Brain EEG signal decoding using Machine Learning

(For partial fulfillment of requirements in ECE421 - Neural Interface Engineering)

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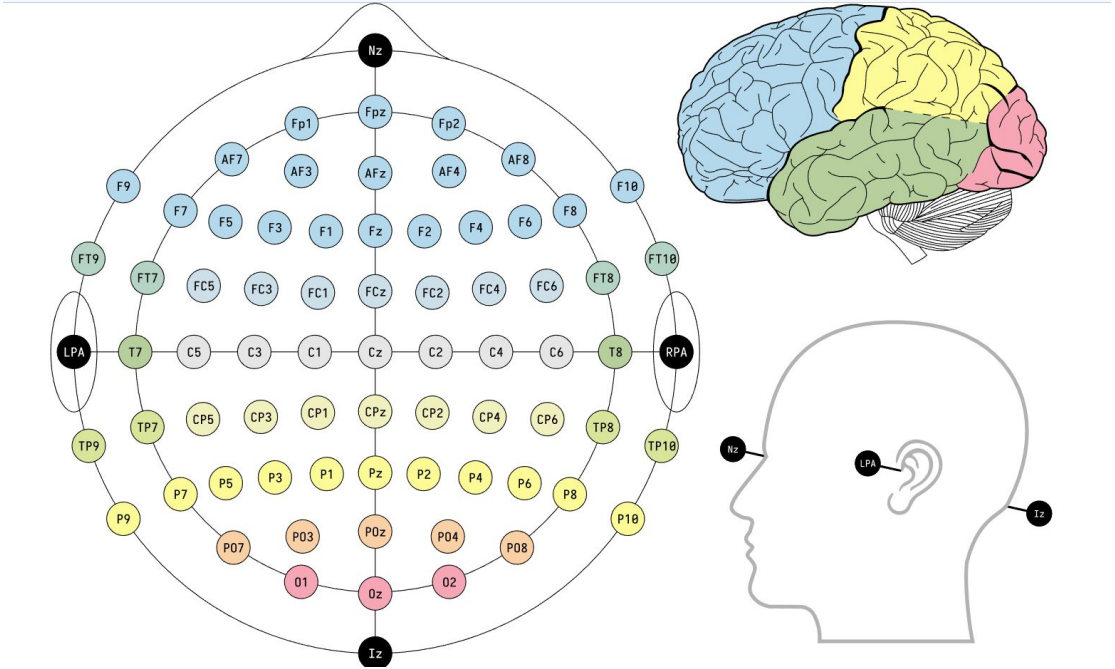


Motivation

Why EEG signals are important ?

1. Cheapest to measure
2. Non-invasive

Challenges -

1. Noisy, bad spatial resolution.

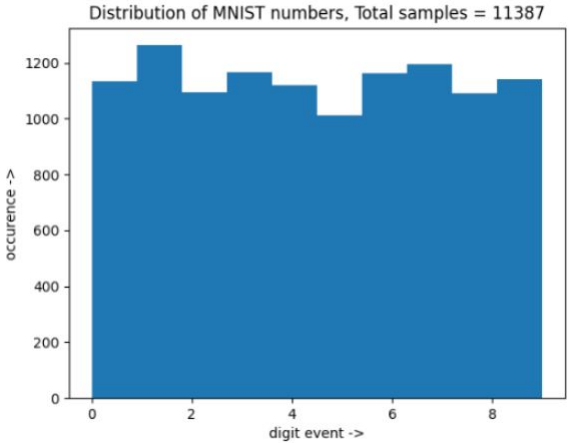
Opportunity -

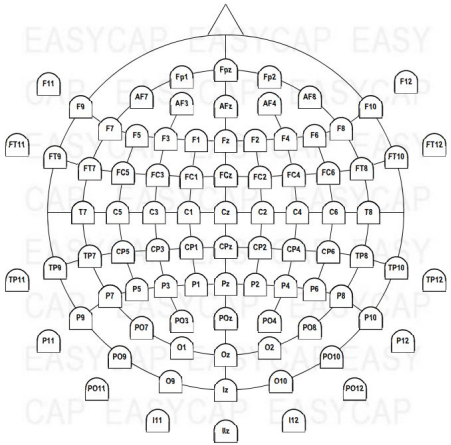
1. Finding Emotions, mental states, attention state, and usage in psychiatric patients, lie detection, etc.

Objective

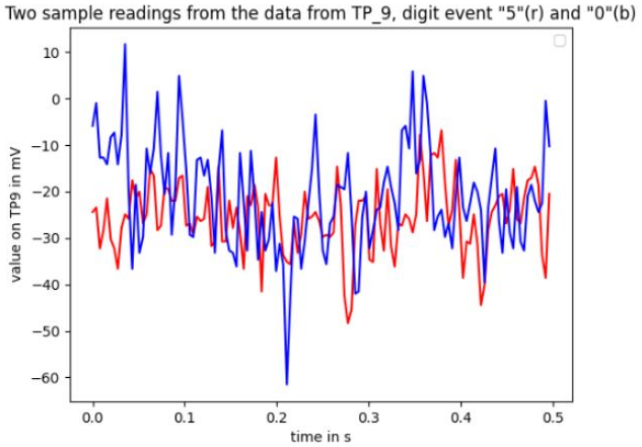
Looking at the data of Brain EEG Signals as different Stimuli are provided to humans.

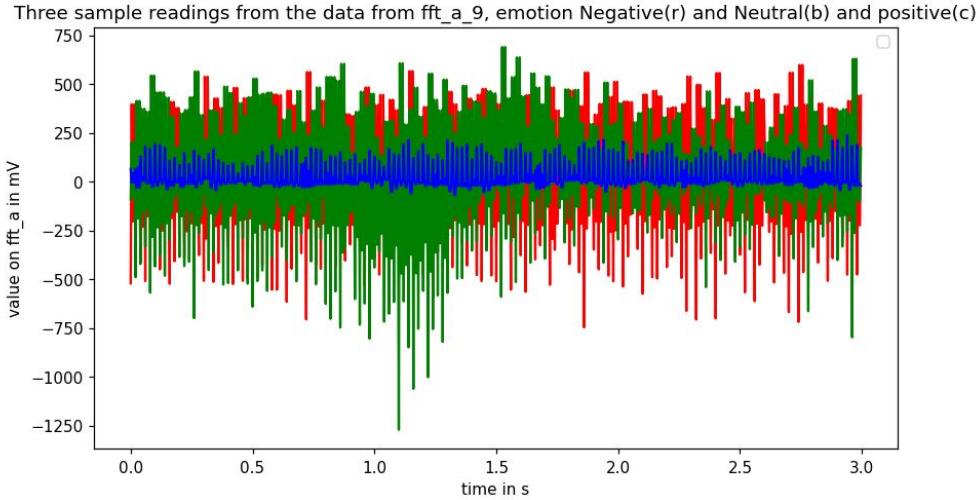
1. Brain MNIST dataset.
    a. Participant shown an image of a digit (0-9) and brain signals are recorded at 256 Hz from 2 sensors for two seconds
    b. TP9 and TP10
    c.
2. Emotions dataset by J.J.BIrd.
    a. Participants shown emotion inducing movie clips, Signals are recorded and preprocessed.
    b. 1500 features were taken into account.





Sample differences in the readings

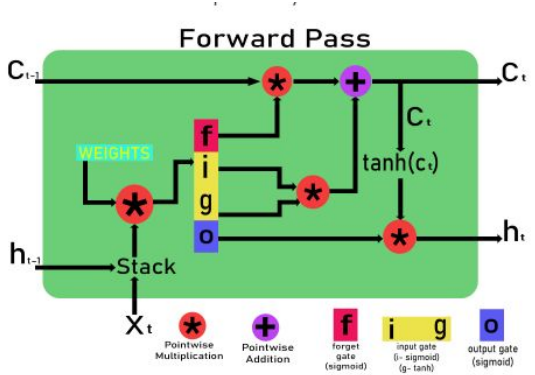




Not much variation in the MNIST dataset, huge differences in signal characteristics in Emotions dataset.

Predictor Models

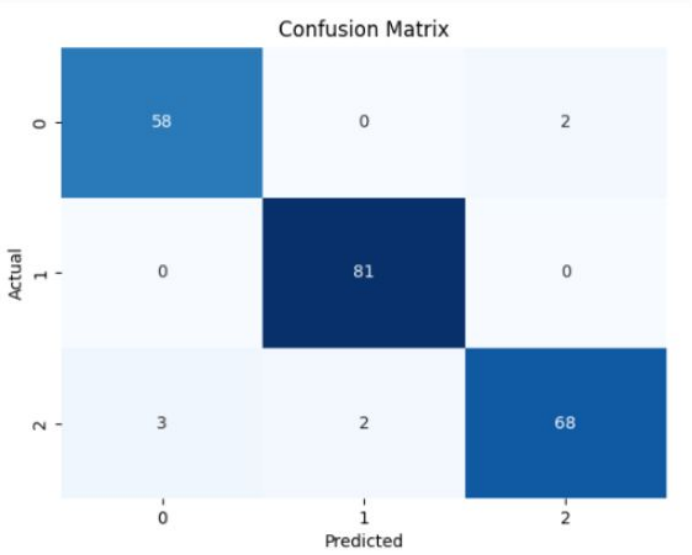
1. Decision Tree
   a. Interpretable, fast and simple.
2. XGBoost
   a. Amongst the most complex neural Network model.
3. Neural Networks
   a. High number of Learning parameters , high memory storage.
4. CNN
   a. Lower number of Parameters, temporal dependence.
5. LSTM
   a. Assumptions of Sequential Data.

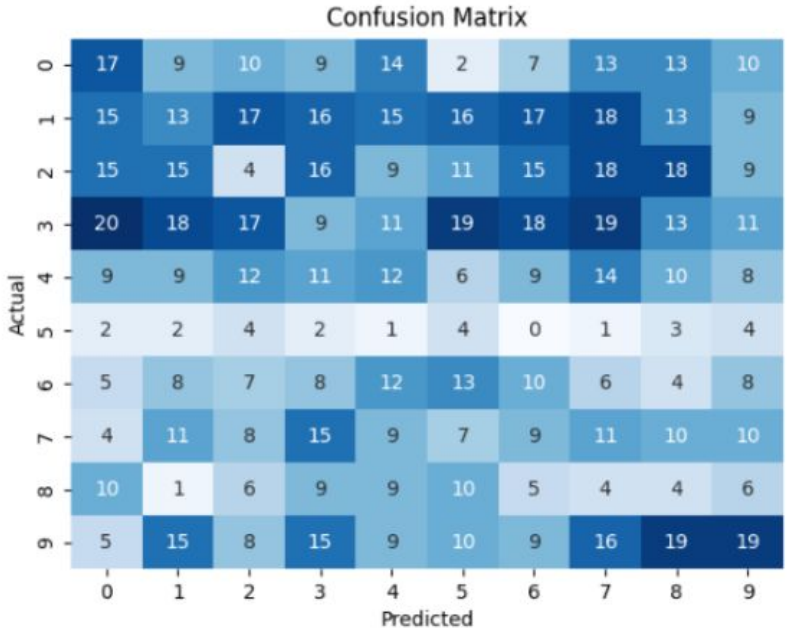


Results

F1 Scores		Algorithm (Accuracy Weighted average F1 scores of classification)				
Datasets	Type of Dataset	Decision Tree	XGBoost	NN	CNN	LSTM
Emotions Dataset	Mental State	0.83	0.88	0.97	0.92	0.88
ImageNet of Brain	Emotional State					0.97[]
MNIST EEG Dataset	Numerical Data	0.11	0.12	0.10	0.11	0.08

Confidence Matrix of best models





Why are the results for Emotions Dataset better than results for MNIST Dataset ?

1. Mathematical or Numerical response might not be strong enough, or doesn't happen near temporal and Parietal lobe.
2. Merely showing of images doesn't really evoke brain activation at all.
3. Brain Activation because of Emotional state is widespread throughout the brain.

Why NN gives the best performance ?

1. Underlying patterns in the data doesn’t really obey the assumption of temporal dependency.
2. LSTM model is not able to capture context over a large time scale.
    a. More data might be solution.
3. One potential Solution -
    a. Combine LSTM and Convolutions to take care of longer term context as well as sorter term context.

Implication w.r.t. Brain Computer Interface devices.

1. Data collection should be targeted. Continuous evaluation of quality should be there.
2. Location of electrodes should be carefully chosen.
3. Simpler models that can provide a good accuracy can also be used to tasks involving low allowable accuracy.
4. LSTM models provides the best opportunity to decode brain signals in real time. (~2000 parameters vs 100,000 parameters)

Thanks

Questions. !

References -

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