EEG-based Classification of Bilingual Unspoken Speech using ANN

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ABSTRACT

The ability to interpret unspoken or imagined speech through Electroencephalography (EEG) is of therapeutic interest for people suffering from speech disorders and 'locked-in' syndrome. It is also useful for brain-computer interface (BCI) techniques not involving articulatory actions. Previous work has involved using particular words in one chosen language and training classifiers in block or sequential mode to distinguish between them. Such studies have reported accuracies of 40-60% and are not ideal for practical implementation. Furthermore, in today's multilingual society, classifiers trained in one language alone might not always have the desired effect. To address this, we present a novel approach to improve accuracy of the current model by combining bilingual interpretation and decision making. We collect data from 5 subjects with Hindi and English as their primary and secondarylanguages respectively and ask them 20 'Yes'/'No' questions ('Haan'/'Na' in Hindi) in each language, with a response time of 10 seconds. We choose sensors present in regions importantto both language processing and decision making to supply inputs to Ensemble classifiers and Artificial Neural Networks (ANN) for prediction. Experimental results reveal an accuracyof 84.6% and 87.69% for decision and language classification respectively using ANN. The overall accuracy of bilingual speech was reported to be 75.38%.

METHODOLOGY

Data Acquisition and Experimental Setup

- In this study, we aim to recognize two words 'Yes' and 'No' in English and ('Haan'/'Na') in Hindi using EEG signals obtained from bilingual subjects. For this purpose, we use the Electrical Geodesics, Inc. (EGI) Clinical Geodesic EEG System 400, which is a 32 channel EEG headset for signal acquisition.

- The sensors of interest in this study are: F7, T7, P7, P3 and C3 for language classification and Fp1, FpZ, Fp2, F3, Fz, F4 for decision making. These sets of sensors are henceforth referred to as L sensors and D sensors respectively. Additionally, the complete set of 11 sensors (L+D) is also explored to find a pattern that gives the highest accuracy

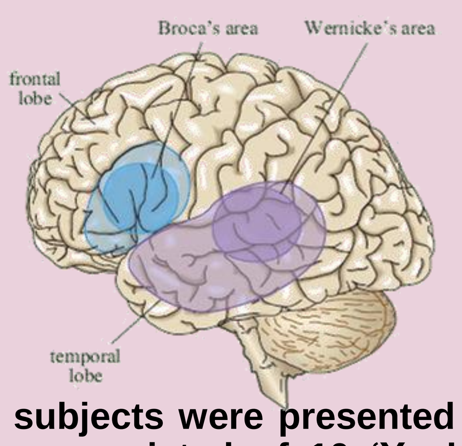


Figure 1. Broca's and Wernicke's areas

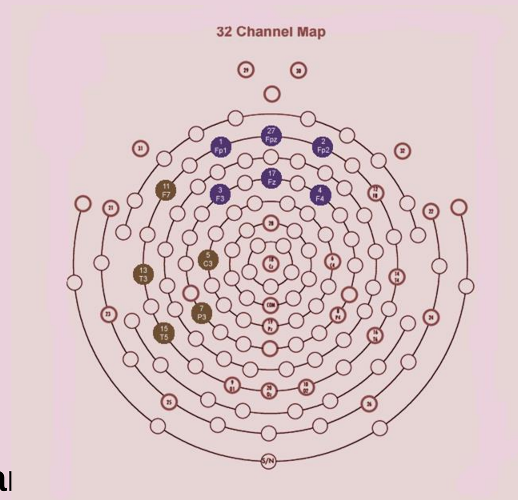


Figure 2. Sensor Map of the EGI Geodesic headset

- The subjects were presented with a phones. These consisted of 10 'Yes' and 10 'No' questions in each language. Questions were played out on a laptop and appeared in random order for different subjects to prevent preconceived or biased answers. After a particular question was played, subjects were asked to continuously think of either 'Yes' or 'No' for a response duration of 10 seconds.

METHODOLOGY

Preprocessing and Feature Extraction

- Raw data obtained from the EGI Geodesic headset was filtered using Net Station Digital 60/50 Hz notch filter to obtain data between 0-40 Hz. The data was segmented to extract values appearing only during the 10 second response time

- The bin_power method in the PyEEG package was used to transform the data using a Fast Fourier Transform (FFT) into the frequency domain. The result was split into five bands (α, β, γ, δ and θ) depending on the frequencies. Only α, β and γ bands were considered as viable features for training the classifiers. infants. A window size of 250, shifting right by one in each iteration, was considered and the powers for all three bands were calculated over the entire duration of 10 seconds. Average power of α, β and γ bands over 2251 windows is calculated.

$$\{\alpha_{k,j}, \beta_{k,j}, \gamma_{k,j}\} = \sum_{i=0}^{250} \{\alpha_i, \beta_i, \gamma_i\} \div 250$$

$$\{\alpha_{avg,j}, \beta_{avg,j}, \gamma_{avg,j}\} = \sum_{k=0}^{2251} \{\alpha_{k,j}, \beta_{k,j}, \gamma_{k,j}\} \div 2251$$

Flow Chart

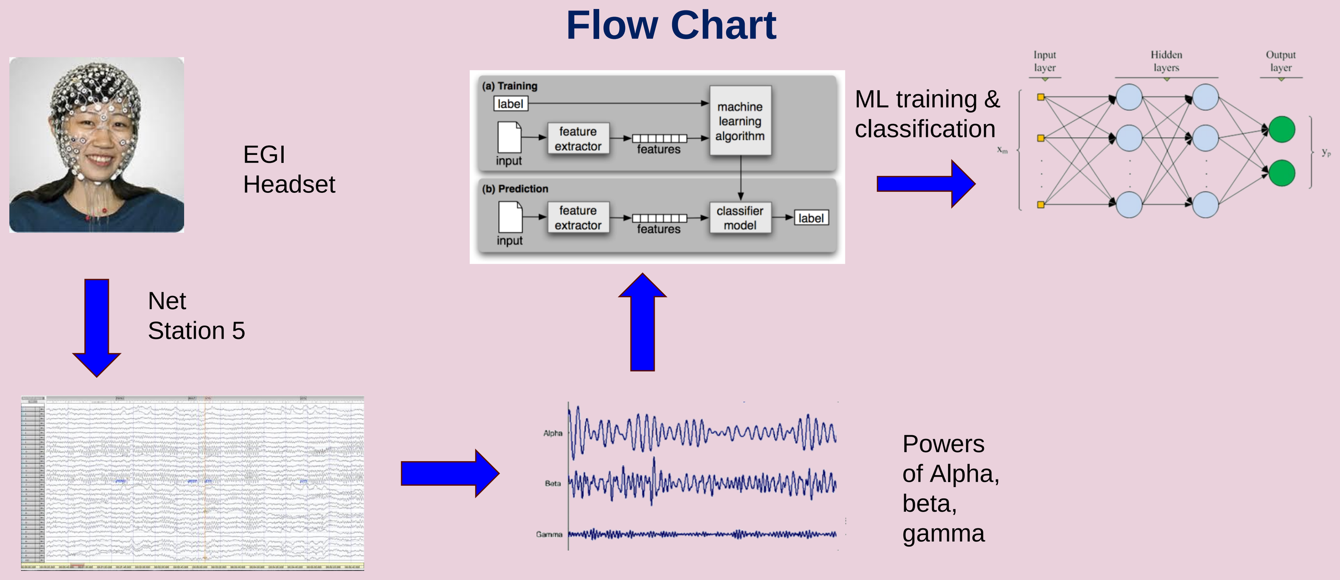
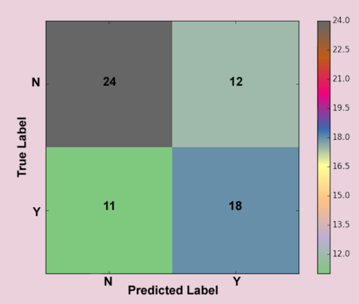


Figure 3. Flow chart of the methodology process

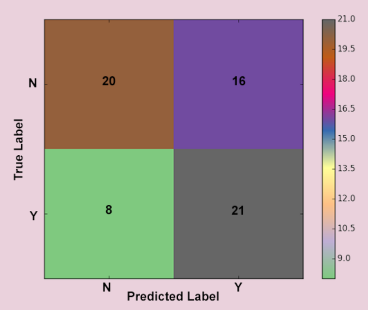
RESULTS

Comparative Analysis of different Machine Learning Classifiers

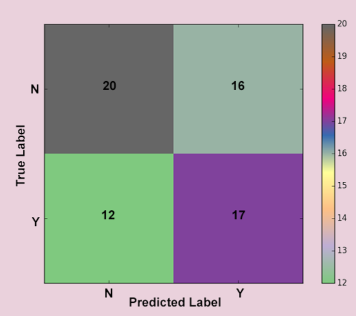
- **Decision Classification**



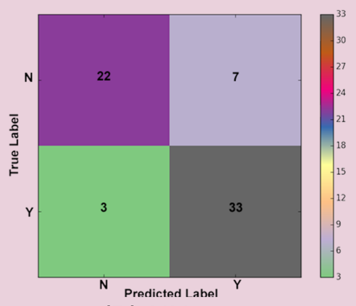
(A) ADA



(B) RF



(C)SVM

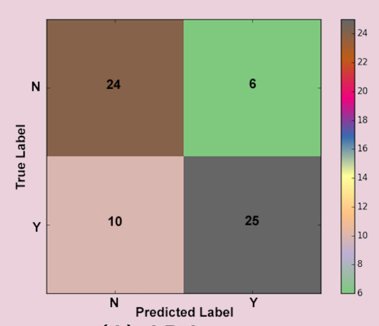


(D) NN

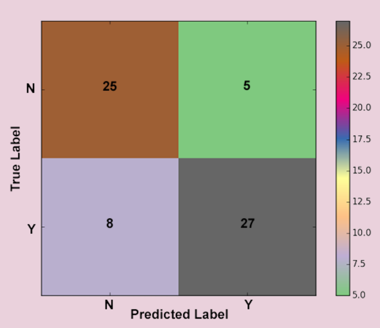
	Accuracy				
	L	D	L+D	Sensitivity	Specificity
NN	70%	84.6%	84.6%	91.66%	75.86%
SVM	55.38%	56.92%	53.8%	58.62%	55.55%
RF	48.80%	63.08%	56.10%	72.41%	55.55%
AB	53.8%	64.69	56.90	62.02%	66.66%

Table 1: Accuracy, Sensitivity and Specificity in Decision classification

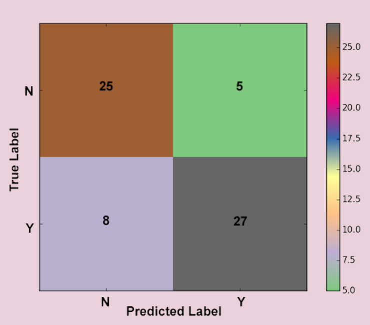
- **Language Classification**



(A) ADA

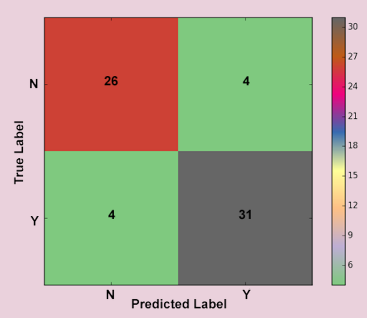


(B)RF



(C)SVM

RESULTS



(D) NN

	L
NN	87.69
SVM	80.00%
RF	80.00%
AB	75.38%

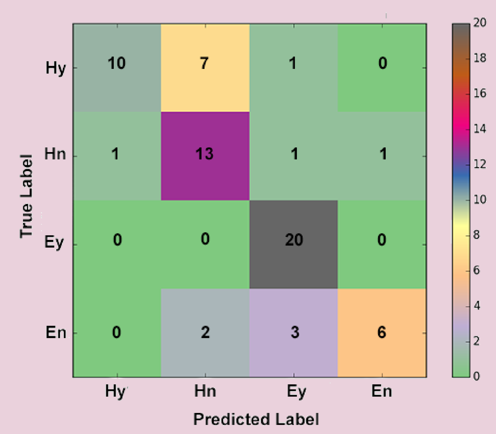
(a)

	Sensitivity	Specificity
NN	88.57	86.67%
SVM	77.14%	83.33%
RF	77.14%	83.33%
AB	71.42%	80.00%

(b)

Table 2: Accuracy(a), Sensitivity and Specificity(b) in Language Classification

- **Language and Decision Classification**



Improvement over previously published studies

STUDY	WORDS, SUBJECTS, ELECTRODES	ACCURACY
Wester and Shultz [10]	5, 21, 16	42%
Calliess [11]	5, 23, 16	49%
Porbadnigk et al. [12]	5, 21, 16	45.5%
Torres-Garcia et al. [3]	5, 21, 16	20%
Salama et al. [6]	2, 7, 1	Offline 56% Online 57%
This Work	**2 in each language(4), 5 , 6 for Decision(D)and 5 for Language(L) and 11 for D +L**	**D - 84.6% L - 87.69% Total - 75.3%**

Table 3: Parameters and criteria for arrhythmia classification.

CONCLUSIONS

- We present a novel automated method of data acquisition using a TCP between the device and acquisition software that reduces eyeblink/motion artifacts leading to better feature extraction.
- We use a rolling mean method to obtain averaged powers of the α, β and γ bands by splitting the time series data into windows of 250 data points leading to better data representation per time point.
- In a novel finding, we are able to classify semantically similar words 'Yes'/'No' and 'Haan'/'Na'(in unspoken speech) in two different languages (English and Hindi) at a high accuracy of 75.38% and classify decision and language at an accuracy of 84.6% and 87.69% respectively using Artificial Neural Networks.
- These findings are a great improvement over previous findings in the same domain. This could be used for real-time devices.

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ACKNOWLEDGEMENTS

We extend our gratitude to DST, Govt. of India for their gracious funding though the CSR Initiative. We would like to thank the management at our home university at BITS Pilani, for providing us with a scientific atmosphere for us to envision and implement this project. We would like to thank the Faculty of Biological Sciences for helping us immensely throughout the duration of the project. We would like to thank Dr. Veeky Baths, Assistant Professor, Department of Biological Sciences for his invaluable technical inputs and continued support during our work. We would also like to thank Mr. Mayur and Mr. Gautham and all other members of the Cognitive Neuroscience Laboratory, BITS Pilani K.K Birla Goa Campus for their timely help and guidance. We also express our gratitude to all our friends at our university for their encouragement and inputs that help us ishape the project to its current state. We would also like to thank our parents for their support and almighty god for giving us the courage and will to get through the project.