Capstone Proposal by

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For Udacity Machine Learning Engineer Nanodegree Program (the "**Program**")

Recognizing patterns of brain activity using Brain Computer Interface

Domain Background

Brain Computer Interface (hereinafter referred as "**BCI**") sometimes called a neural-control interface (NCI), mind-machine interface (MMI), direct neural interface (DNI), or brain–machine interface (BMI), is a direct communication pathway between an enhanced or wired brain and an external device. BCI differs from neuromodulation in that it allows for bidirectional information flow. BCIs are often directed at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions[1].

Brain computer interface technology represents a highly growing field of research with application systems. Its contributions in medical fields range from prevention to neuronal rehabilitation for serious injuries. Mind reading and remote communication have their unique fingerprint in numerous fields such as educational, self-regulation, production, marketing, security as well as games and entertainment. It creates a mutual understanding between users and the surrounding systems[2].

Student motivation is research and learning the BCI technology with applying Machine Learning algorithms to create systems of communications between human and machine or in between humans with machine as intermediaries, using brain activity and BCI device.

Student's future projects will focus on developing hardware and algorithms that will be used in compact devices to advance communication technology.

Student possess all necessary technology to complete capstone project. The electroencephalogram (EEG) device – Ultracortex "Mark IV" EEG Headset (8 channels) from www.openbci.com is used for this task.

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[1] https://en.wikipedia.org/wiki/Brain–computer_interface

[2] https://www.sciencedirect.com/science/article/pii/S1110866515000237

The goal of this project is to train machine learning algorithms to distinguish particular brain activity when person is performing in certain states or actions: reading, writing, moving limbs, visualizing symbols.

Following research was used as inspiration and background information: "Brain–Computer Interface Spellers: A Review" by Aya Rezeika, Mihaly Benda, Piotr Stawicki, Felix Gembler, Abdul Saboor, and Ivan Volosyak[3].

Problem Statement

Advanced communications technology can be used in telecommunication, gaming, virtual reality and other domains. BCI and machine learning techniques can be used to create instruments capable to advance communications.

Narrowing down the problem, student is going to practice high level approach in order to streamline research in the area. It means this project will not focus on creating advanced speller systems[4] that could be another sophisticated instrument of non-muscular communication. However, student will focus on developing algorithms that will be capable to recognize generic brain patterns:

1) Imagination of a limbs' movement;
2) User's reading (book) and writing (letter) state;
3) Imagination of shapes and forms (spheres, triangles, squares, cubes, etc.).
4) Going further within the project student will try to recognize brain patterns that occur while imaging numbers from 0 to 9. This was earlier achieved within similar projects[5].

To achieve the project goal student will use data obtained from EEG device and feed it to machine learning algorithm to train and recognize patterns of signals recorded. Machine learning algorithm will be built on basis of Neural Network using Keras libraries.

There will be no live data collection-recognition algorithm until this project ends as far as this project focuses on recognition algorithm rather than hardware tuning.

Datasets and Inputs

Data is pre-collected from EEG device. Signal inputs are represented in microvolts, logged and recorded in high resolution with 1000 Hz sample rate. Device has 8 channels (electrodes) and therefore the dataset consists of 8 columns representing

[3] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5924393/
[4] Ibidem.
[5] https://www.independent.co.uk/news/science/read-your-mind-brain-waves-thoughts-locked-in-syndrome-toyohashi-japan-a7687471.html

dataflow from electrodes, timestamp column and index. Each row of data represents one fraction of data point sample at given millisecond. One sample data input will be consisting of equal number of rows. The number of rows depends both on the 'length' of 'thought' depicting or imagining the state/action of mental condition and on sample size, which will be optimized within the project.

There are separate datasets for each user's state or action. For instance, there is dataset recorded, while user was writing the letter and separate dataset recorded while user was reading the book. One dataset size is up to 100 000 rows that is equal to approximately 2 minutes of recording. To feed data into algorithm datasets will be combined and labeled. One of raw data files extracts is downloaded into repository.

Please note, data used in this course is Student's personal data, which will be used exclusively and only for the purpose of capstone project of this Program. Udacity has no right to share this data with other students or any third person or third party without Student's explicit permission. Data extract posted on GitHub contains small sample to demo the dataset only.

Solution Statement

Neural network (NN) will be used to train algorithm on distinguishing brain wave/signal patterns obtained from EEG. NN architecture will be tailored and customized within the progress of the project depending on NN performance.

Before feeding data into NN, the dataset will be preprocessed (labelled) and normalized.

Benchmark and Evaluation

Dataset used for project will be divided on training and testing sets. Additional data maybe generated to test algorithms as well.

To test model performance the accuracy will be measured. Keras model.evaluate function will be used to evaluate accuracy of the model.

Additional benchmarking will be done by means of generating new data using BCI/EEG and testing brain signals recognition using the developed algorithmic model.