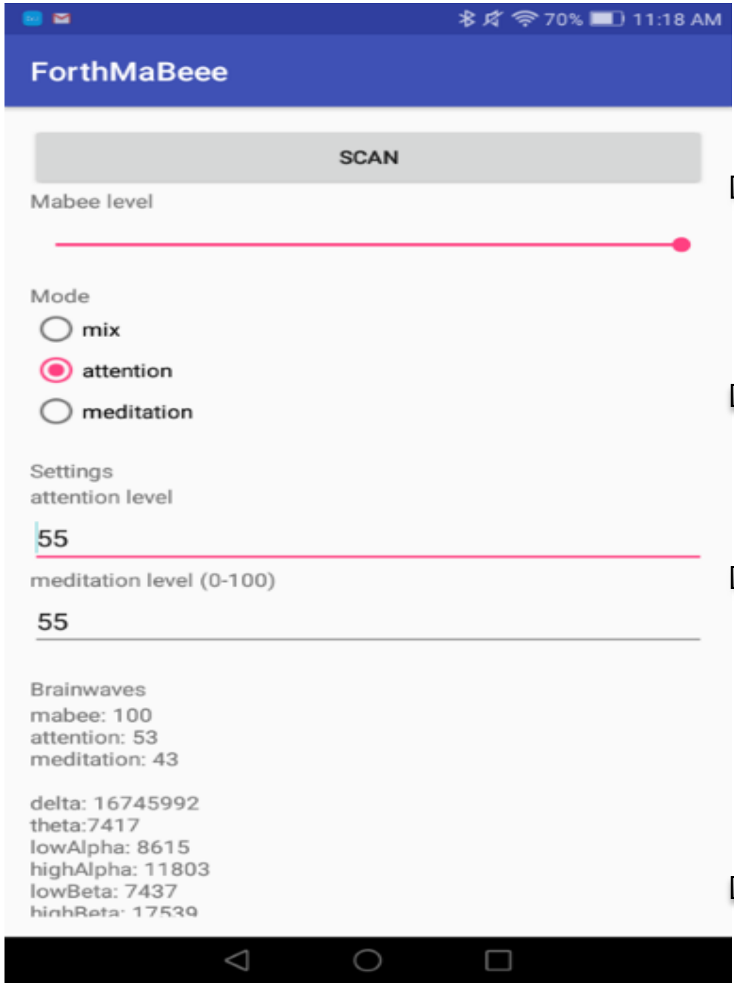

Fig 4. BCI game application

The scan button search MaBeee device and get connected.

3 mode has been created (Mix, attention and meditation).

Settings are set as attention level and meditation level.

The data transmitted from the brain wave sensor is displayed at 1 second intervals.

Game execution

Advancement of BCI Game

- To make BCI game more complex and interesting, We need to design various original command.
  - For example speed up , slow down, stop, right, left etc.
  - The purpose of this research is to develop original commands by classifying the mental state of the users.
- We are also thinking of applying BCI features in other platforms rather than games in the future.

Mental state classification

Mental state classification

- In this experiment we collect the data form the sensors in 3 pattern from 3 subjects.
- Analyze those data in 3 different classifiers SVM, RandomForest and LSTM.
- For additional experiment we used another sensor with 14 channel (Emotiv Epoc+).
- Here we compare the data accuracy level of both sensors ("Neurosky MindWave" and "Emotiv Epoc+") in 3 different classifiers.

Machine Learning Techniques used

- SVM (Support Vector Machine)
  - Kecman, Vojislav. (2005). Support Vector Machines- An Introduction.10.1007/10984697
- Random Forest
  - Damodar Reddy Edla, Kunal Mangalorkar, Gauri Dhavalikar,Shubham Dodia (2018). Classification of EEG data for human mental state analysis using Random Forest Classifier, procedia computer science, volume 132, pp.1523-1532, ISSN 1877-0509
- Deep learning (LSTM)
  - Kumar shiu, Sharma Alok, Tsunoda Tatsuhiko. Brain wave classification using long short-term memory network based OPTICAL predictor. Sci Rep 9, 9153 (2019)

SVM

- SVM stands for Support Vector Machine.
- SVM is supervised machine learning that analyze data for classification and regression.
- Library for SVM was developed at the National Taiwan University (2011). LIBSVM is an open source machine learning.

RandomForest

- RandomForest is a supervised learning algorithm.
- An ensemble learning method for classification and regression.
- It builds multiple decision trees and merge them together to get more accurate and stable prediction.
- Is faster comparing to other machine learning algorithms.

LSTM(Long Short-Term Memory)

- LSTM is an recurrent neural network (RNN) architecture.
- Common LSTM unit is composed of a cell, an input gate, an output gate and a forget gate.
- The cell remembers values over arbitrary time intervals and the three gates regulate the flow of information into and out of the cell.
- LSTM networks are made to classify, processing and making predictions based on time series data.

Sensors

- NeuroSky MindWave Mobile
- EMOTIV EPOC+

Neurosky Sensor data

- In this research, we used Neurosky MindWave Mobile to extract brainwave data.
- This device can extract 2 mental states attention and meditation(0-100 power specter).
- Beside mental states, 8 different level of data(0.5Hz to 49.75Hz) can be extracted.
- Extracted data are delta, theta, low and high alpha, low and high beta, low and mid gamma.

Data collection application

- An android application was developed to collect data from NeuroSky MindWave Mobile.
- In this application sensor is needed to be paired with android device via Bluetooth.
- Tapping "Start saving data" button saves EEG data in android device memory.

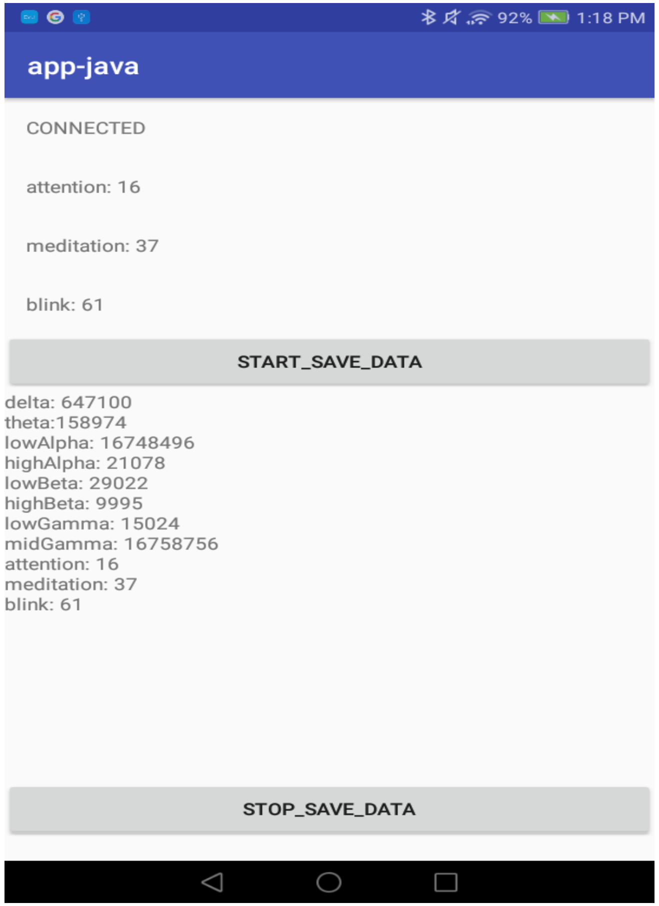

Fig 5. Data collection application

Data structure -NeuroSky

Table 2. NeuroSky data structure

delta	theta	lowalpha	highalpha	…	lowgamma	midgamma
13245	12398	24538	16542	…	165243	18672
15272	17532	27253	17523	…	1934	16538
…	…	…	…	…	…	…
16725	18553	16422	24356	…	17830	27153
1243	13224	18764	4689	…	20984	27280

Collects 8 parameter data from (delta – midgamma).

EMOTIV EPOC+

- Emotiv Epoc+ sensor is the advance brainwave sensor with 16 electrode and 14-channel.
- Emotiv Epoc+ Sensor is research-oriented wireless headset that record 14-channel EEG.
- Outputs 5 parameters (Alpha, Theta, LowBeta, HighBeta, Gamma) with 14 channels.

Fig 6. EMOTIV EPOC+ Sensor

EMOTIV EPOC+ Application

- To collect the data from Emotiv Epoc+ Sensor, application was developed in Xcode.
- In this application sensor is connected with computer via Bluetooth.
- Save button saves the brain data displayed in the application.
- For each channel data was collected.

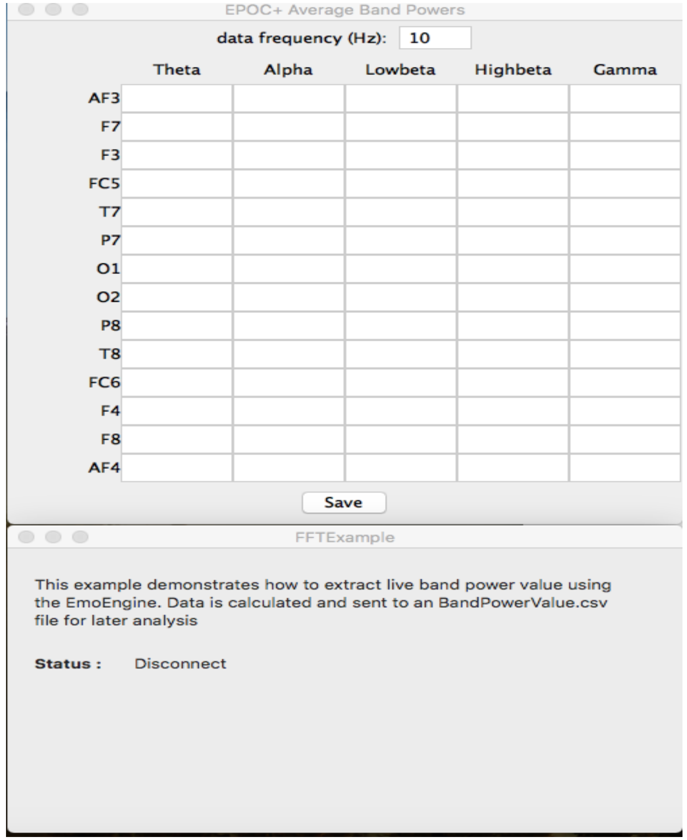

Fig 7. Application for EMOTIV EPOC+ Sensor

Data structure -EMOTIV EPOC+

Table 3. Emotiv Epoc+ data structure

AF3_theta	AF3_alpha	AF3_Highbeta	…	AF4_Highbeta	AF4_Gamma
1.3245	1.2398	2.4538	…	1.6524	1.8672
0.5272	1.7532	0.2725	…	2.1934	0.6538
…	…	…	…	…	…
1.6725	0.8553	1.6422	…	3.7830	2.7153
0.1243	0.3224	0.8764	…	0.0984	1.7280

From 14 channel 5 parameter data has been collected (14 X 5 = 70).

Experiments

- The data were collected from 3 subjects in 3 pattern
  - "simple mathematical problem" as concentration.
  - "listening music" as relaxation
  - "without doing anything"
- Test data was gradually increased: 1 minute, 2 minute and 3 minute.
- And also 1 minute data was taken for calculating accuracy.
- All the data were collected in CSV file.
- Weka (introduced in 1993) data mining tool was used.

Input Data structure

Table 4. input data structure

type	delta	theta	lowalpha	highalpha	···	lowgamma	midgamma
c	13245	12398	24538	16542	···	165243	18672
c	15272	17532	27253	17523	···	1934	16538
···	···	···	···	···	···	···	···
n	16725	18553	16422	24356	···	17830	27153
r	1243	13224	18764	4689	···	20984	27280

Results

NeuroSky -SVM

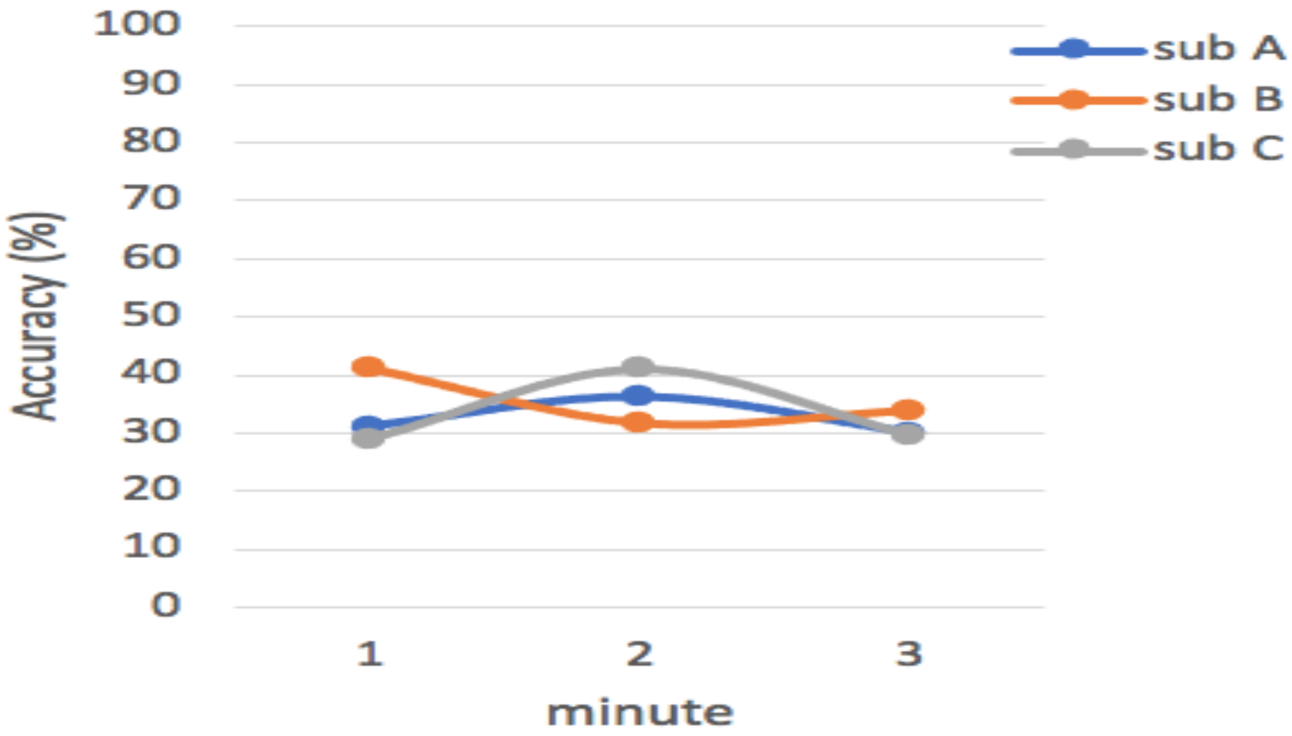

Fig 8. Accuracy of SVM analyzed data

NeuroSky -RandomForest

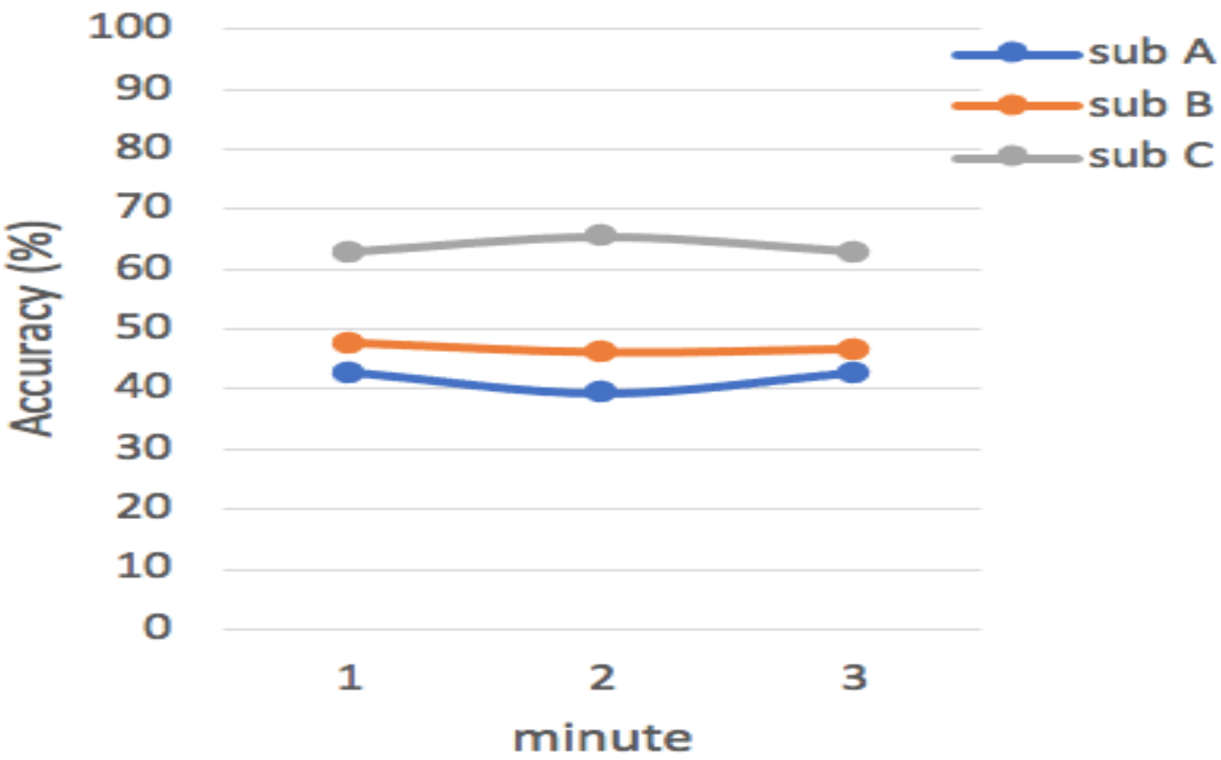

Fig 9. Accuracy of RandomForest analyzed data

NeuroSky -LSTM

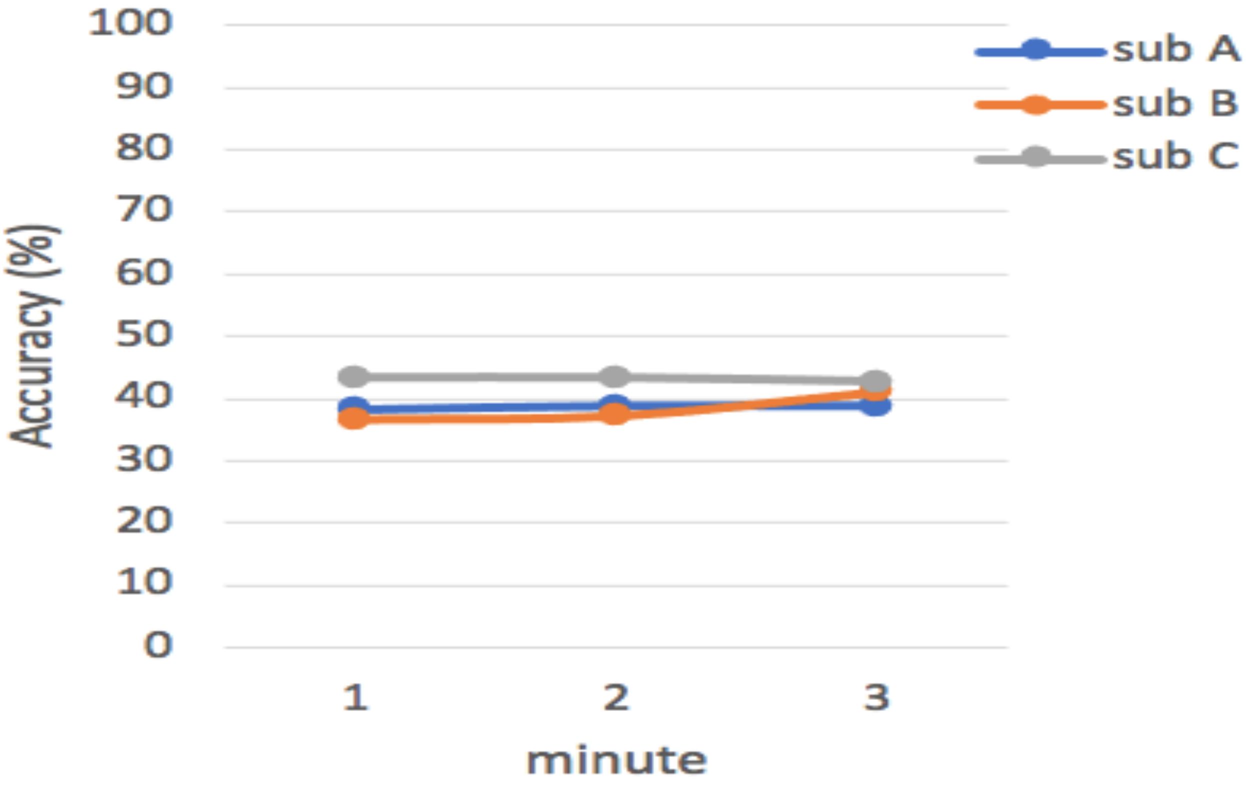

Fig 10. Accuracy of LSTM analyzed data

NeuroSky

Table 5. Accuracy rate in SVM

Subject	1min	2min	3min
A	31.11%	36.11%	30%
B	41.11%	31.66%	33.88%
C	28.88%	41.11%	29.44%

Table 6. Accuracy rate in RandomForest

Subject	1min	2min	3min
A	42.77%	39.44%	42.77%
B	47.66%	46.11%	46.66%
C	62.77%	65.55%	62.77%

Table 7. Accuracy rate in LSTM

Subject	1min	2min	3min
A	38.33%	38.88%	38.88%
B	36.66%	37.22%	41.11%
C	43.33%	43.33%	42.77%

EMOTIV EPOC+ -SVM

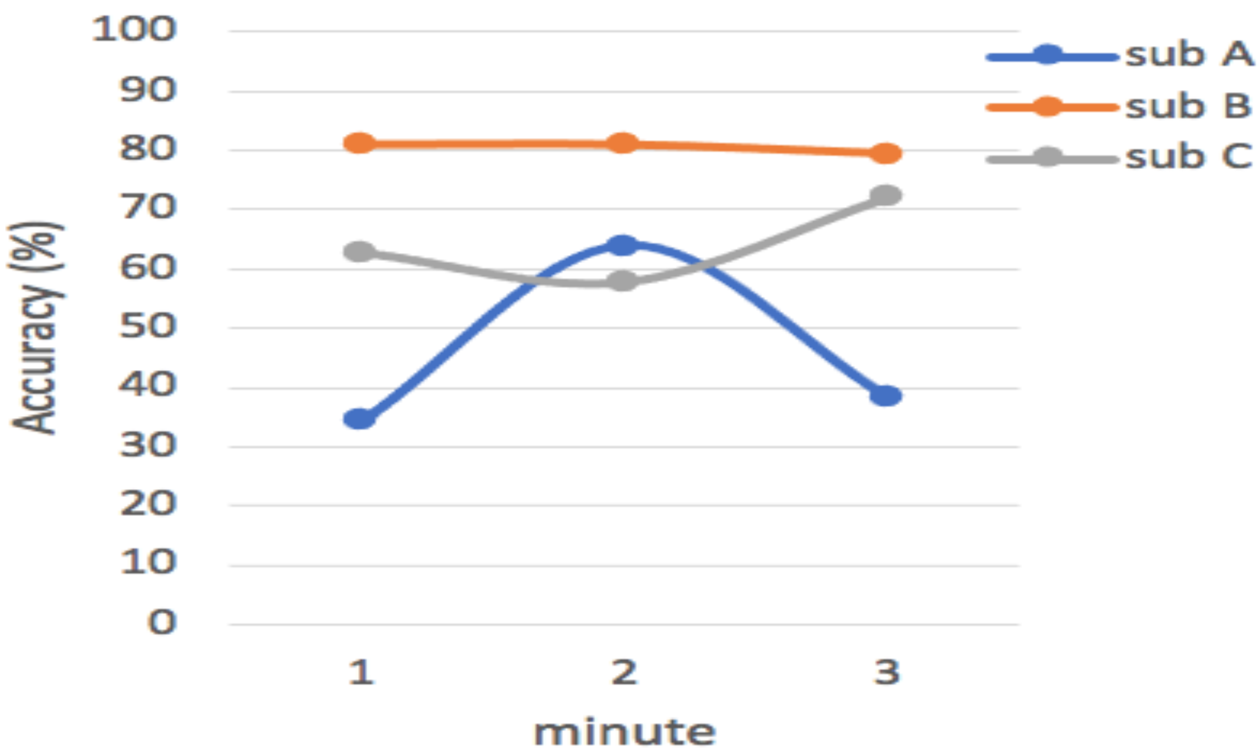

Fig 11. Accuracy of SVM analyzed data

EMOTIV EPOC+ - RandomForest

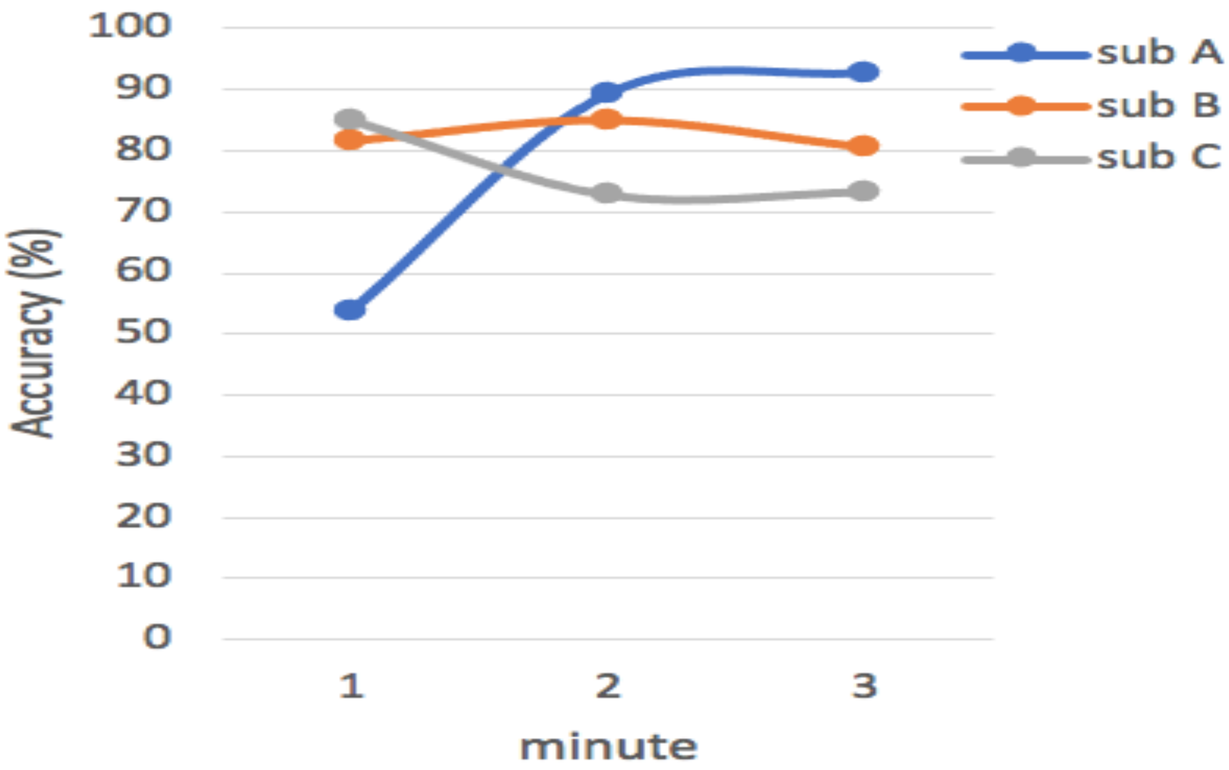

Fig 12. Accuracy of RandomForest analyzed data

EMOTIV EPOC+ - LSTM

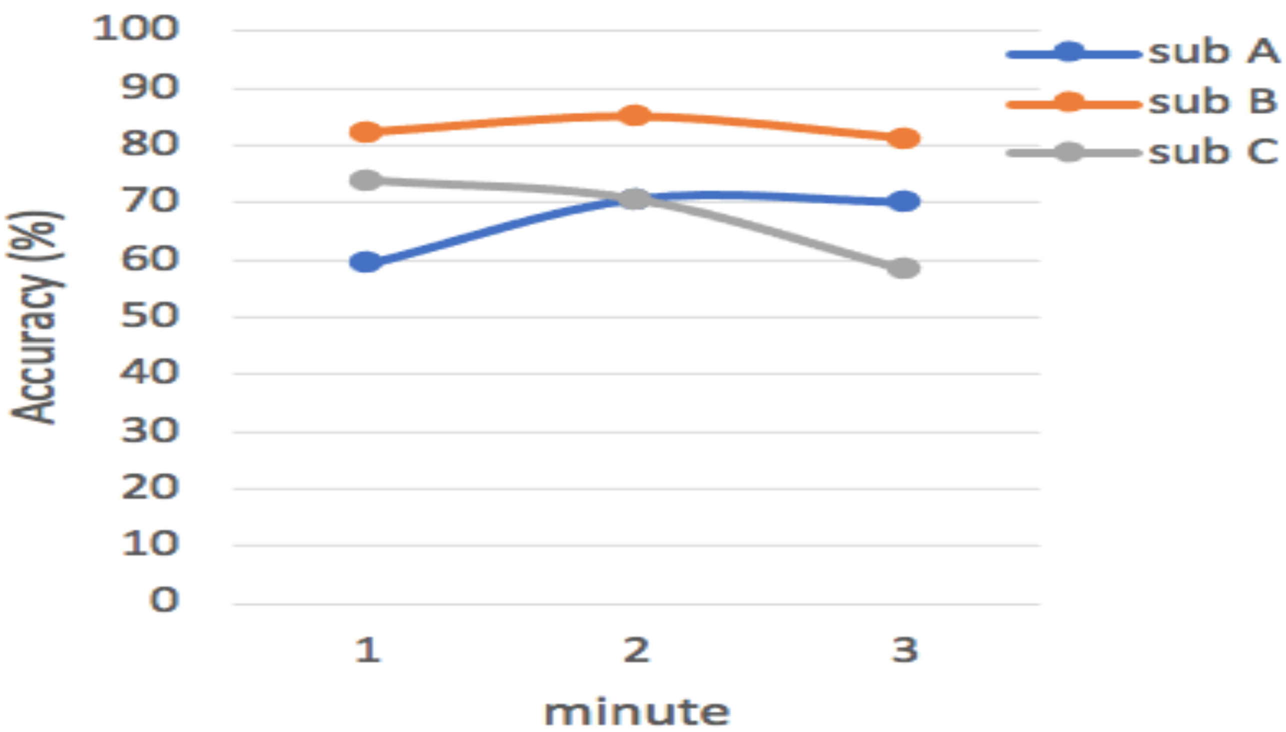

Fig 13. Accuracy of LSTM analyzed data

EMOTIV EPOC+

Table 8. Accuracy rate in SVM

Subject	1min	2min	3min
A	34.44%	63.88%	38.33%
B	81.11%	81.11%	79.44%
C	62.77%	57.77%	72.22%

Table 9. Accuracy rate in RandomForest

Subject	1min	2min	3min
A	53.88%	89.44%	92.77%
B	81.66%	85%	80.55%
C	85%	72.77%	73.33%

Table 10. Accuracy rate in LSTM

Subject	1min	2min	3min
A	59.44%	70.55%	70%
B	82.22%	85%	81.11%
C	73.88%	70.50%	58.33%

Related research

- In 2018, Jordan J. Bird and colleagues aimed to categorize mental states based on EEG data from the TP9, AF7, AF8 and TP10 electrodes. They use Muse headband EEG sensor and categorized three possible states (relaxing, neutral, concentration). Support Vector Machines and Random Forests, attaining an overall accuracy over 87%.
- In 2015, Hironori Hiraishi designed a robot which is controlled using brainwaves. They are also using SVM method for classification. They were able to achieve about 80% accuracy. They were also able to accurately classify unstable brainwave data and control a robot using brainwaves from a simple EEG sensor.

Conclusion 1

- This BCI game is all about concentration, meditation and mix level.
- Simple brainwave sensor with 1 signal channel and MaBeee device has been used.
- Using MaBeee device for the BCI game was challenging.
- Playing game as a competition between 2 plyers was interesting.

Conclusion 2

- Data structure between two sensor is different.
- NeuroSky MindWave sensor is single channel where EMOTIV EPOC+ Sensor is 14 channel.
- Data accuracy percent of EMOTIV EPOC+ sensor is higher than the NeuroSky MindWave Sensor in each classifier.
- Comparing the data accuracy between 3 classifiers, data accuracy level was high in RandomForest.

Future Work

- For advance BCI game in future we use analyzed data model for the better performance.

- Use more parameter as a command.

- In future we can help paralyzed people to control prosthetic limbs with their mind through BCI.

Conference presentation

- Sukh Sagar Subedi, Hiraishi Hironori(2020) Design of BCI games by using a battery type IoT device and simple Brainwave sensor, Proceeding of TheTwenty-Fifth International Symposium on Artificial Life and Robotics 2020 (AROB 25th 2020) ISAROB, pp.40-43, 2020.1.

- Sukh Sagar Subedi, Hiraishi Hironori(2021) Mental State Classification By Using Brainwave Sensors, Proceeding of The Twenty- Sixth International Symposium on Artificial Life and Robotics 2021 (AROB 26th 2021) ISAROB, pp.139-143, 2021.1.