Analysis of EEG Signals

for thought-controlled prosthetics

Summer Undergraduate Research Award (SURA)

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MOTIVATION

Develop a computational basis for developing real-time brain controlled actions, such as thought-controlled prosthetic limbs or electronic devices.

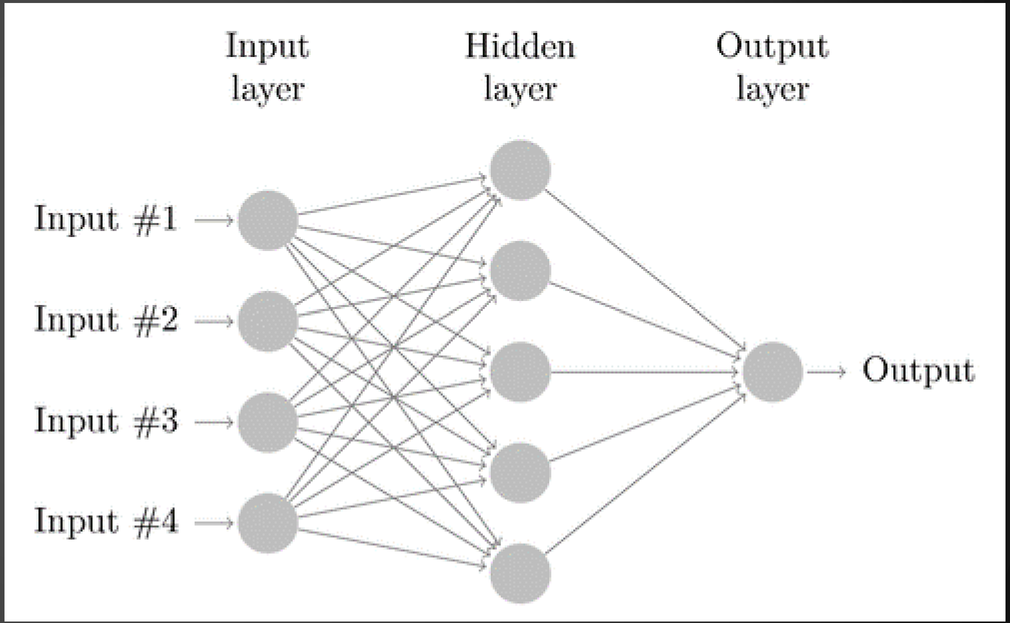
Whenever we execute, or even think of executing a motor activity, neurons in certain sections of the brain get fired up, which eventually manifests itself into the change in the averaged electrical activity of the region, as recorded by the EEG device.

MOTIVATION FOR ANNs – Part 1

- Process of acquiring EEG signal is very dynamic.
- Signal averaged over many neurons.
- Overall signal to noise ratio is pretty poor [Schlogl, 2002].
- Unlike existing BCIs can't rely on aggregate signal parameters [Larsen, 2011].
- ANNs modelled on lines of human brain model appeals to be a natural Machine Learning Alternative.
- Exploits the dynamic nature of data using the principle of Hebbian Learning.

MOTIVATION FOR ANNs – Part 2

- Input Neurons: Data to be classified
- Output Neurons: Represent the clusters to categorise various signals
- Hidden Neurons: Feature Extractors



PROBLEM SUMMARISED

1. Devising appropriate experiments and generating relevant data
2. Raw data -> Usable data [dimensionality reduction]
3. Listing out the appropriate motor classification of the input data and thus defining the ANN parameters
4. Training and testing the network and explicating any motor action in terms of chosen motor classification

EXPERIMENT PHASE – Part 1

Venue: EEG Lab at IDDC, IIT Delhi

Instruments Used:

- 14 channel wireless EEG headset (EMOTIV)
- Advantage: Allowed marking of events.
- Disadvantage: Dynamic positioning of electrodes across sittings and wireless interference.
- 32 channel wired EEG headset
- Advantage: Higher sampling rate.
- Disadvantage: No provision for event markers.

EXPERIMENT PHASE – Part 2

Experiment Format: Dynamism of the brain, small amplitude of the EEG signals impose a lot of constraints on the format of experiments.

Format followed: “block formats” [Porbadnigk et al.]

Initially supposed to cover 10 motor actions, in three formats of:

- jerks
- continuous movements
- thought of the motor activity

EXPERIMENT PHASE – Part 3

Associated Problems:

- Lengthy movements that perturbed the setup or subject
- Time gap in marking the jerk movements

After multiple failed events on one particular act the experiment was limited to motor actions of continuous right arm movements (thought and actual) and rest state.

EXPERIMENT PHASE – Part 4

Subjects: 3 different subjects

Experiment Description:

Each sitting lasted for 2-3 hours in a dark noise free room.

- Rest state Recorded
- Commit Right Arm Movement for 30 seconds
- Rest
- Commit the thought of Right Arm Movement for 30 seconds

The 32-channel EEG setup used for some experiments of this study

ANALYSIS PHASE

Dimensional Reduction of the EEG data :

Feeding raw data would necessitate a very large network and high computational time complexity.

Converting to Frequency Domain:

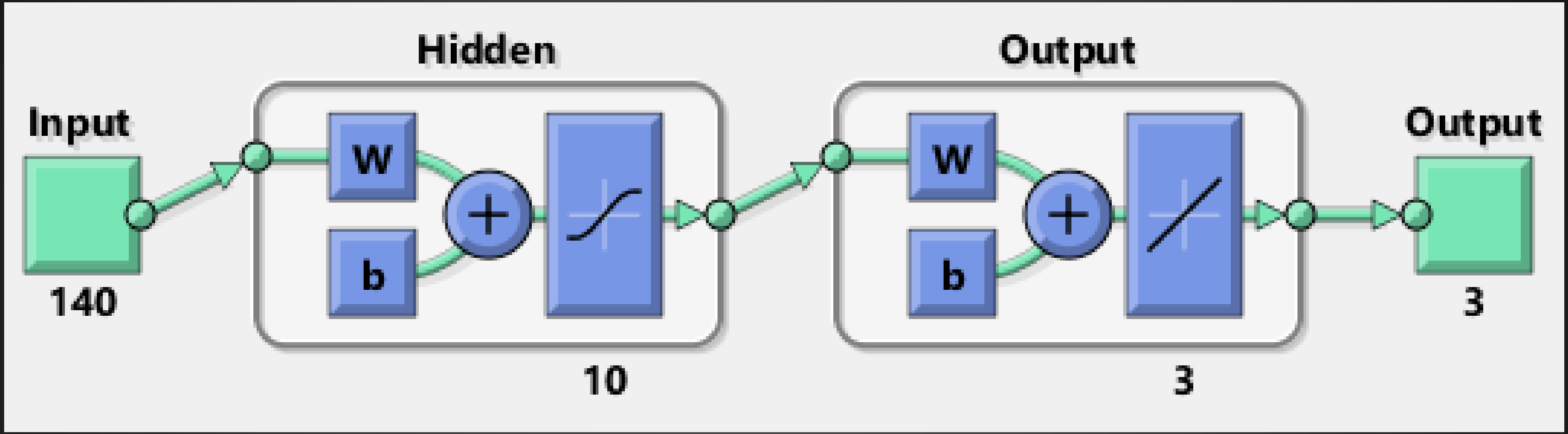
- Best way to look at variations in the signal and check repeated occurrences of certain signal values.
- Closely related to “amount of information”.
- Signal Range divided into 10 bins and outliers were curtailed to the extreme bins. Sampled at every 1 second (Real-time attribute of the system).

DATA FACTS

- 14 channels,10 bins ==> column vector to be of size 140.
- 3 classifications
  - Rest: 100
  - Movement: 010
  - Thought of Movement: 001
- No. of input output training samples :68
- No. of samples used for testing :28
- No. of nodes in hidden layer :10

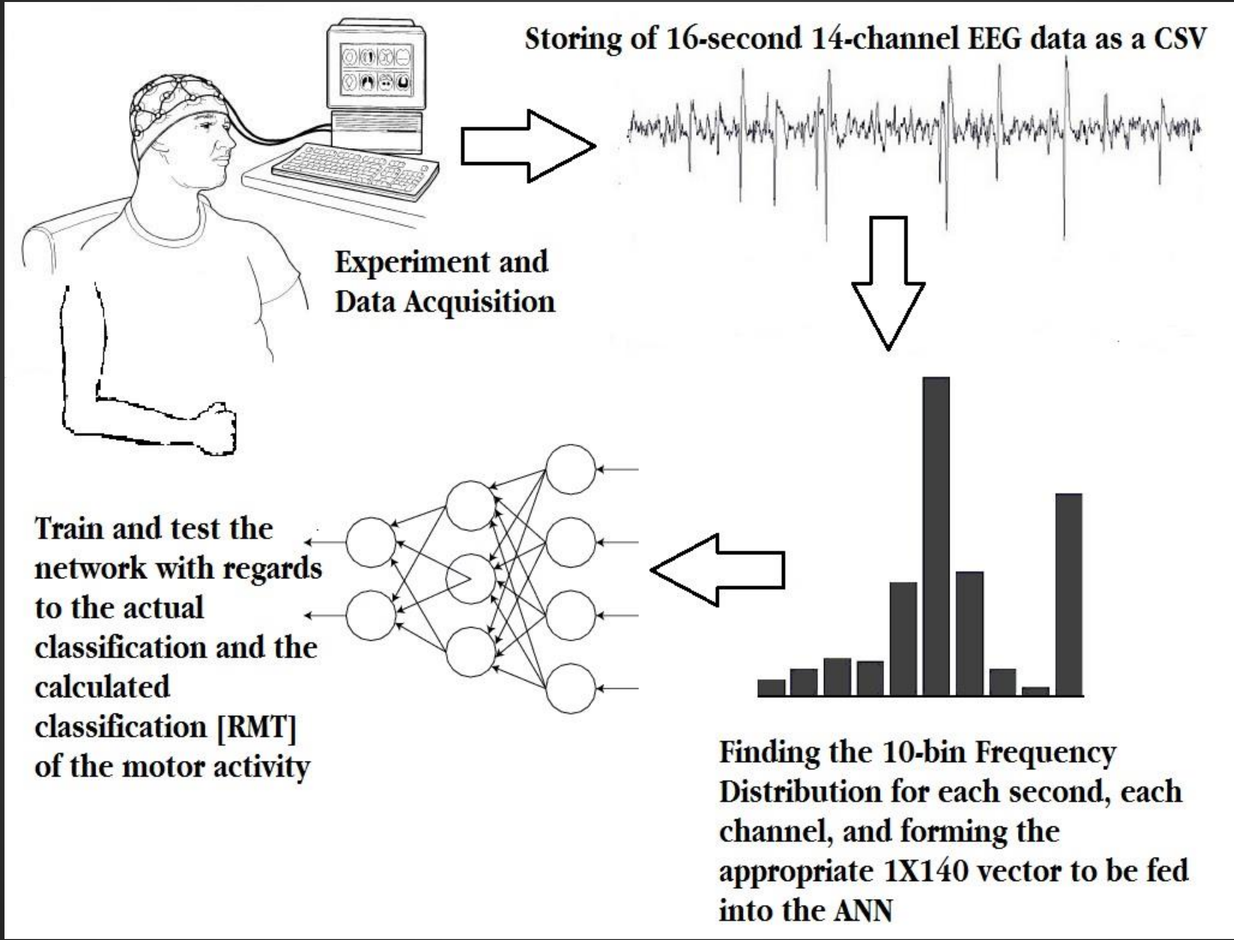
[Hornick et al., 1990]

ANALYSIS DESCRIPTION

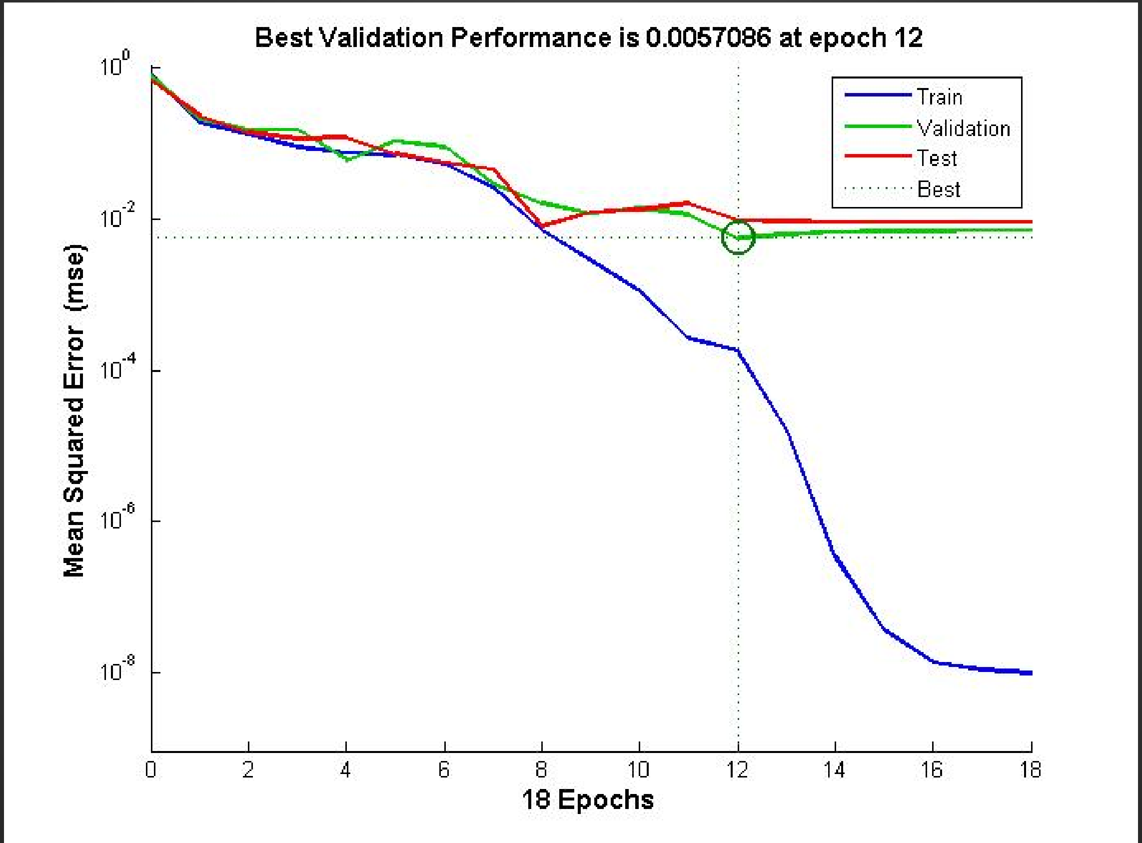


- Hidden layer: sigmoidal function
- Output layer: linear activation function [Jain, 1996]
- Backpropagation algorithm was used for training the network and setting weights.

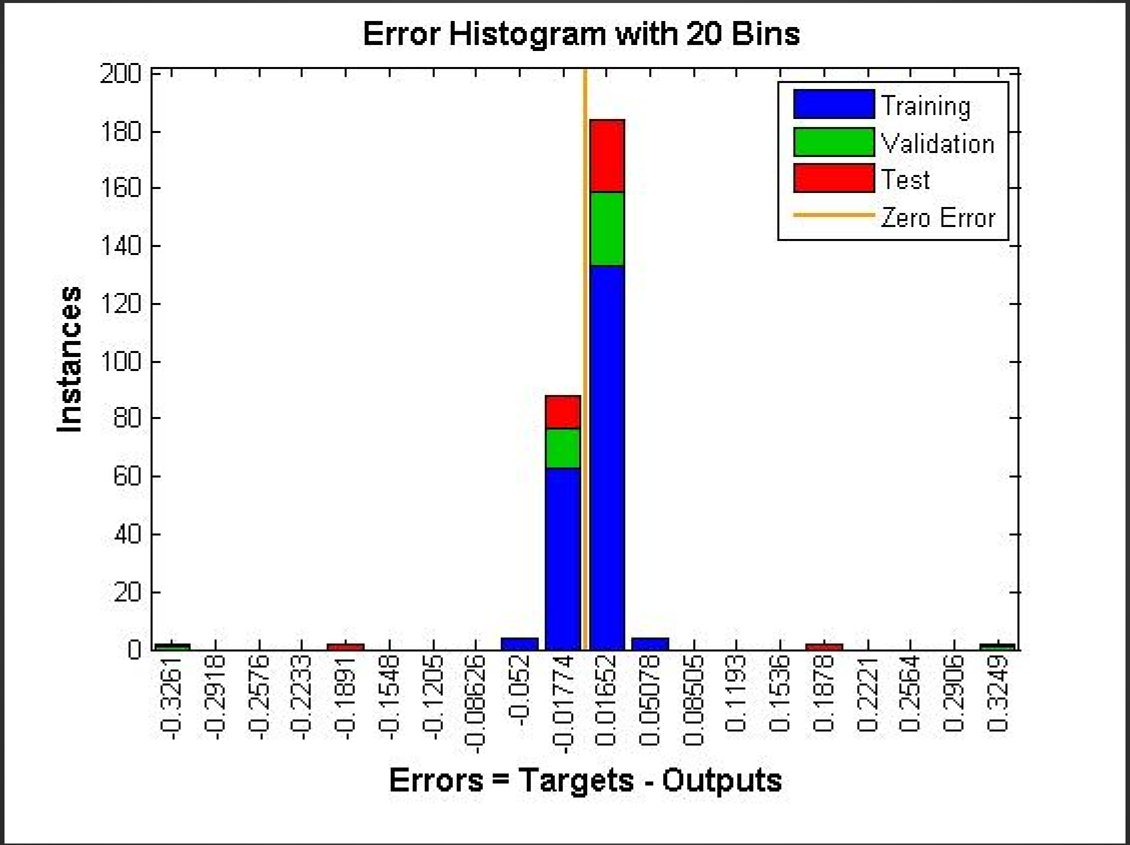
COMPLETE OVERVIEW



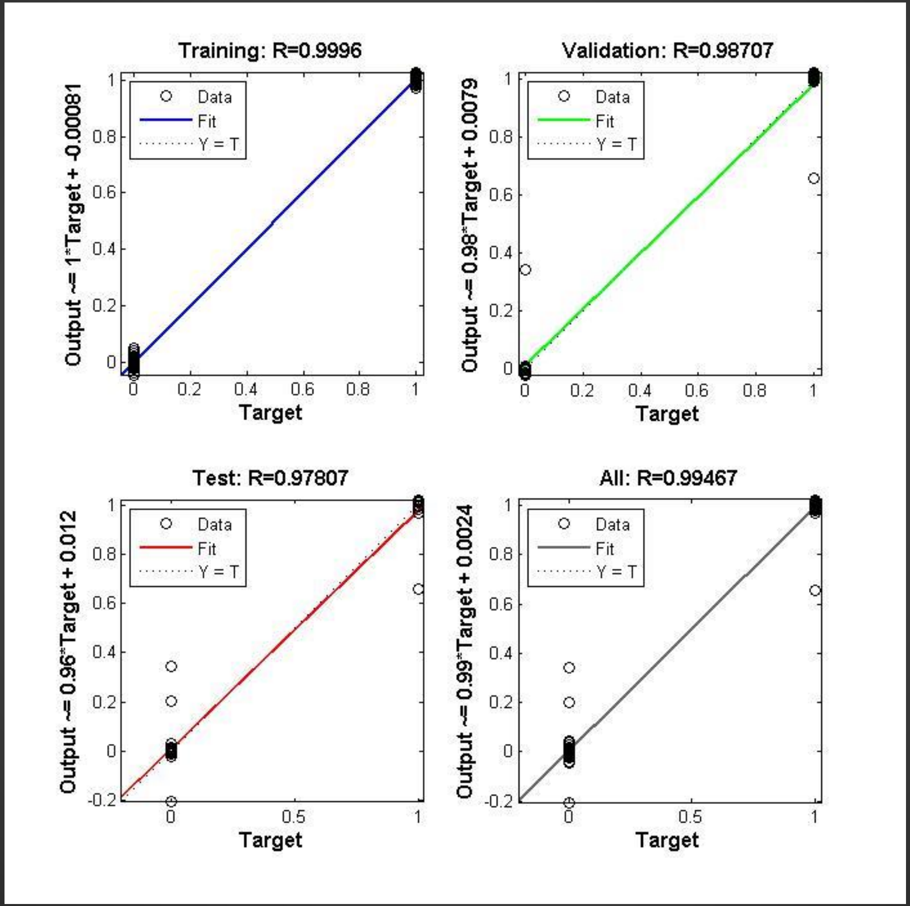
DATA ANALYSIS RESULTS – Part 1



DATA ANALYSIS RESULTS – Part 2



DATA ANALYSIS RESULTS – Part 3



IN CONCLUSION

SUCCESSFUL IN:

- Devising a suitable experimental structure and data manipulations, while respecting the real-time nature of the study's application, and the given apparatus.
- Validating the accuracy of the trained neural network via various metrics.
- Differentiating thought-of-movement from actual movement (at least in this rudimentary scenario).This could be exploited for creating prosthetic limbs for different kind of patients more appropriately.

FAILED IN:

- Extending the action set to more number of motor activities.
- Improving the accuracy of training samples by using “jerks” instead of “continuous movements”. (The primary reason being inadequacy of available EEG apparatus and the software bench for handling quick event markers.)

Future Extension

- Using targeted electrodes located at relevant cortex lobes instead of all 14/32 channels.
- More rigorous training with vast amounts of data.
- Experiment with more neural networks.
- Using other imaging techniques, such as fMRI. Or directly using electromyography (EMG).
- Suggesting ways to convert the model from theory to practice, as far as real-life applications are concerned.

Thank You
Questions?