Human-Computer Interaction using Neuromuscular Signals

Team Members:

Rabin Nepal [073/BEX/331]

Rimesh Lawgun [073/BEX/333]

Sanjay Rijal [073/BEX/342]

Upendra Subedi [073/BEX/347]

Project Supervisor:

Mr. Dinesh Baniya Kshatri

Lecturer

Department of Electronics and Computer Engineering

Institute of Engineering, Thapathali Campus

October 19, 2020

Presentation Outline

- Motivation
- Objectives
- Scope of Project
- Instrumentation and Requirement Analysis
- Methodology
- Speech EMG Dataset
- Results
- Analysis and Discussion
- Accomplished and Remaining Tasks
- References

Motivation

Objectives

- To extract and transfer EMG signals from articulatory muscles to a computer
- To process and convert the articulated speech signals to text

Scope of Project

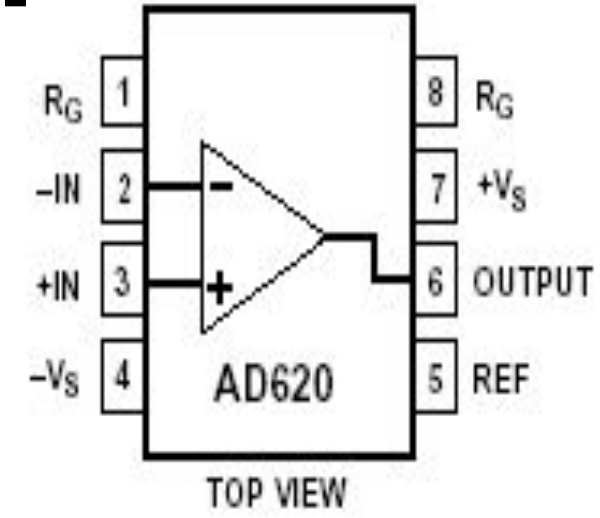
- **Project Capabilities**
  - Detects words, letters or digits that a person is articulating internally
  - Displays the articulated speech on monitor as text
- **Project Limitations**
  - Detection of sentences and symbols
  - Two way interaction between the user and the computer

Instrumentation and Requirement Analysis
[Hardware Component - 1]

- **EMG Electrodes**
  - Ag-AgCl electrodes

    (low price, easy availability)

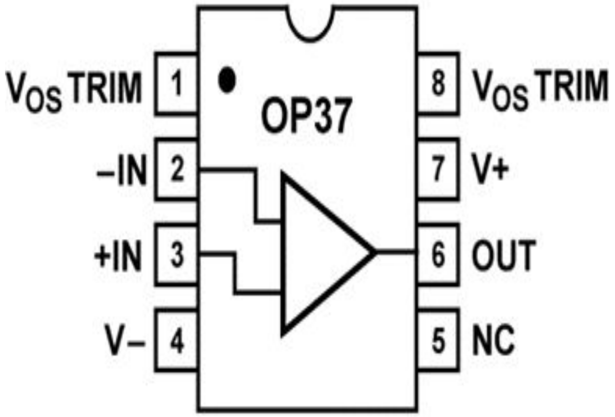
Electrode



- **Amplifiers (AD620 and OP37G)**
  - Low noise Instrumentation Amplifier AD620

    (100 dB CMRR at G=10, gain range 1-10,000)
  - Operational Amplifier OP37G for active filter

    (low noise, high open loop gain)



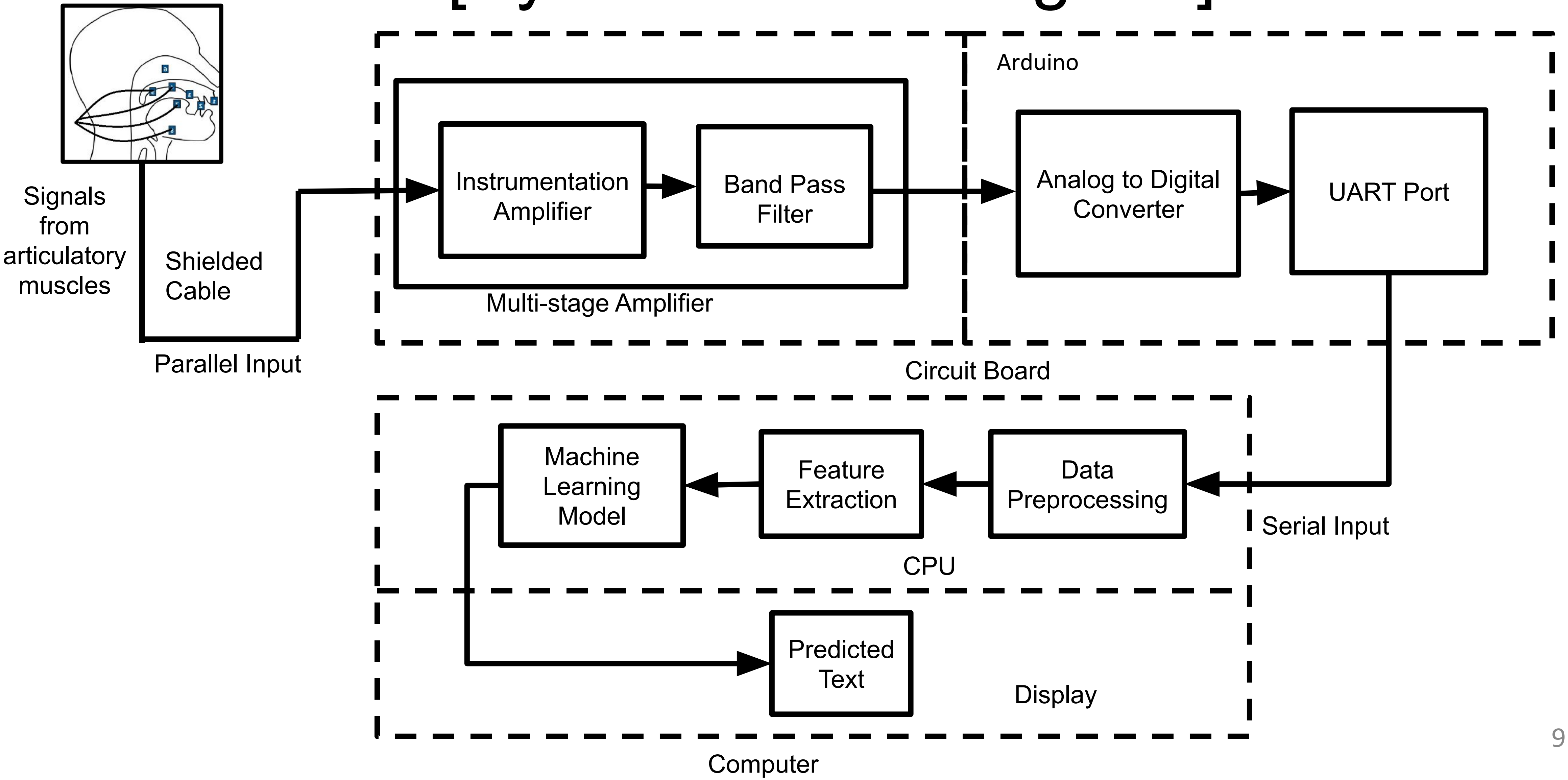
Instrumentation and Requirement Analysis
[Hardware Component - 2]

- **Arduino UNO**
  - Integrates multi-channel 10 bit SAR ADC for signal digitization
  - Samples analog voltage between 0 to 3.3 V
  - Provides serial plotter for data visualization
  - Interfaces with computer for serial data transfer

Instrumentation and Requirement Analysis
[Software Platform]

- **Python**
  - Mainly used Scipy, Librosa, Scikit Learn, Tensorflow
  - Used for feature extraction and ML implementation
- **KiCad**
  - Open source circuit designing software
  - Used for designing schematic and PCB layout of amplifier and filter

Methodology - 1
[System Block Diagram]

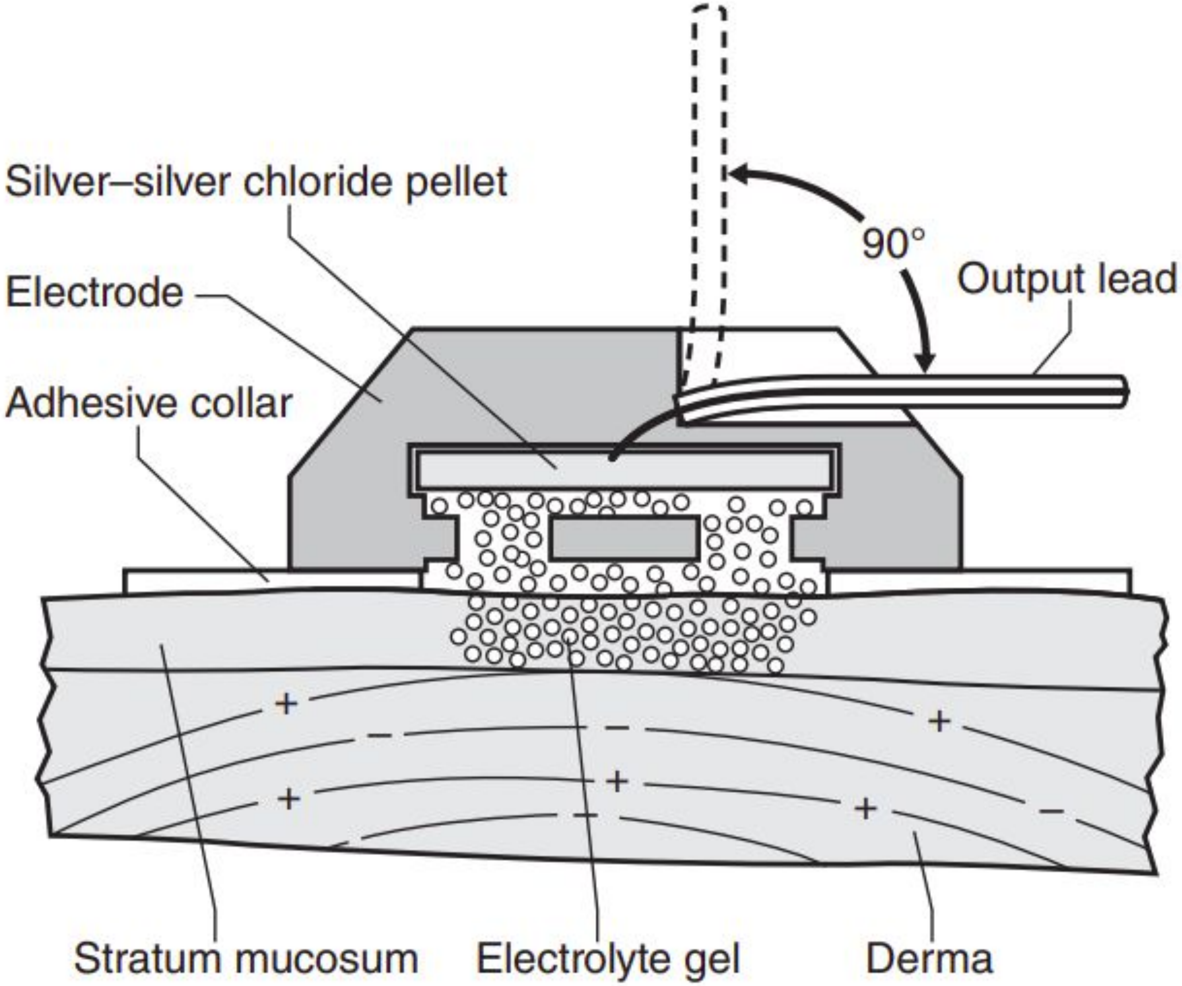


Methodology - 2
[Muscle Selection]

EMG Channel	Muscle name
1	Anterior belly of the digastric
2	Zygomaticus Major
2,3	Levator Angulis Oris
4	Platysma
5	Unused
6	Depressor Anguli Oris

Methodology - 3
[Electrode Placement and Signal Extraction]

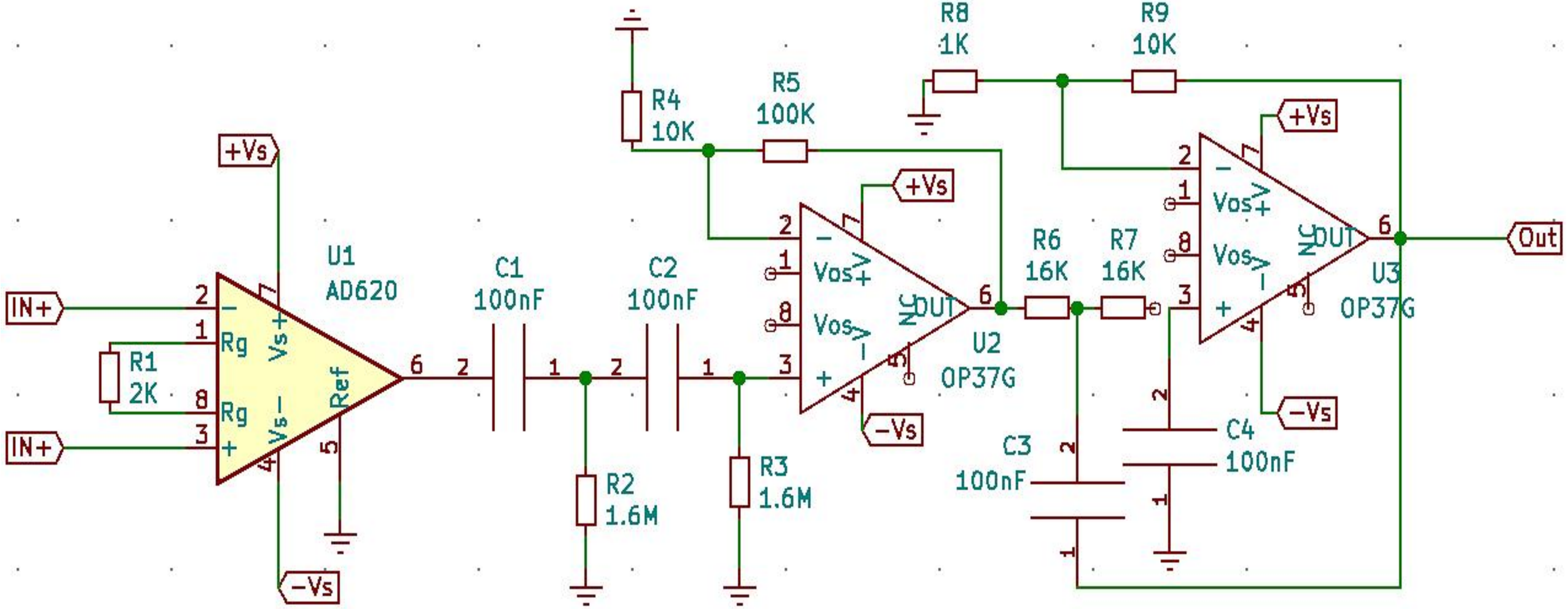
- Ag-AgCl electrodes attached on skin at targeted muscles
- Ionic conduction leads to extraction of EMG signal at skin-electrode interface



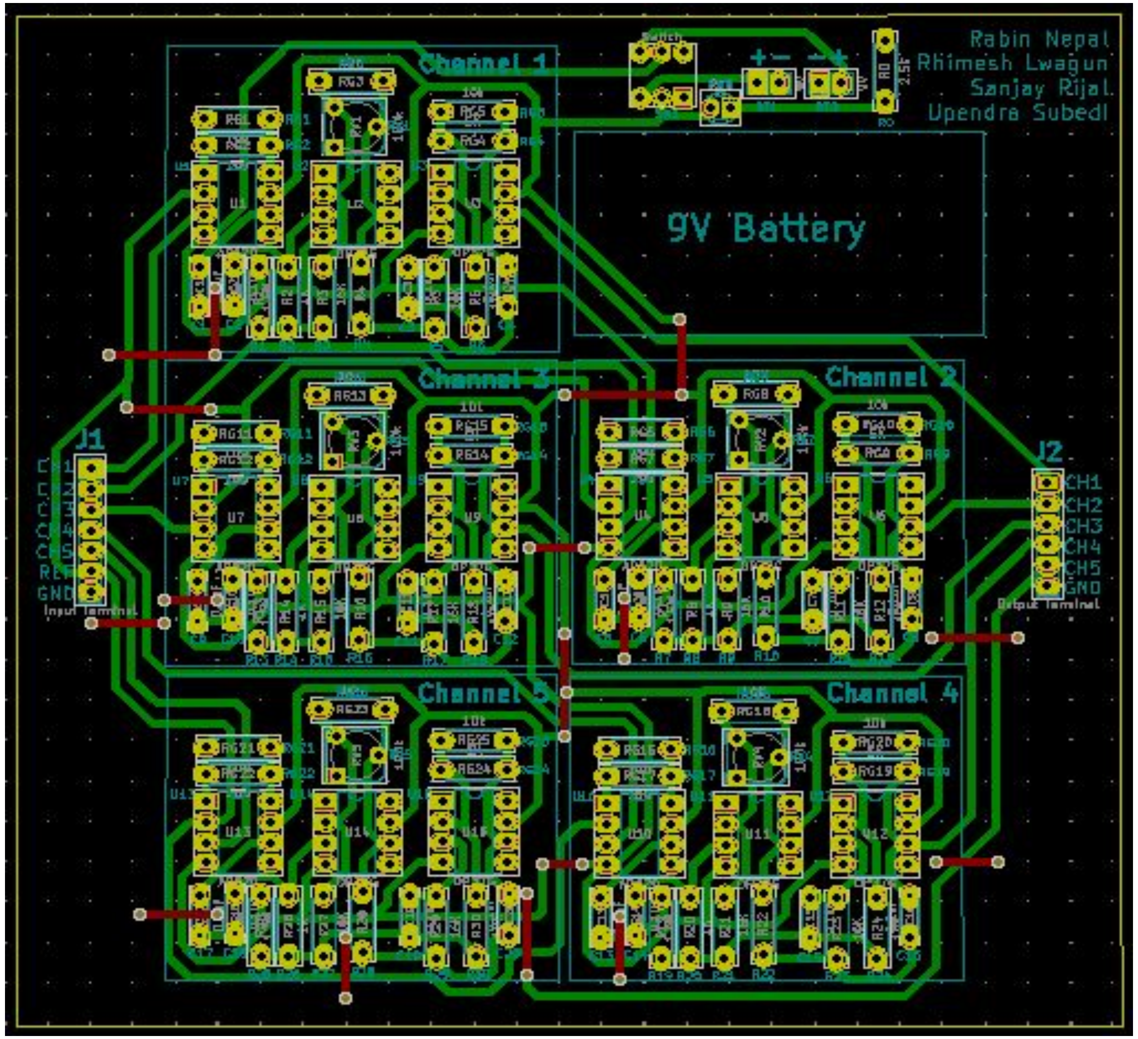
Methodology - 4
[Signal Amplification and Filtration]

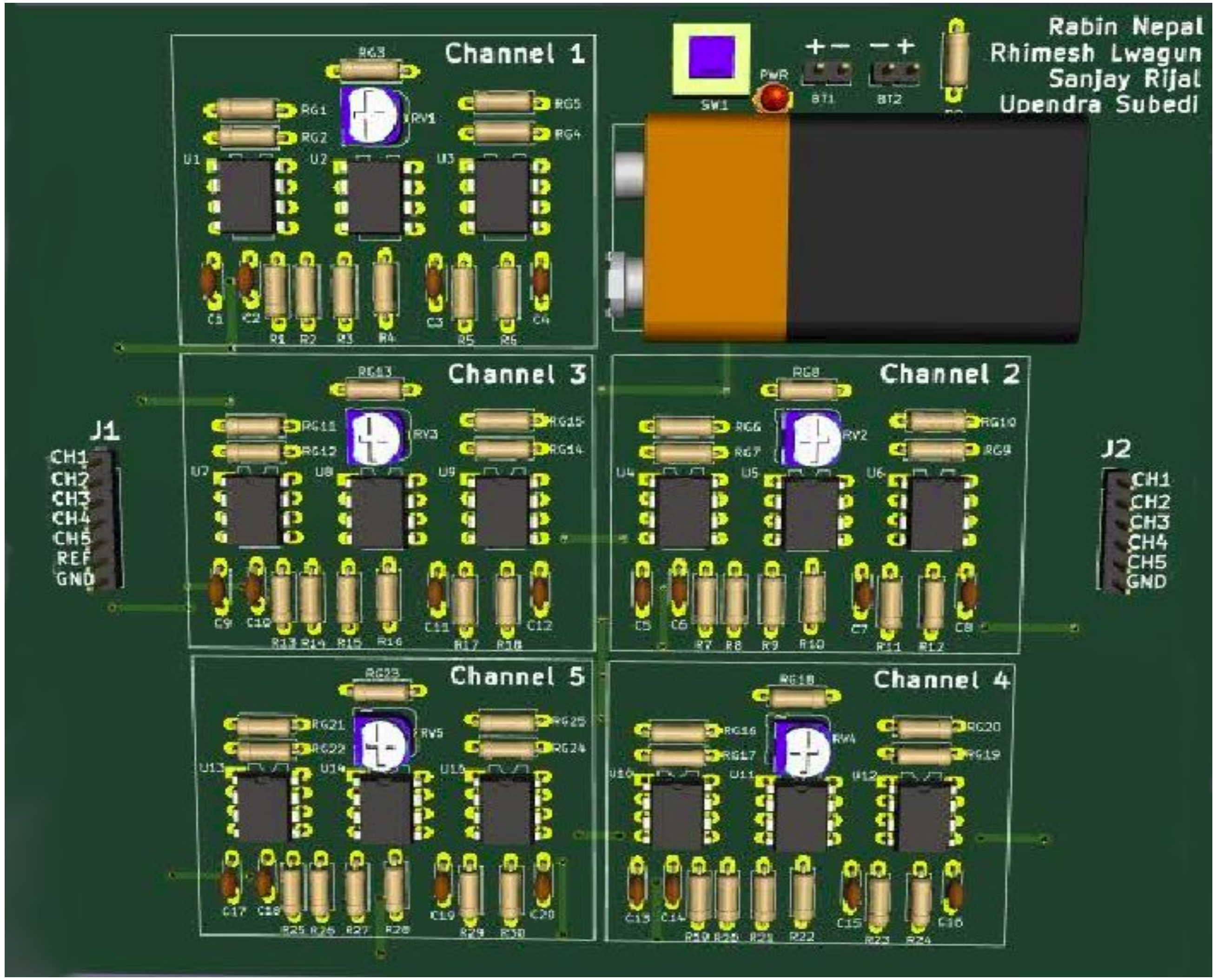
- Micro-volt EMG signals get amplified by AD620 with a gain of 10.8
- Second order active Butterworth HPF with cutoff frequency at 1 Hz and amplification factor of 471
- Second order active Butterworth LPF with cutoff frequency at 100 Hz and amplification factor of 1.5

Methodology - 5
[Single Channel Schematic]



Methodology - 6
[Multi-channel PCB Design]





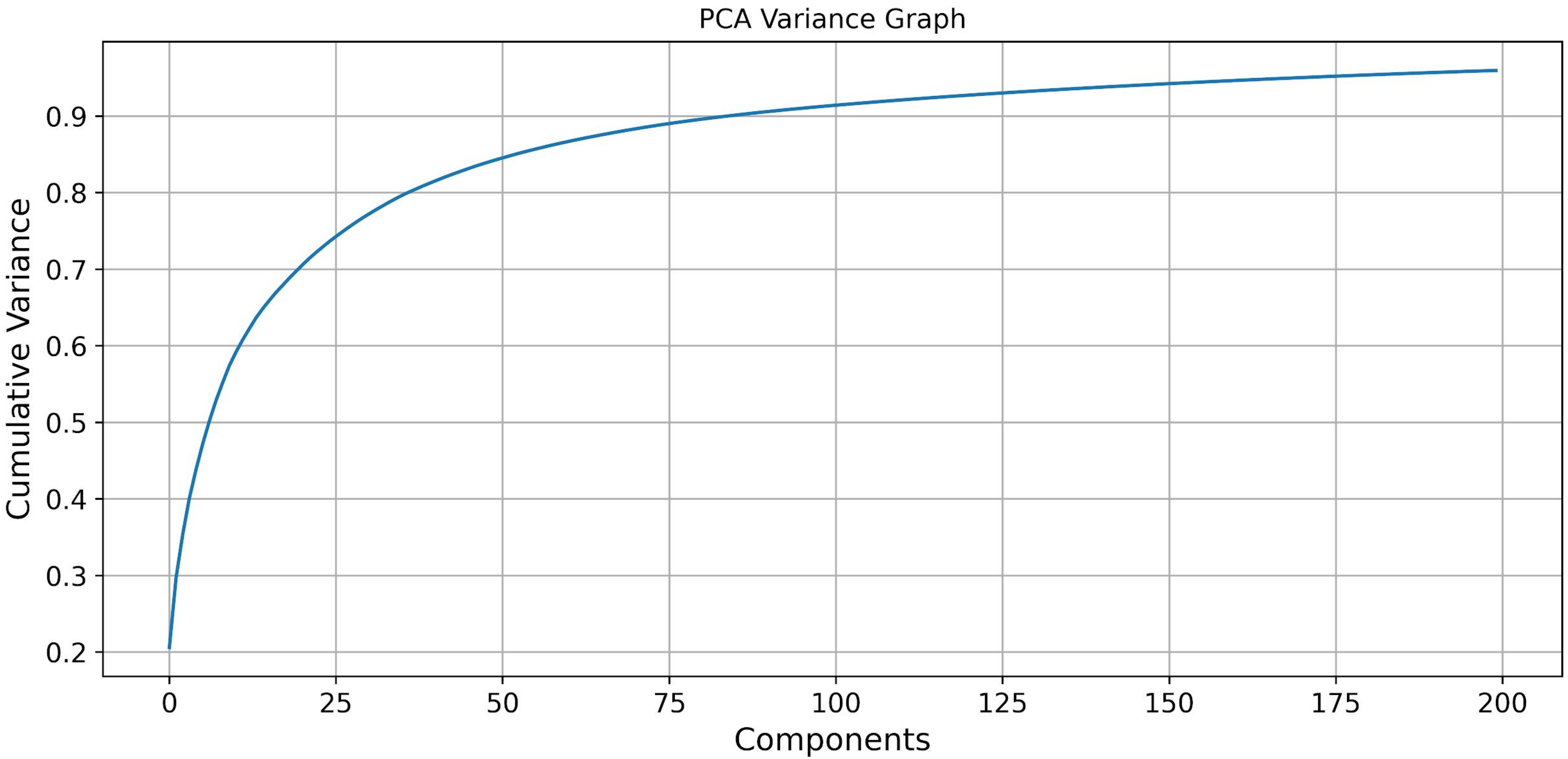
Methodology - 7
[Signal Conversion and Communication]

- ADC of Arduino converts analog signal to digital form
- Sampling frequency of 600Hz
  - Nyquist criteria ($f_s \geq 2 \times f_m$, f_m = 100 Hz)
- Serially interfaced Arduino transfers data to computer
- 1 start bit, 5 - 9 bits of data frame, 1 parity bit and 1 stop bit

Methodology - 8
[Signal Processing]

- Data Scaling
  - ADC values converted to μV
  - Standardization (z-score) along each channel
- Length Normalization
  - Make data of equal length within 95^{th} percentile
- Windowing
  - Frame size 27ms and frameshift 10ms
- Dimension Reduction
  - 200 Components with 95% variance

Methodology - 9
[Dimensionality Reduction]



Methodology - 10
[Temporal and Spectral Features]

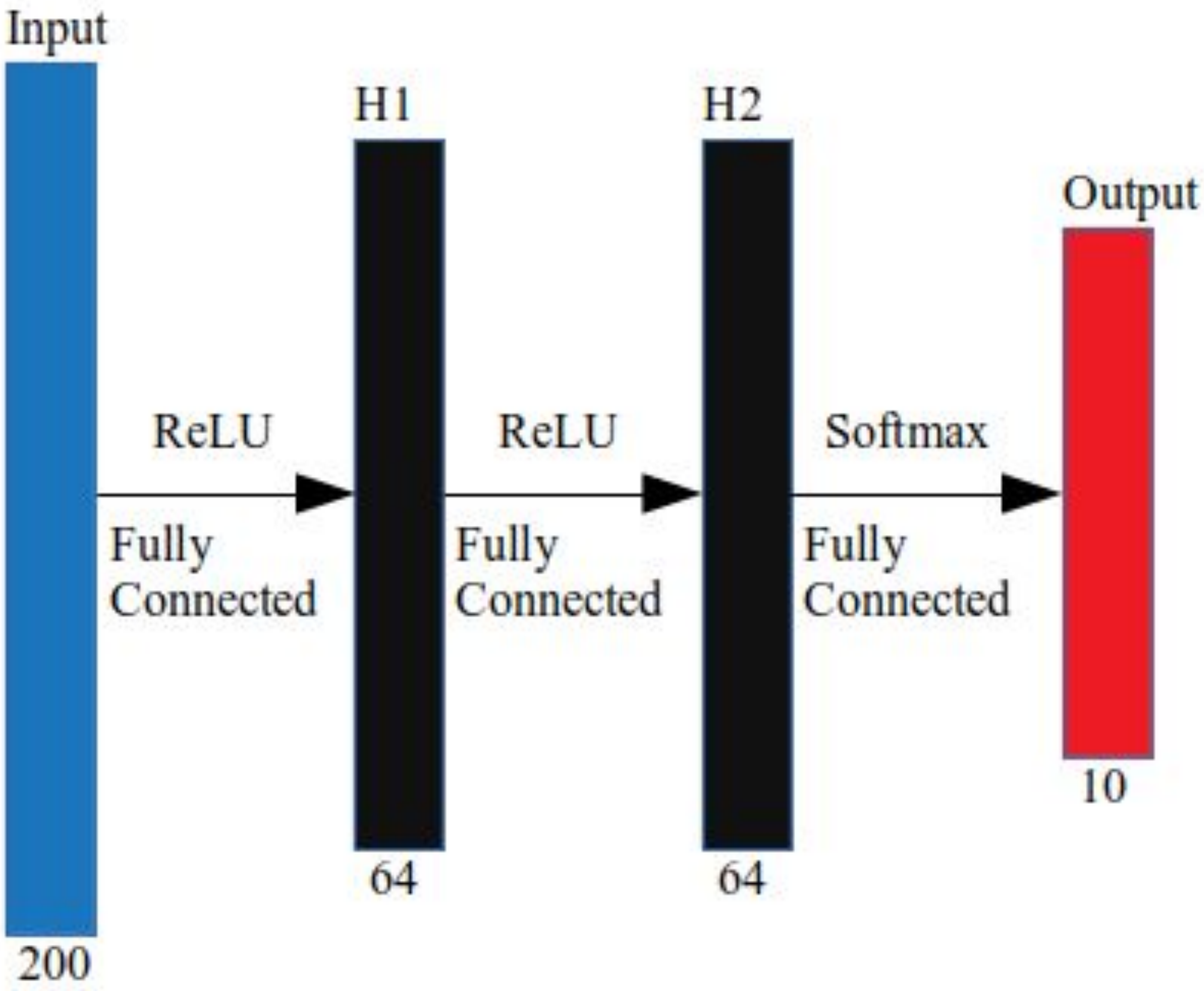
Temporal Features

- Double Nine Point Average
- Zero Crossing Rate
- Frame Based Power
- High Frequency Signal
- Rectified High Frequency Signals

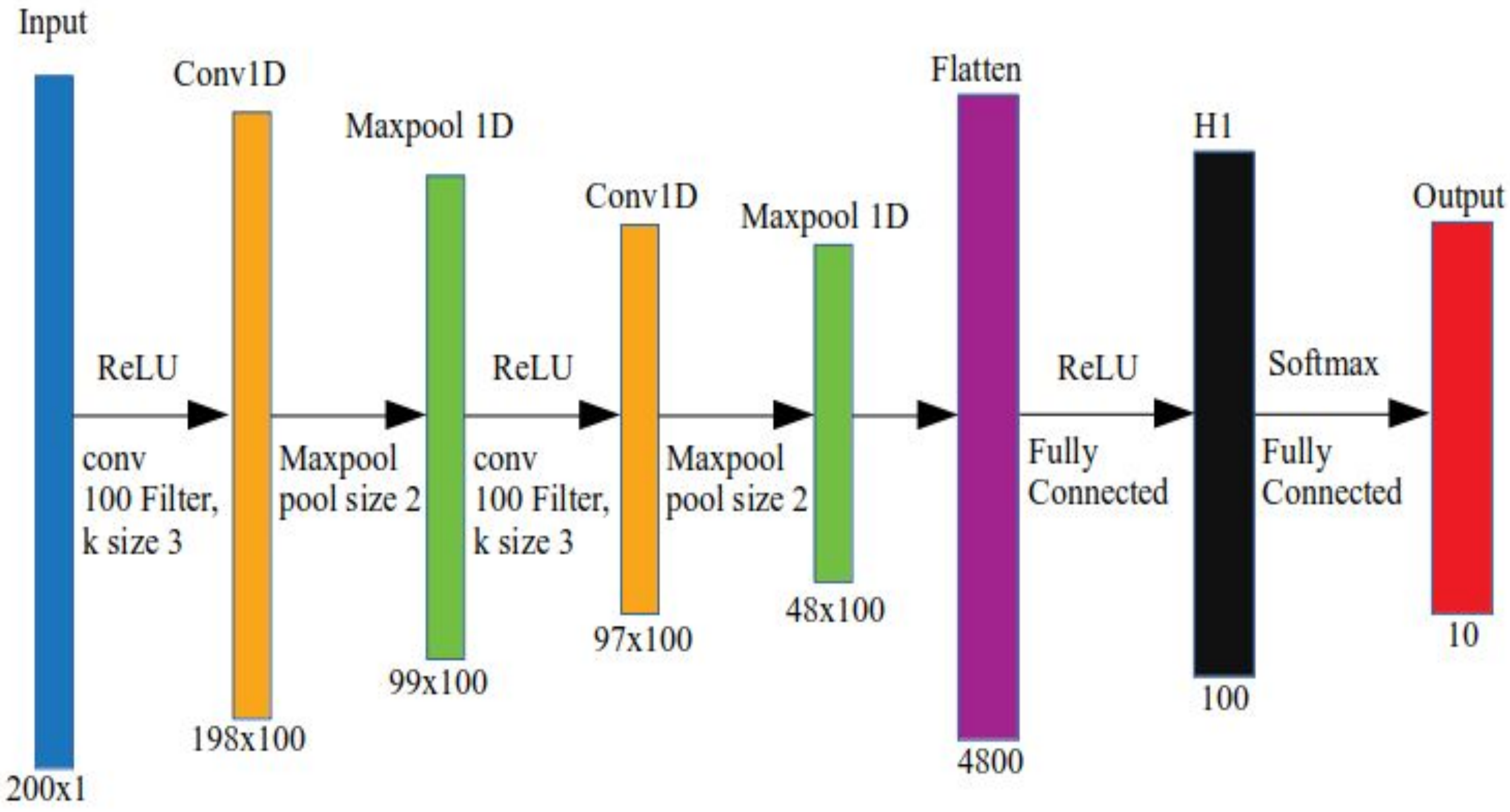
Spectral Features

- Short Time Fourier Transform (STFT)
- Mel - Frequency Cepstrum Coefficient (MFCC)

Methodology - 11
[MLP Architecture]



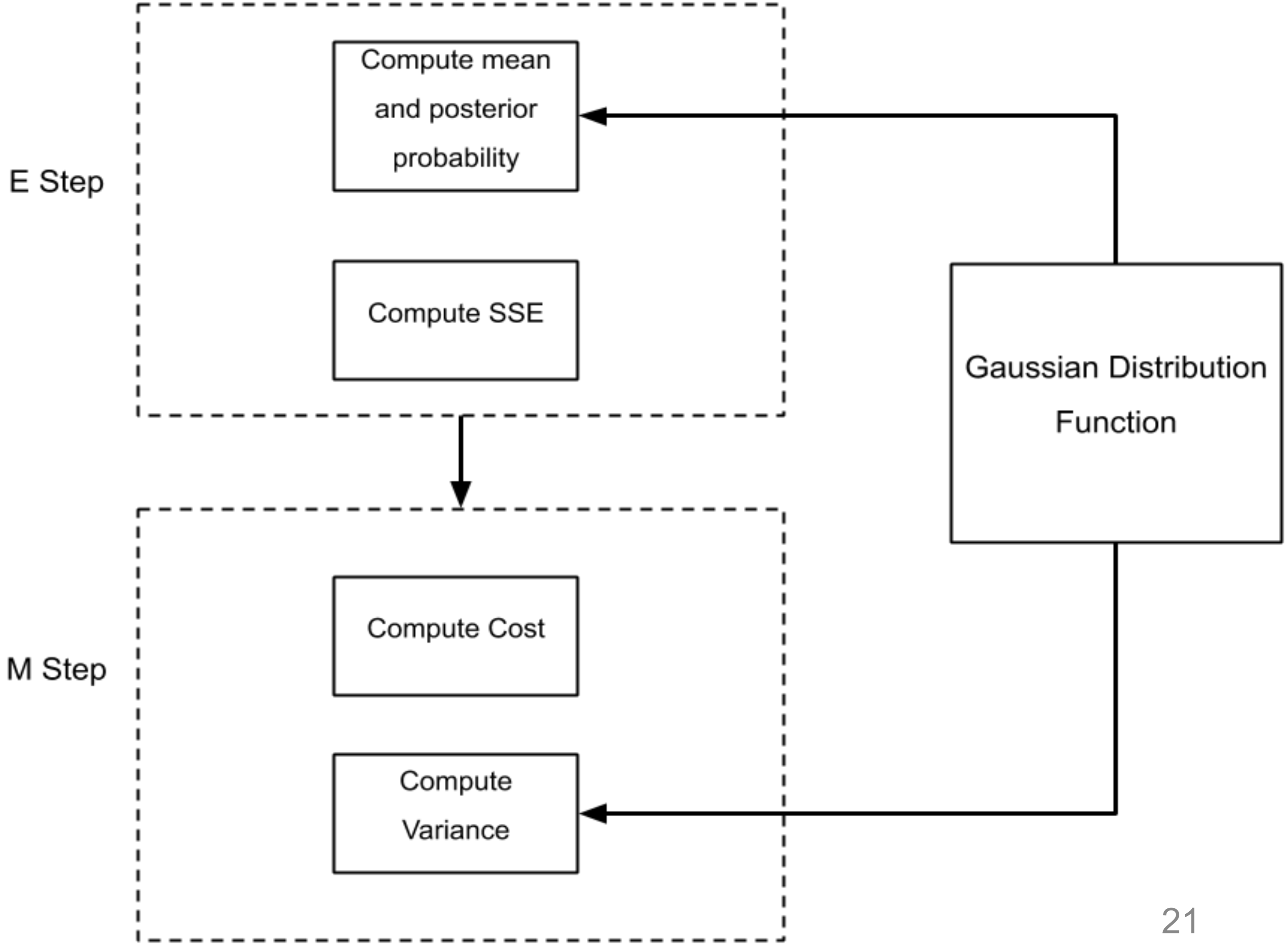
Methodology - 12
[CNN Architecture]



Methodology - 13
[K-means Block Diagram]

E = Estimation

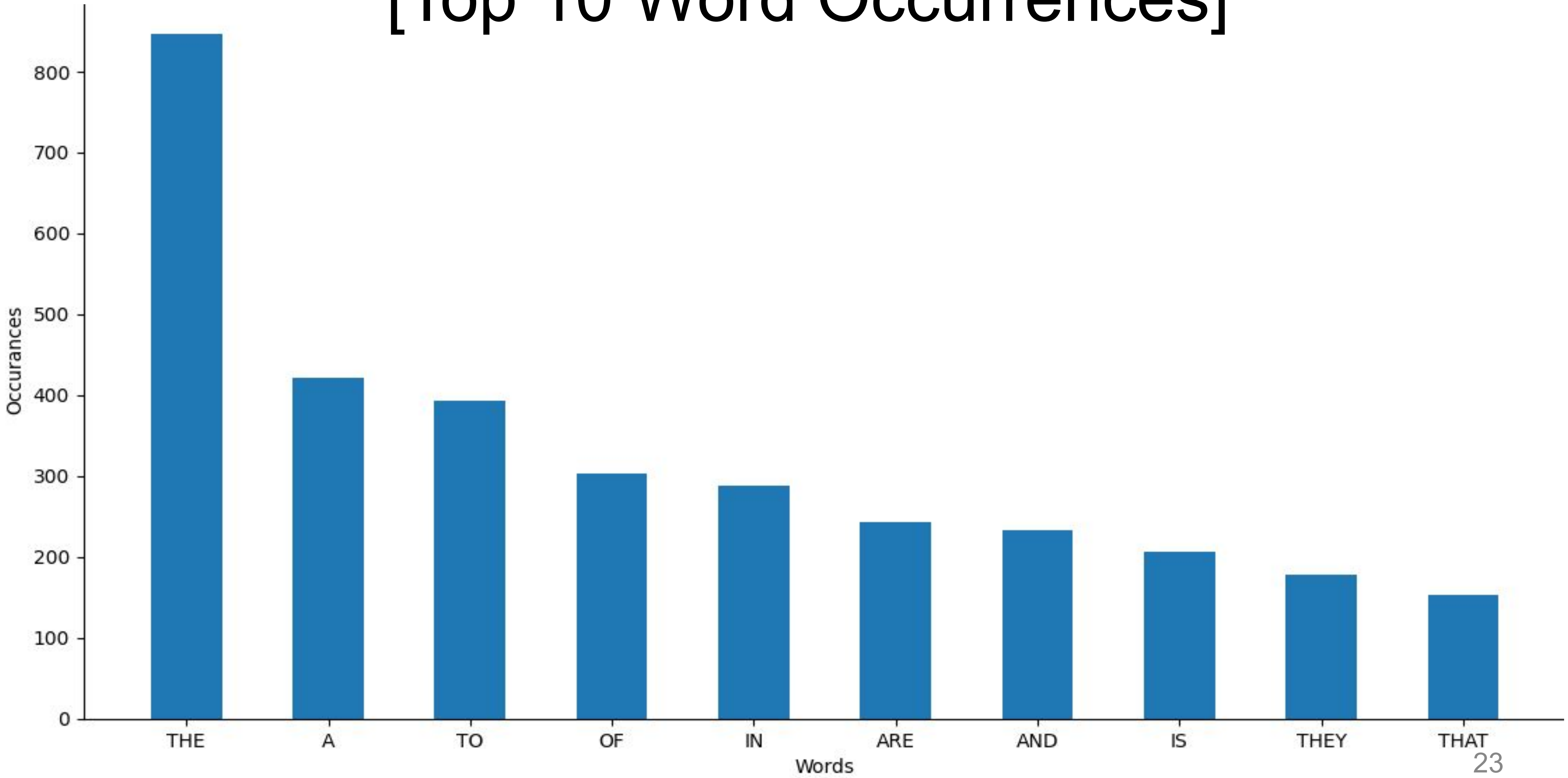
M = Maximization



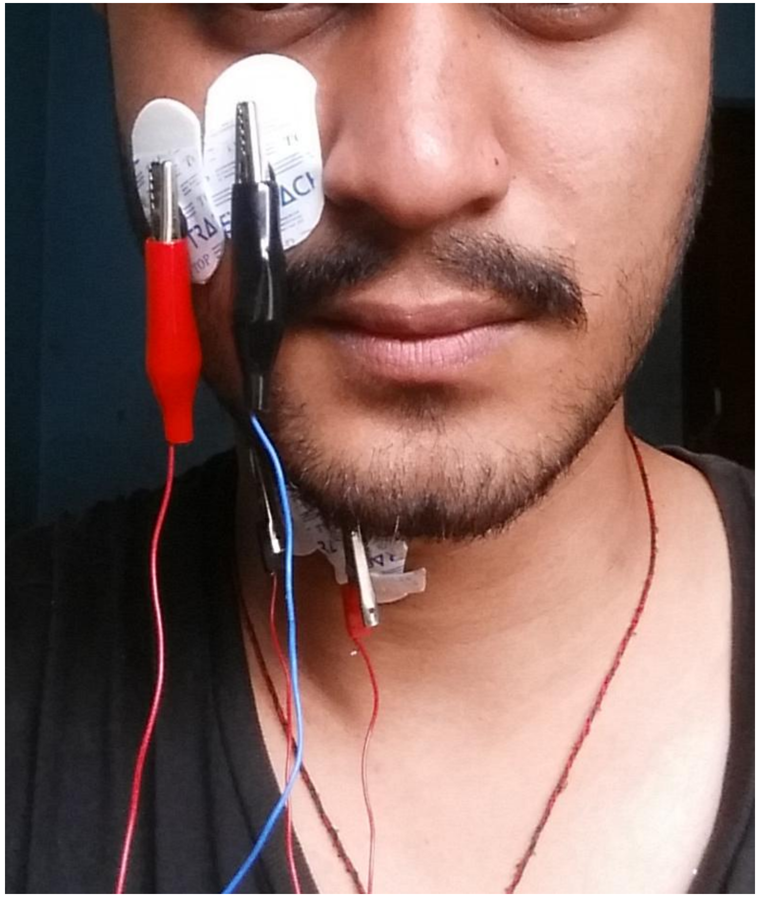
Speech EMG Dataset - 1
[EMG-UKA Trial Corpus]

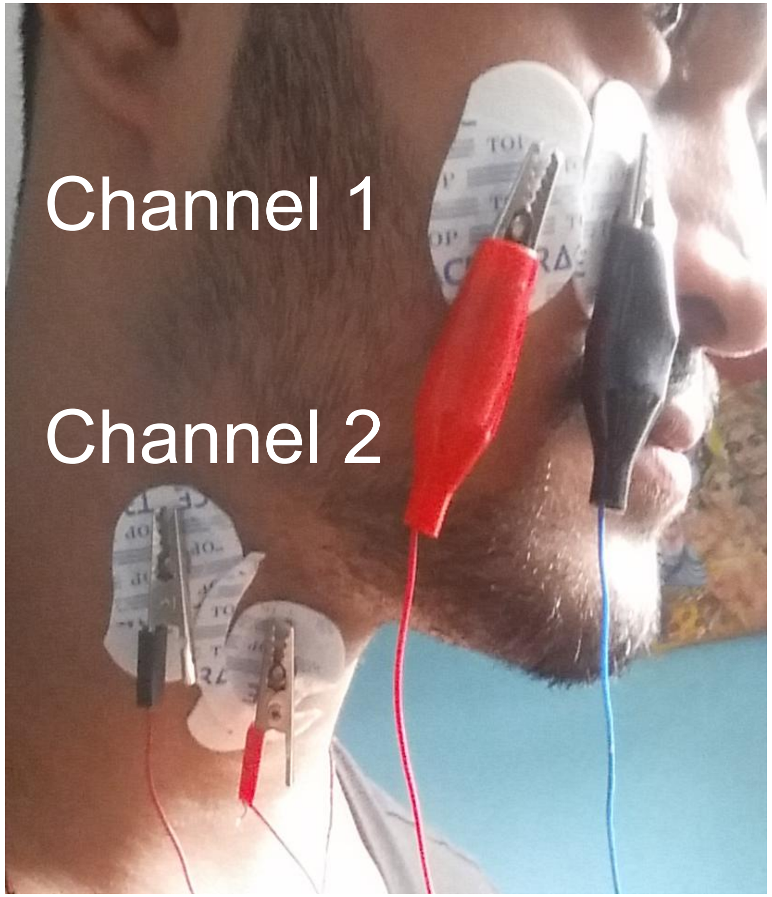
Mode	Sampling Rate (Hz)	Channels	Length (hh:mm:ss)	Speaker Count	Session Count
Audible	16000	2	01:52:24	4	6
	600	7	01:08:16	4	6
Whispered	600	7	00:21:47	4	6
Silent	600	7	00:22:21	4	6
The speakers were between 24 and 30 years old, 3 male and 1 female					
Some sessions were recorded in all speaking modes					

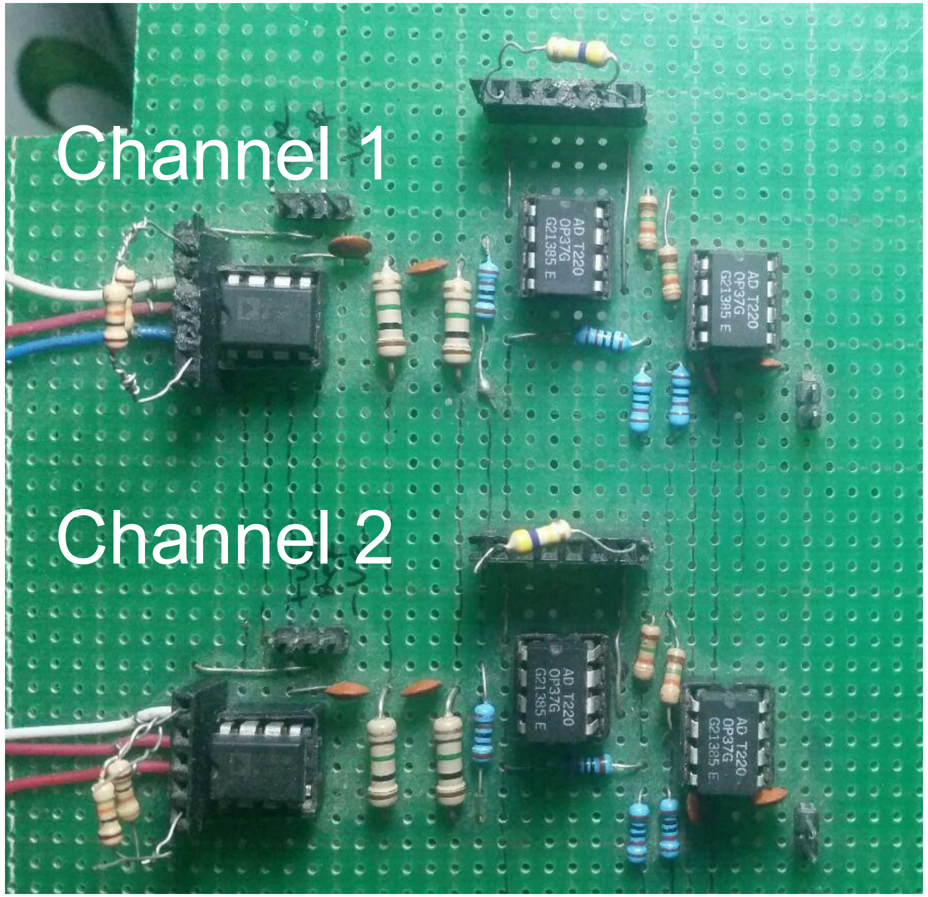
Speech EMG Dataset - 2
[Top 10 Word Occurrences]



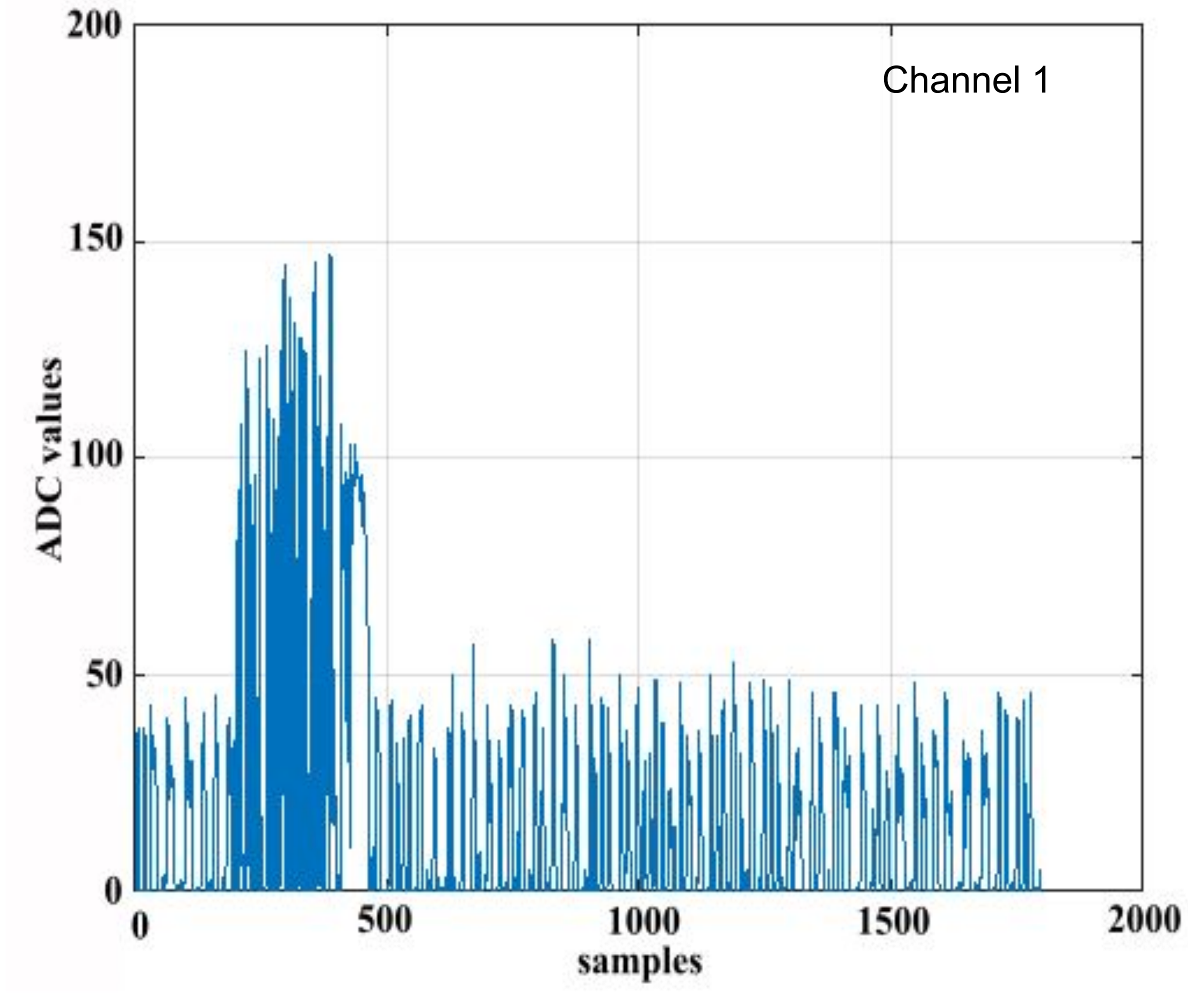
Results - 1
[Dual Channel Hardware Setup]

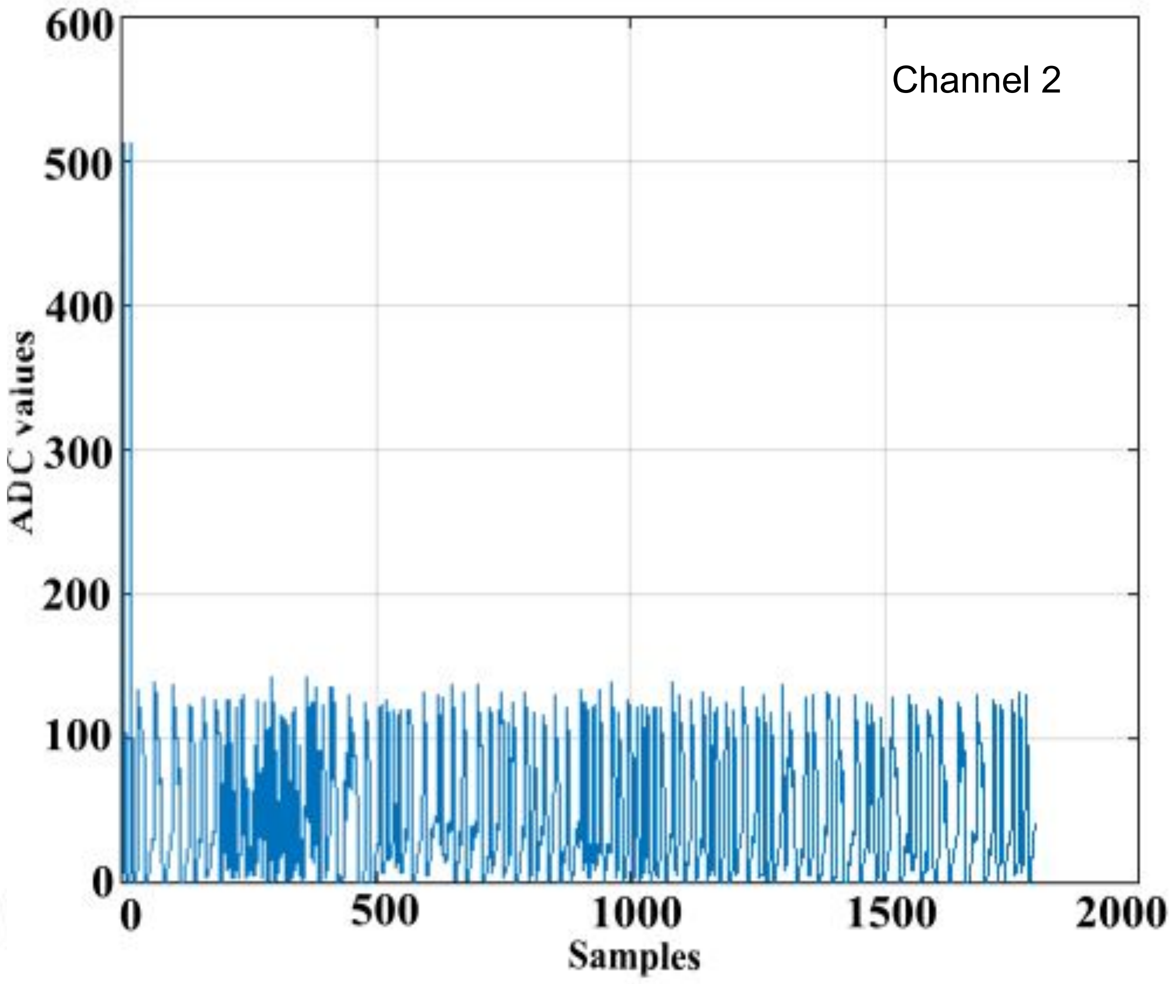




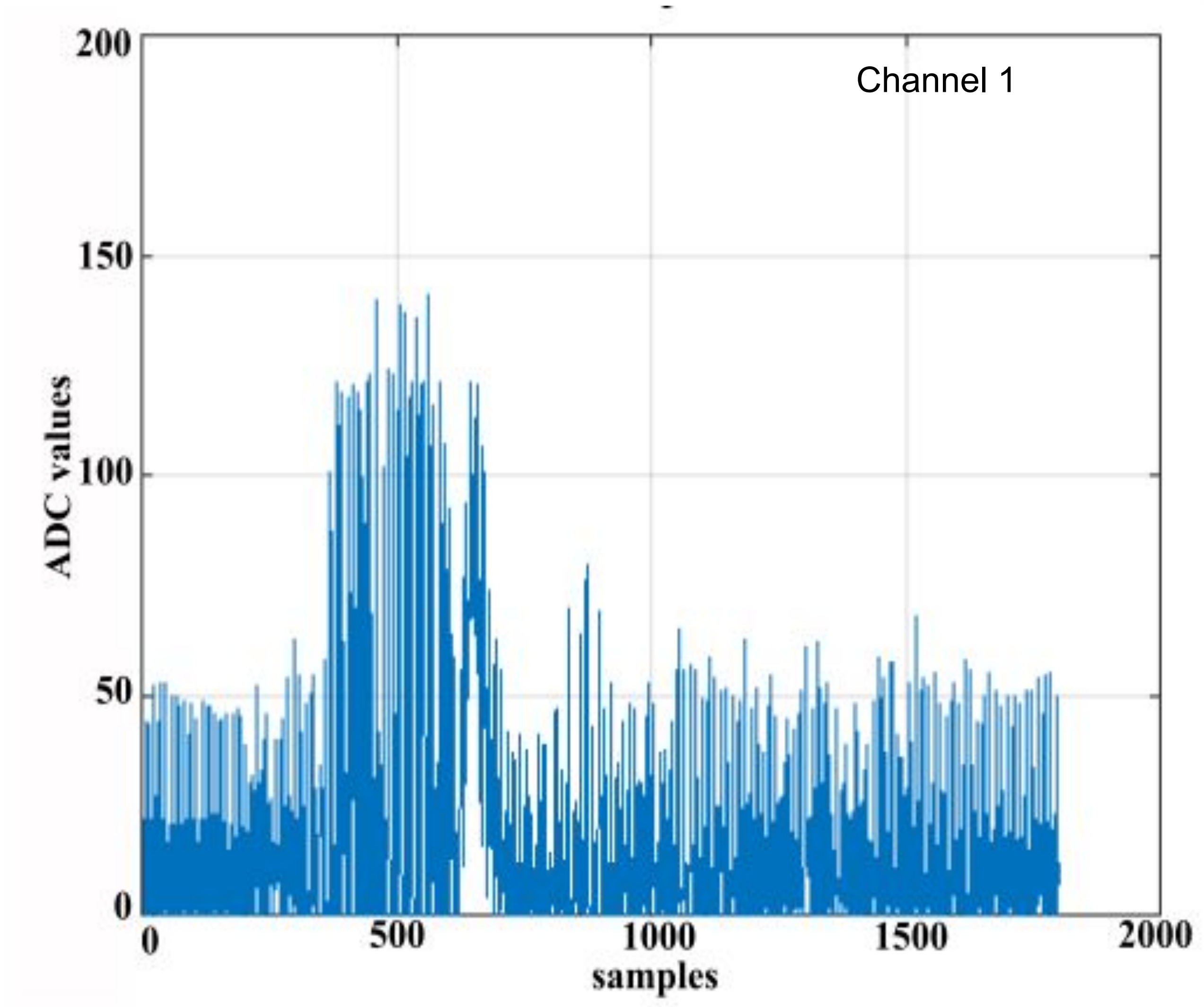


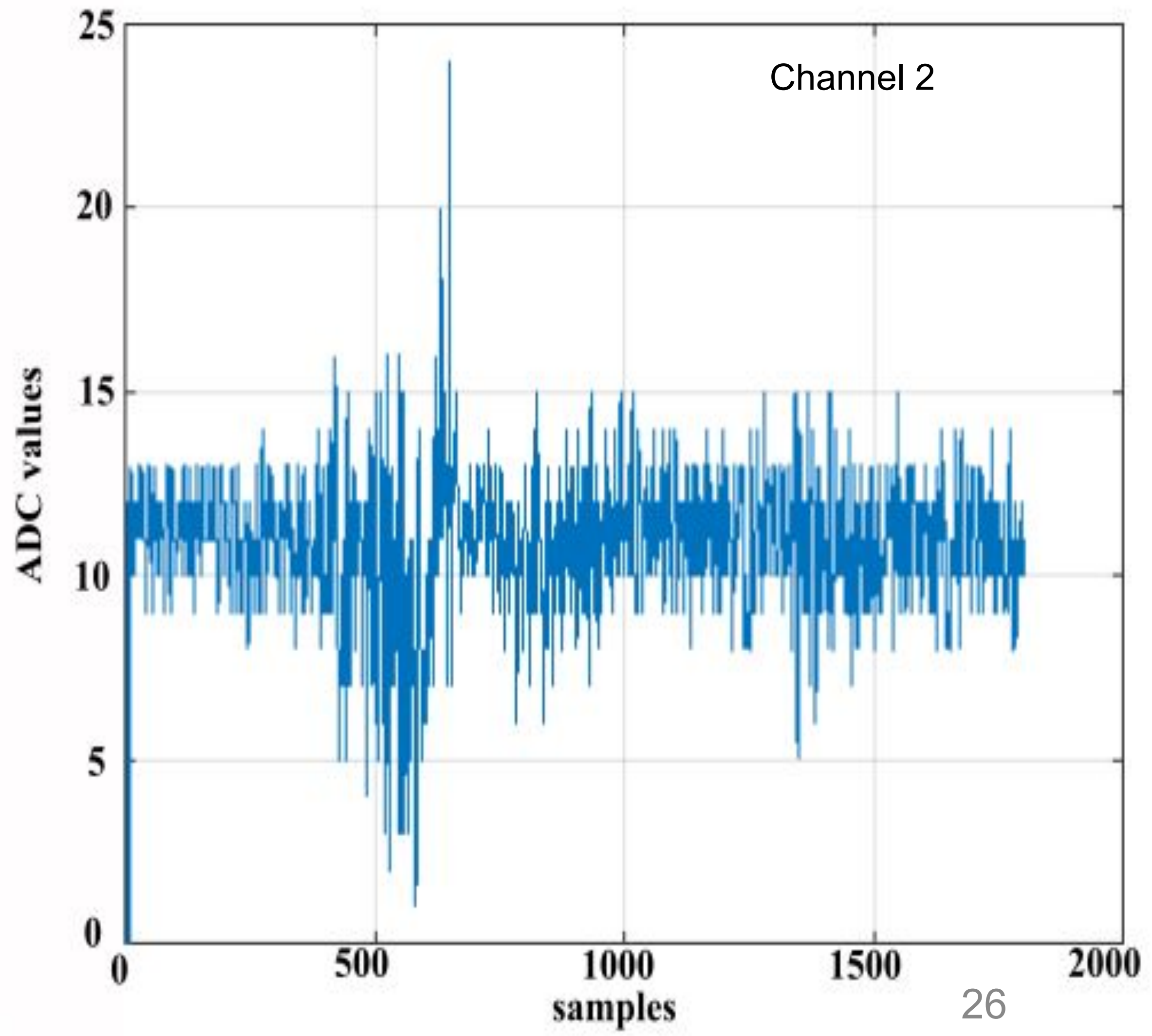
Results - 2
[EMG Signal When Articulating Word “AND”]



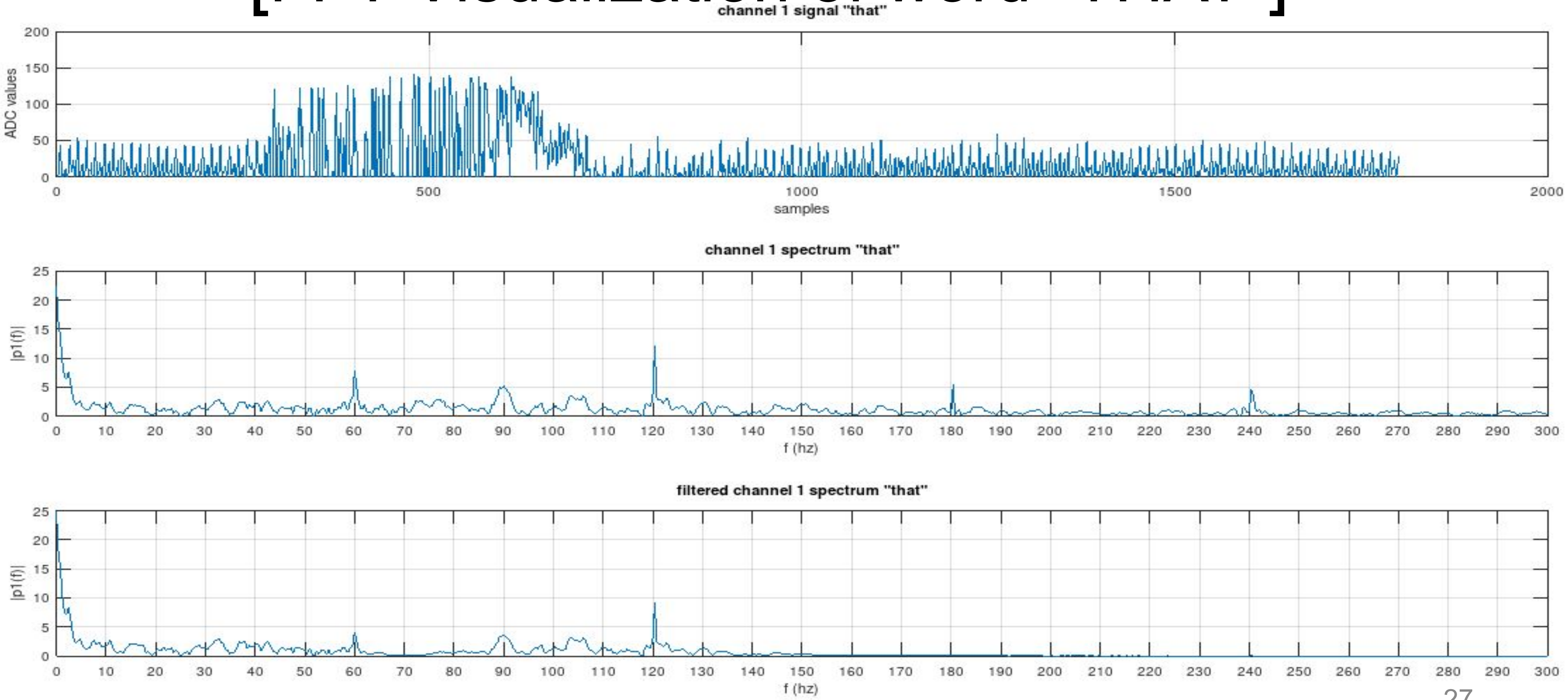


Results - 3
[EMG Signal When Articulating Word “THAT”]

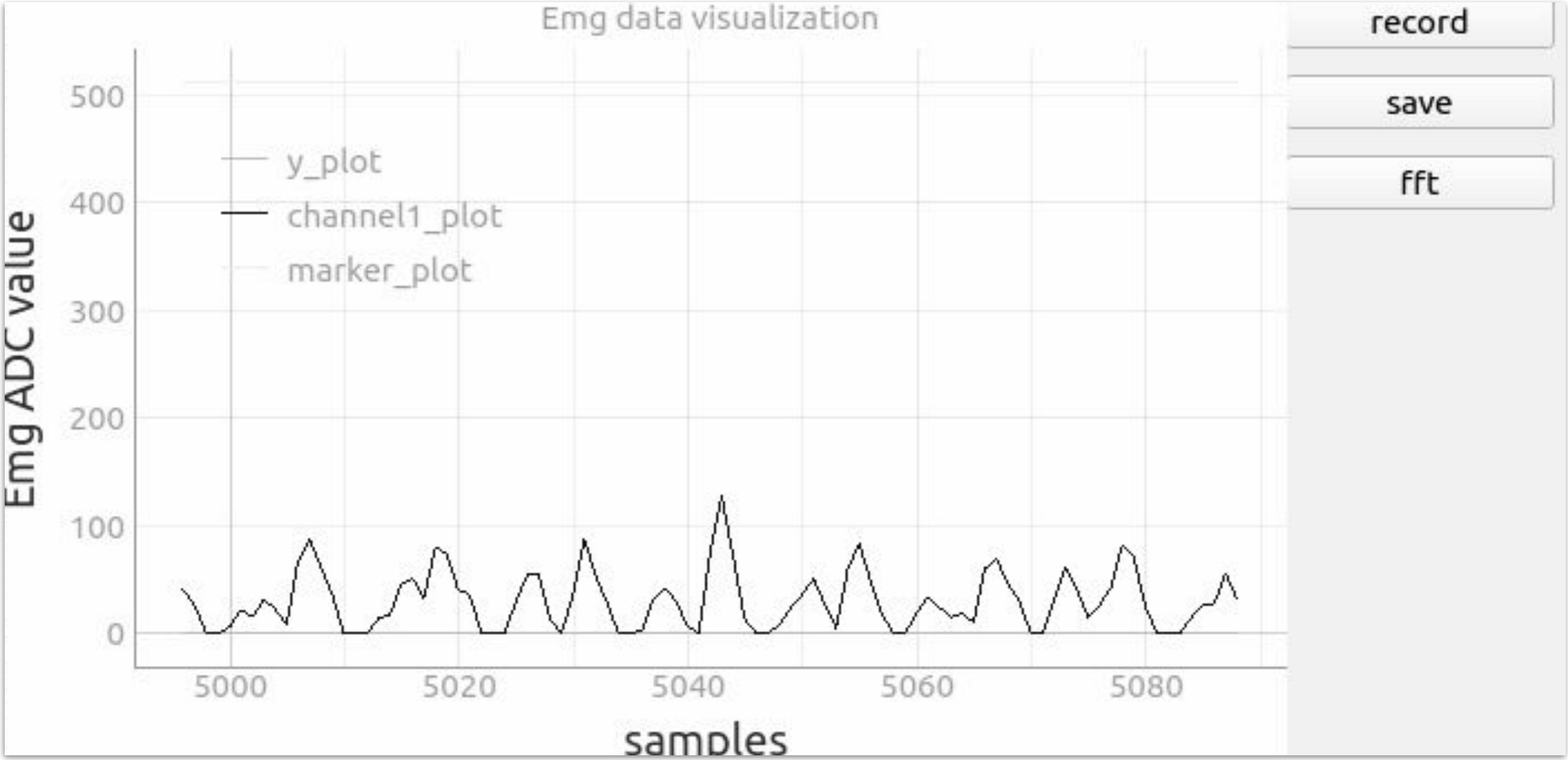




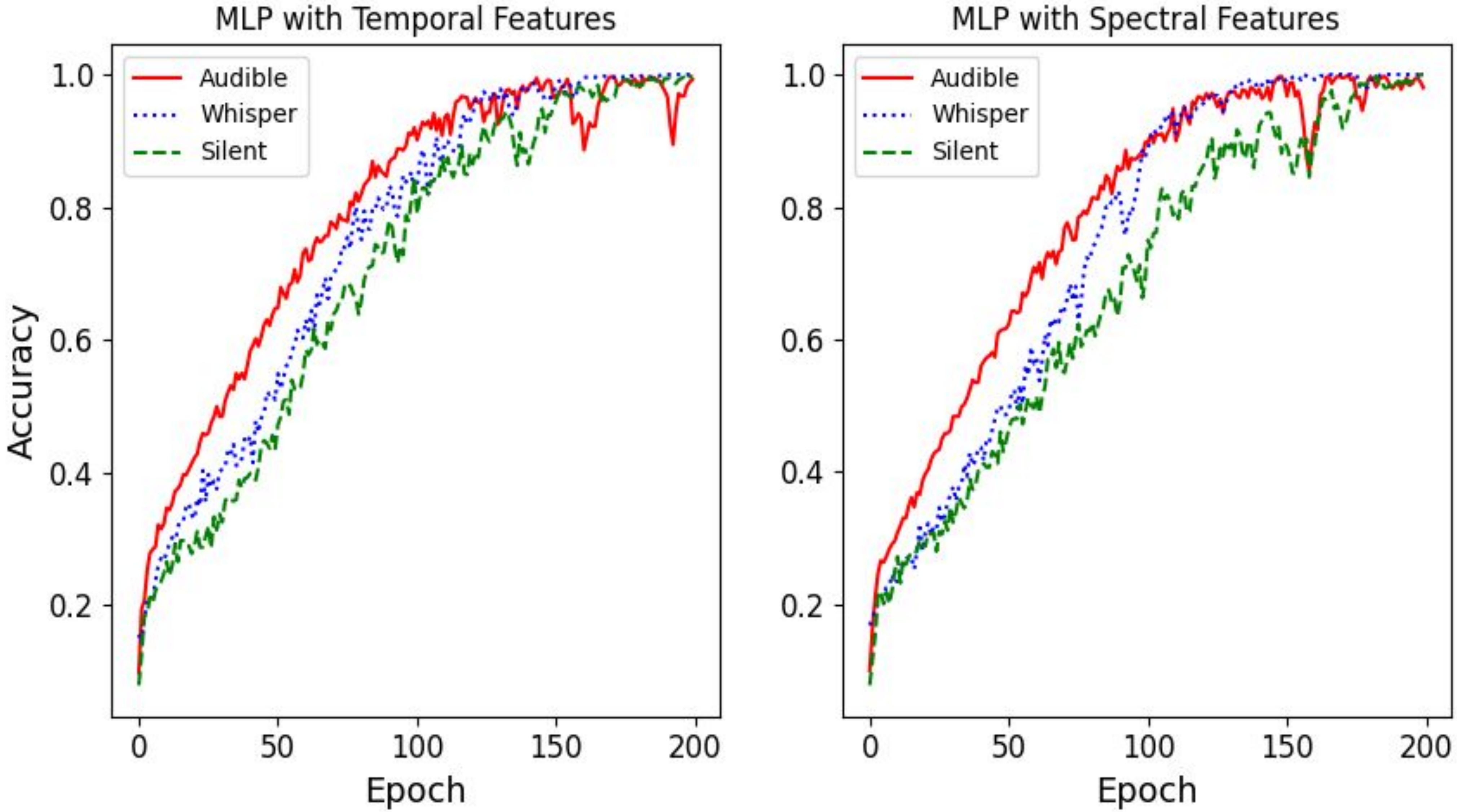
Results - 4
[FFT Visualization of word “THAT”]



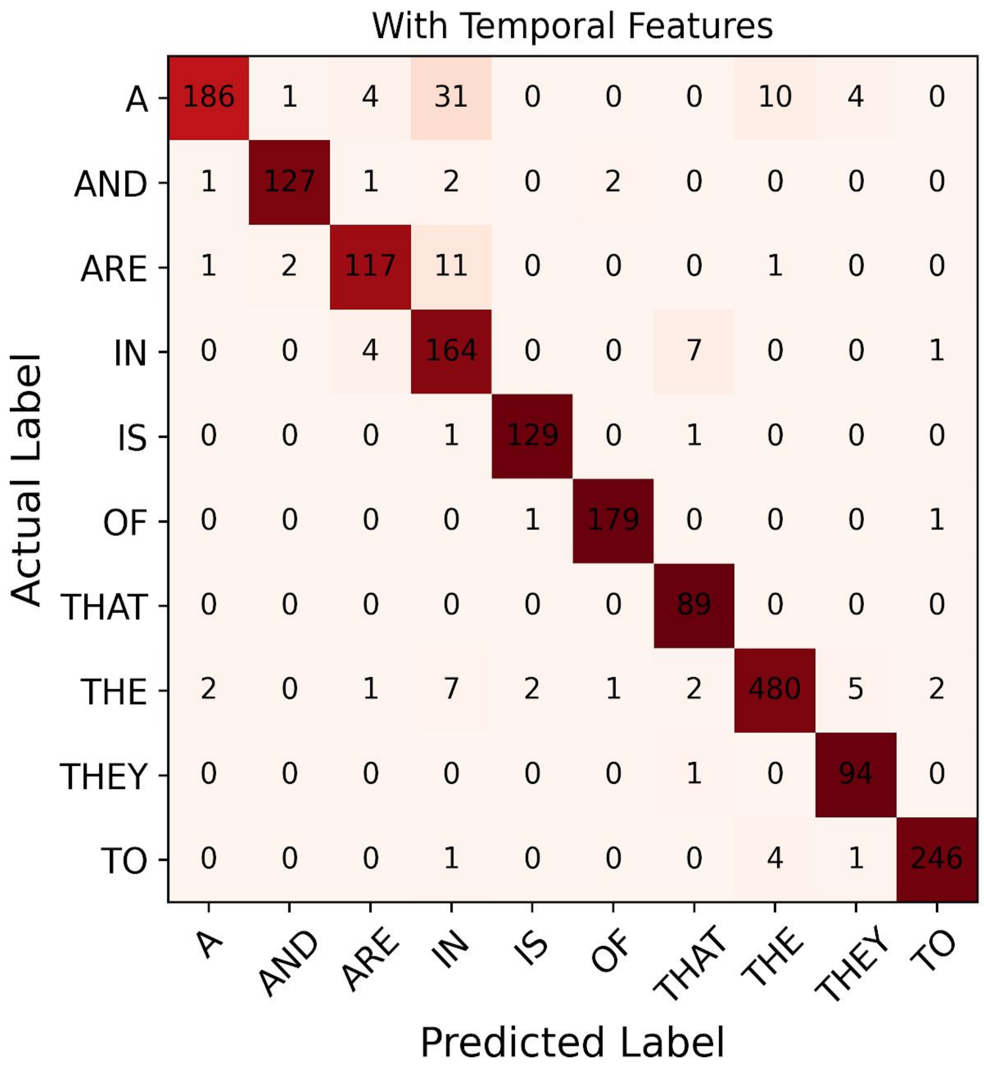
Results - 5
[Interface for Visualizing and Recording EMG]

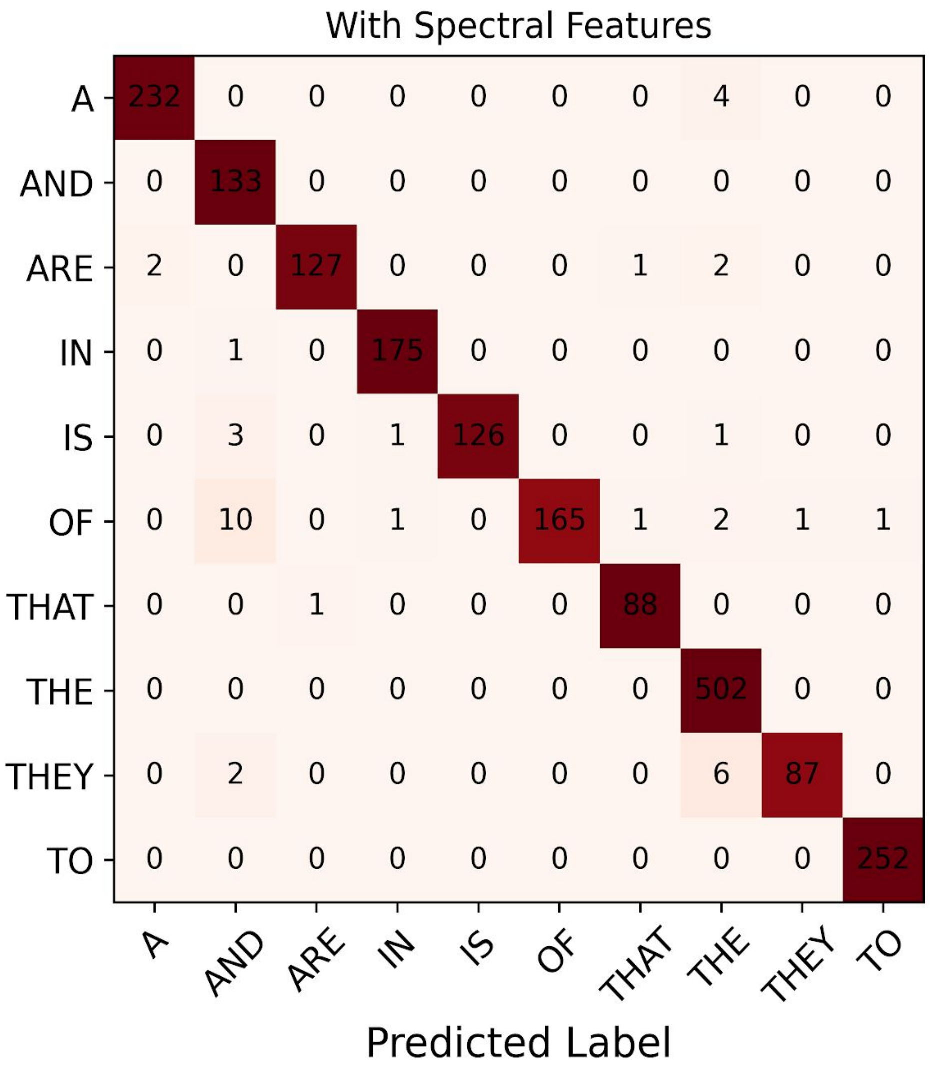


Results - 6
[MLP Model Accuracy]

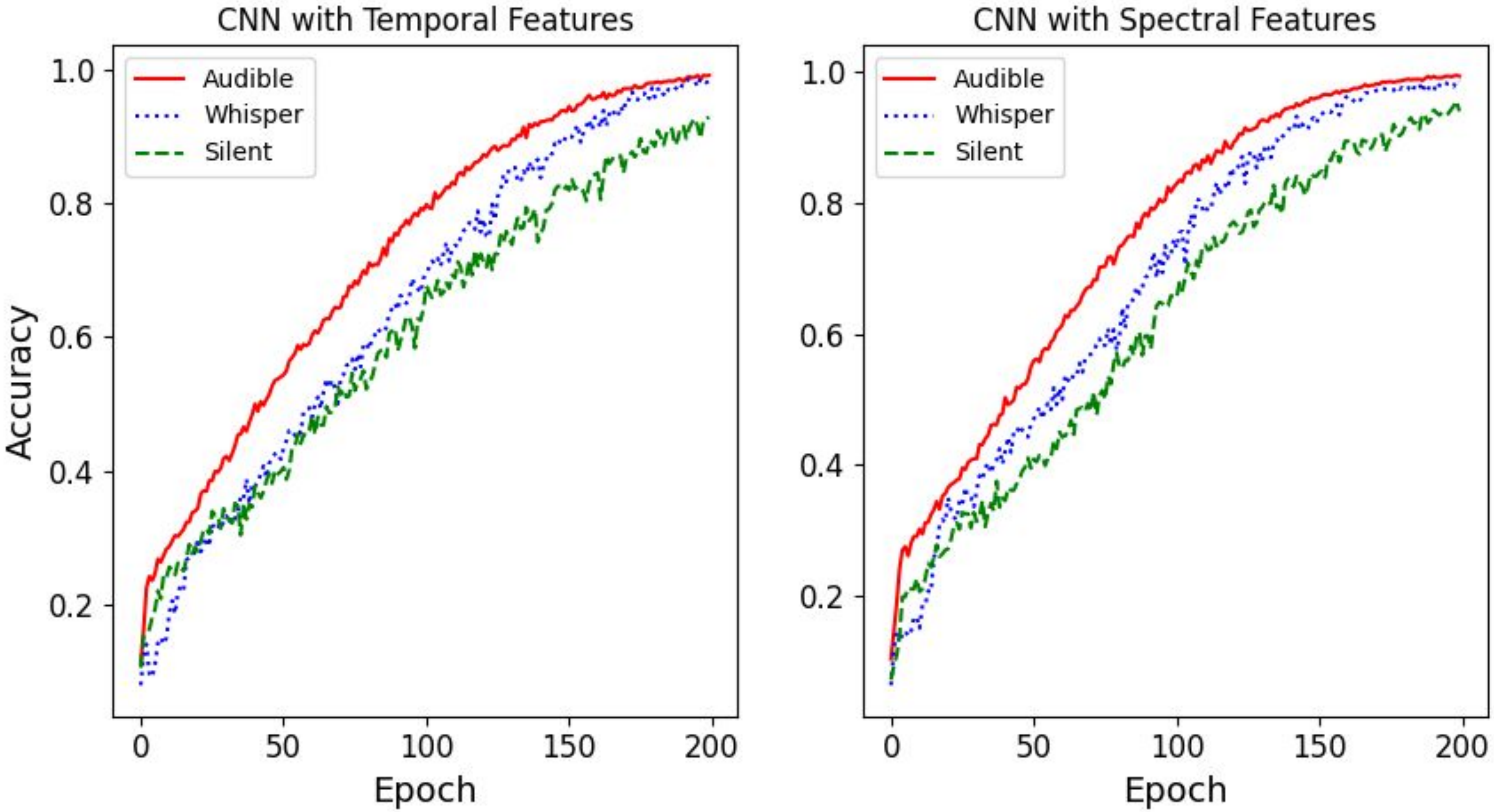


Results - 7
[MLP Model Confusion Matrix]

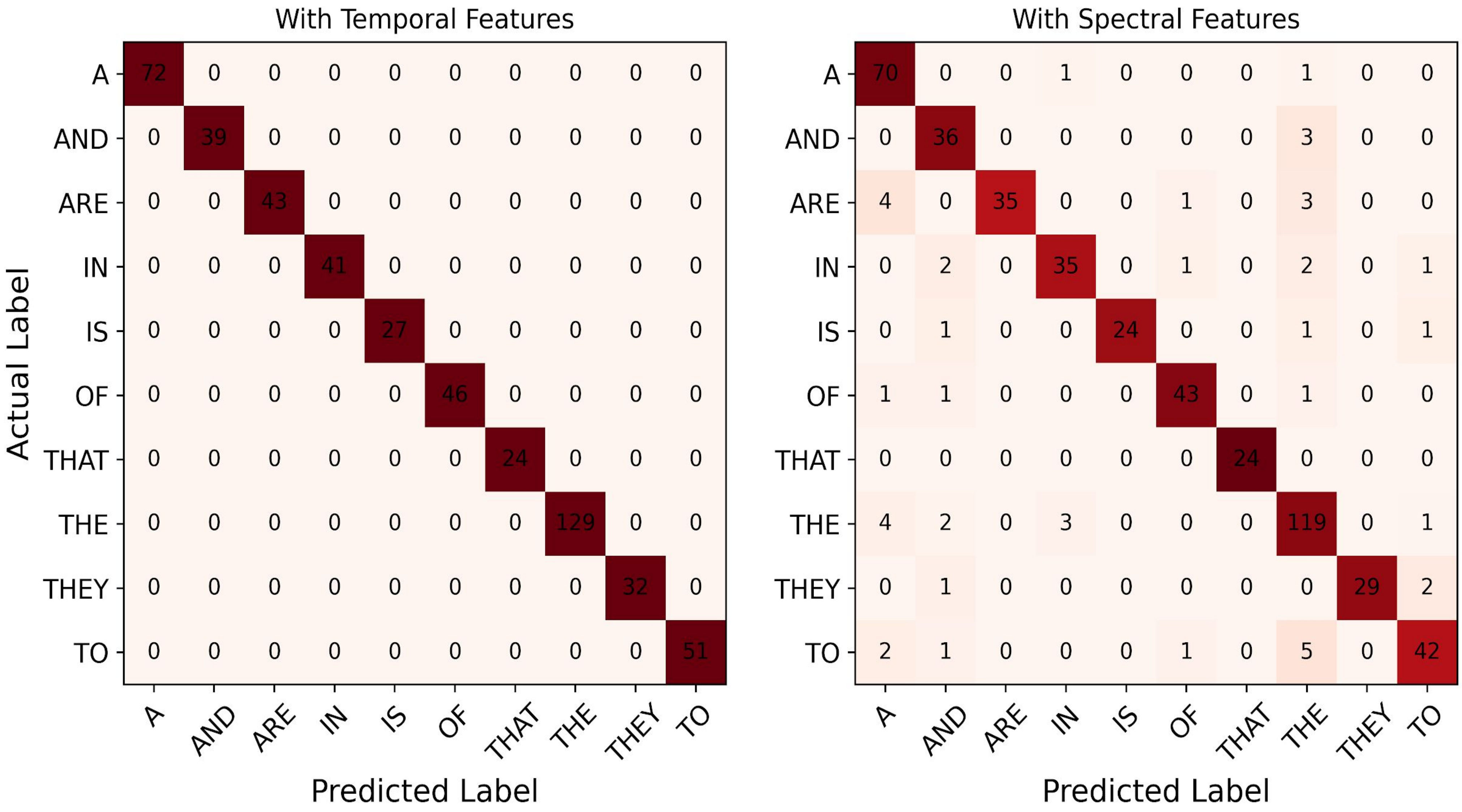




Results - 8
[CNN Model Accuracy]



Results - 9
[CNN Model Confusion Matrix]



Results - 10
[Supervised Model Summary (Audible Mode)]

Models	Feature Type	Train Accuracy	Test Accuracy	Precision	Recall	F1 Score
KNN	Temporal	68.76	33.72	0.53	0.48	0.49
MLP	Temporal	99.01	35.81	0.98	0.97	0.97
CNN	Temporal	98.39	39.62	0.99	0.98	0.98
KNN	Spectral	58.01	47.90	0.55	0.52	0.52
MLP	Spectral	100	40.90	1	1	1
CNN	Spectral	99.74	36.28	1	1	1

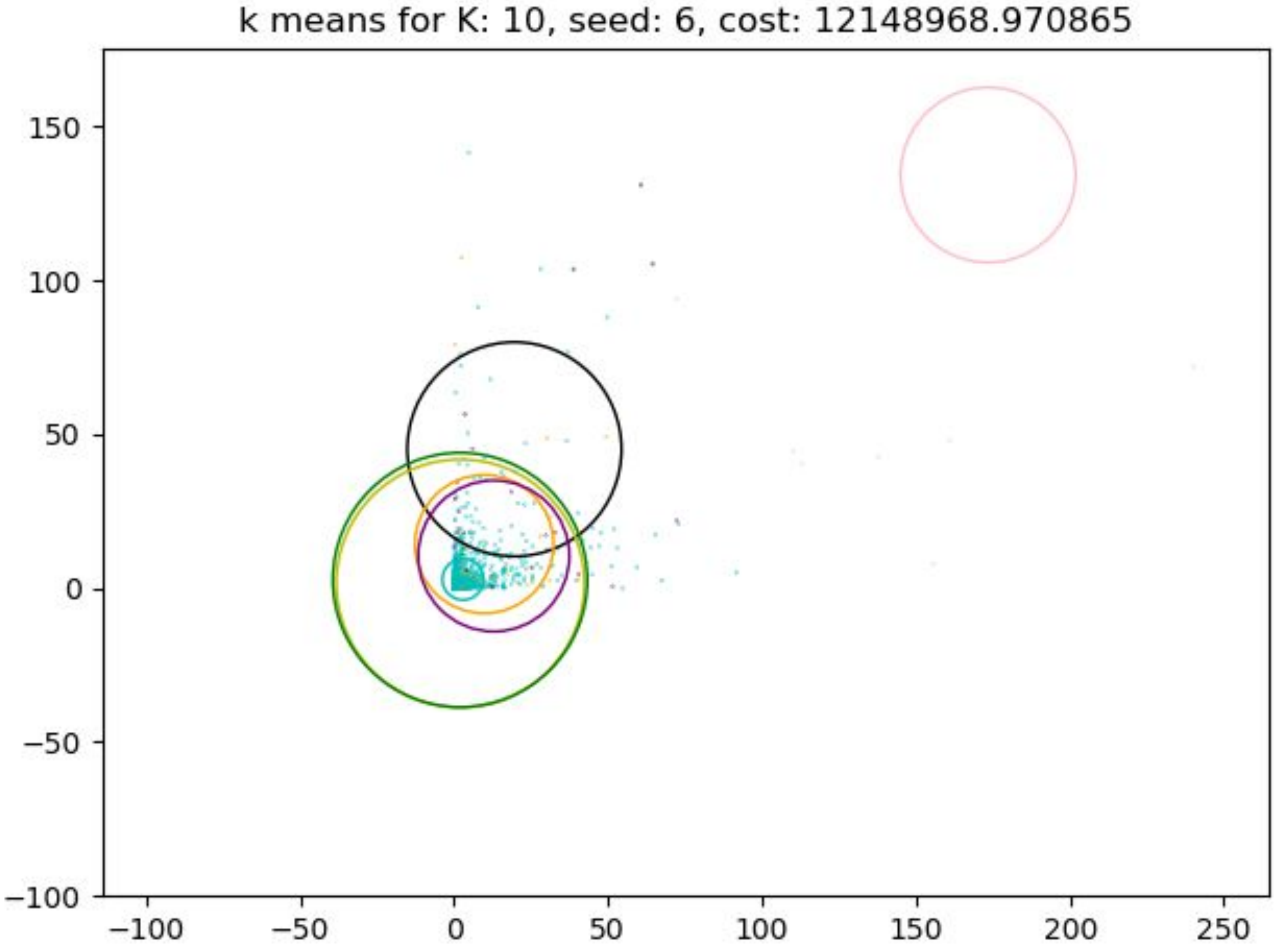
Results - 11
[Supervised Model Summary (Whisper Mode)]

Models	Feature Type	Train Accuracy	Test Accuracy	Precision	Recall	F1 Score
KNN	Temporal	44.14	26.79	0.44	0.39	0.39
MLP	Temporal	97.88	28.07	0.96	0.99	0.99
CNN	Temporal	96.36	19.28	0.91	0.85	0.87
KNN	Spectral	45.25	31.57	0.40	0.37	0.38
MLP	Spectral	100	42.10	1	1	1
CNN	Spectral	99.01	28.07	0.99	0.99	0.99

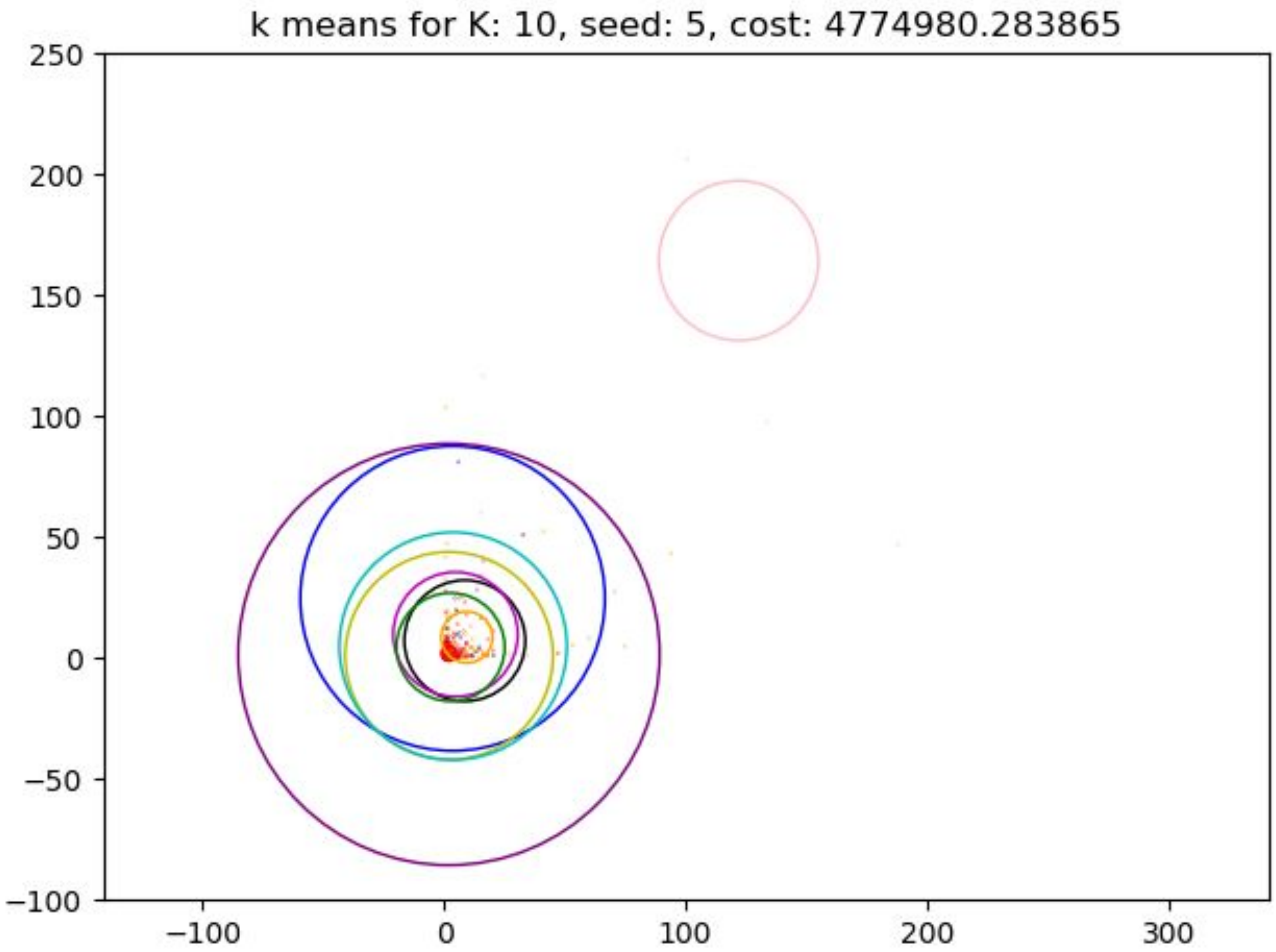
Results - 12
[Supervised Model Summary (Silent Mode)]

Models	Feature Type	Train Accuracy	Test Accuracy	Precision	Recall	F1 Score
KNN	Temporal	41.52	28.11	0.38	0.32	0.31
MLP	Temporal	89.57	21.05	0.94	0.93	0.94
CNN	Temporal	91.07	19.39	0.90	0.89	0.89
KNN	Spectral	43.45	29.82	0.41	0.37	0.37
MLP	Spectral	99.05	24.56	0.99	0.99	0.99
CNN	Spectral	92.46	24.61	0.94	0.92	0.93

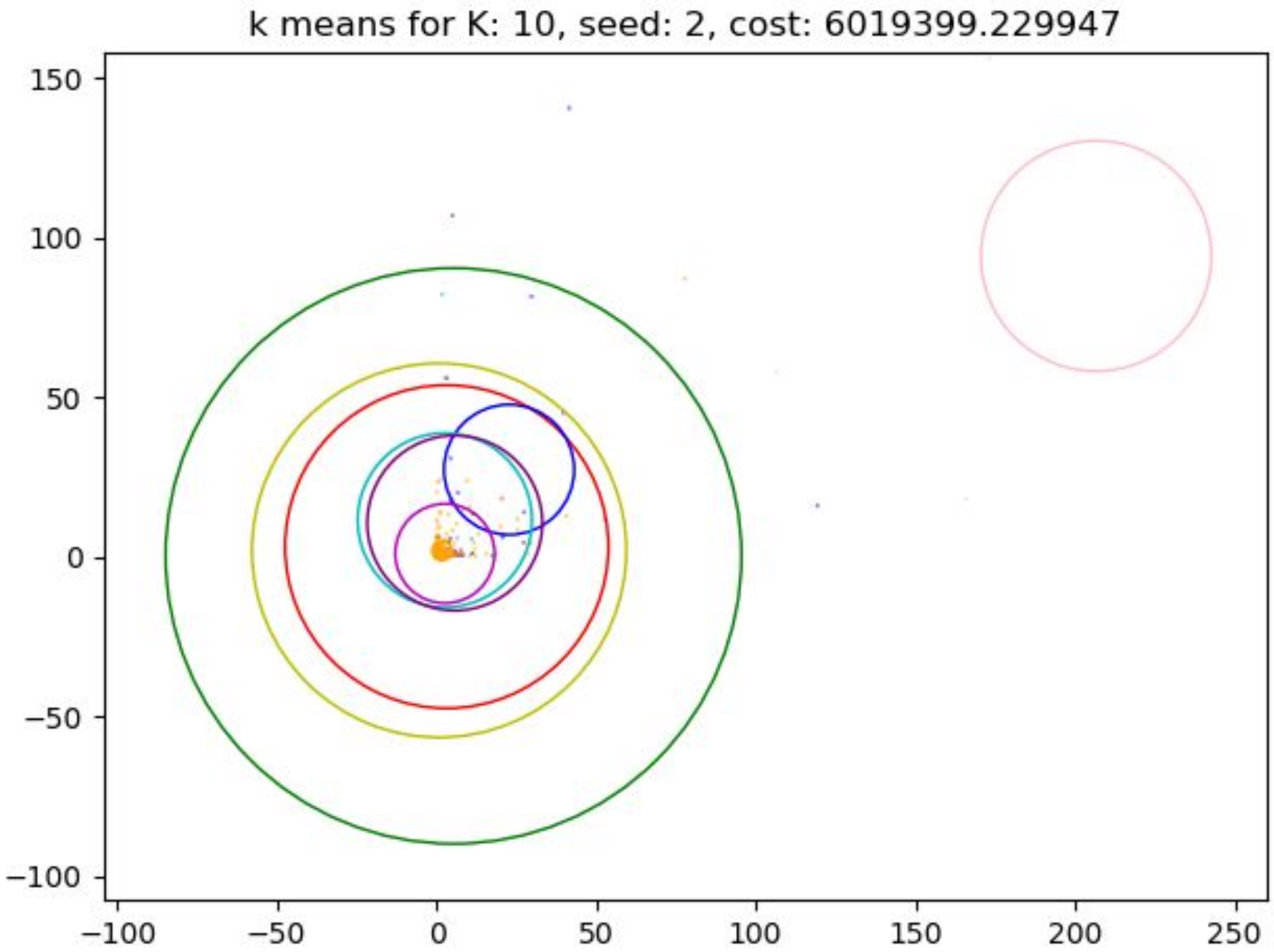
Results - 13
[K-means Plot for Audible mode (K=10)]



Results - 14
[K-means Plot for Whispered mode (K=10)]



Results - 15
[K-means Plot for Silent mode (K=10)]



Analysis and Discussion - 1

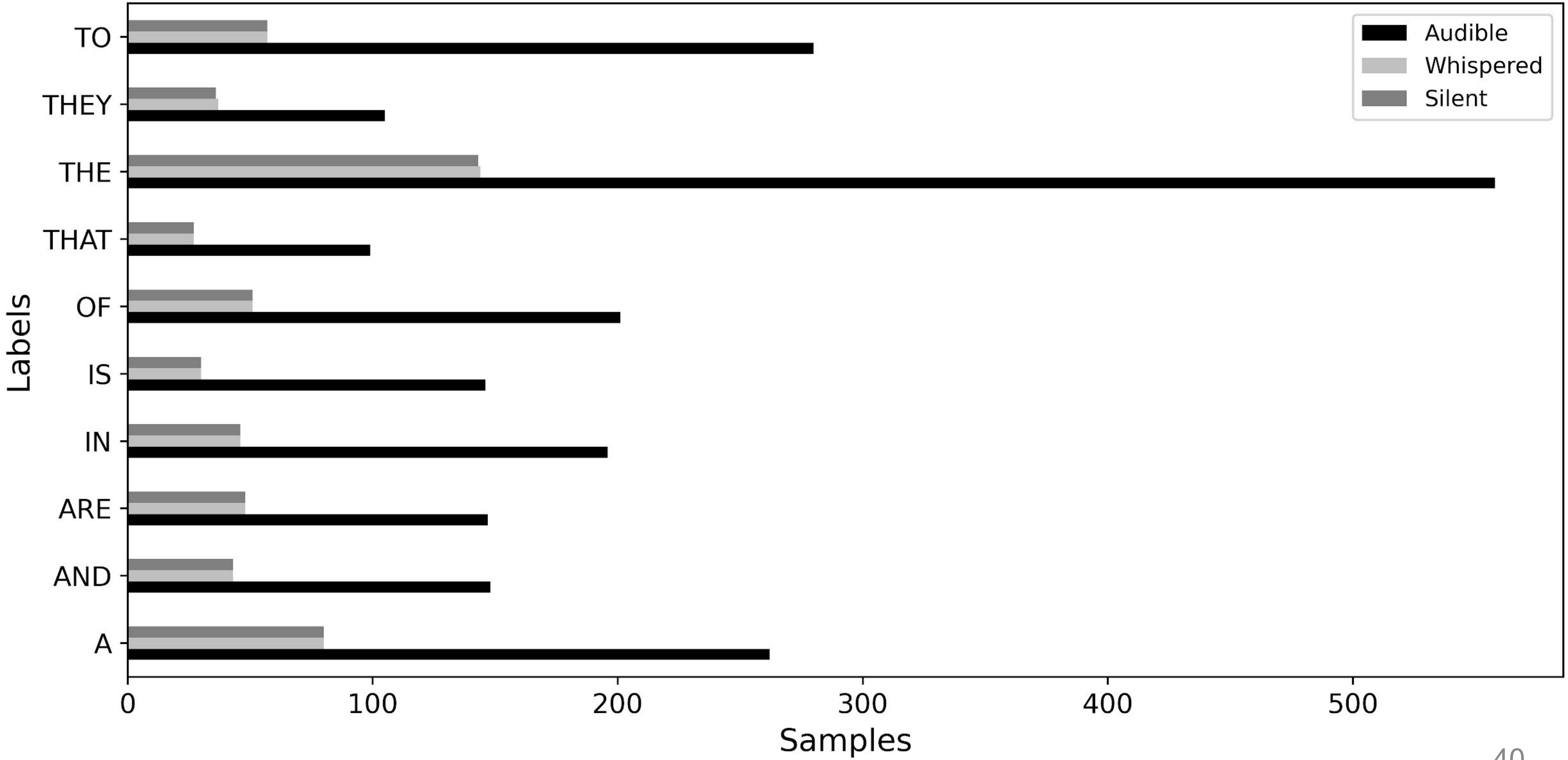
- Data loss during serial communication

- Line noise encountered at 60 Hz and its harmonics

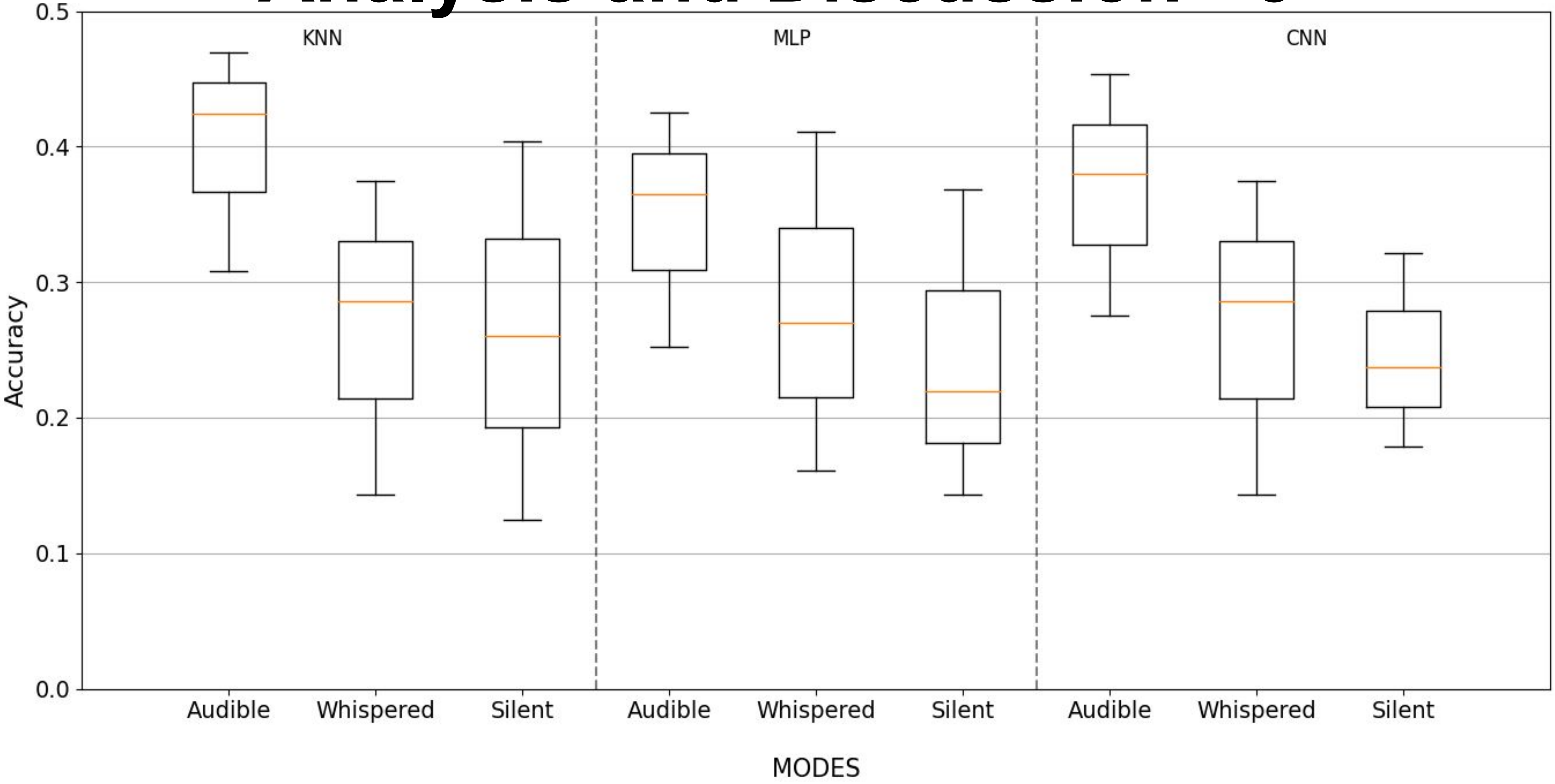
- Exact sampling frequency was not achieved

- Session dependency of data (Electrode Placement)

Analysis and Discussion - 2



Analysis and Discussion - 3



Analysis and Discussion - 4

Hyperparameters	Tested Parameters	Optimum Parameter	Accuracy For Optimum Parameter (%)
Epochs	20, 50, 100, 200	100	18.89
Batch Size	20, 50, 70 , 80, 100, 150	80	18.89
Hidden Nodes	64, 100, 150, 200, 300	64	20.14
Activation Function	ReLU, Sigmoid, Tanh, Linear	ReLU	16.76
Optimizer	SGD, RMSprop, Adagrad, Adadelta, Adam, Adamax, Nadam	Adam	17.82
Learning Rate	0.000001, 0.00001, 0.00003, 0.0001, 0.0003, 0.003, 0.03, 0.3	0.003	24.06
Dropout Rate	0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9	0.7	24.06

Analysis and Discussion - 5
[K-means Analysis]

No. of clusters (K)	Cost Values		
	Audible Mode	Whispered Mode	Silent Mode
1	48403892.367	9941683.388	12414276.628
2	24620486.454	8754925.771	11003163.448
3	20483158.822	7375674.222	10194351.654
4	18985628.517	6906657.715	8761844.147
5	15206828.721	6428972.626	8288547.830
6	14087568.160	6028904.735	7474337.261
7	13447004.529	5535020.849	7026519.250
8	12976077.841	5418646.888	6864662.314
9	12509659.173	4545957.983	6593630.427
10	12148968.970	4774980.284	6509246.797

Accomplished and Remaining Tasks

S.N	Tasks Accomplished	Tasks Remaining
1.	Testing and recording of facial EMG signals from designed circuit	Fine tuning the circuit parameters for optimal data acquisition
2.	Extraction of features from the EMG signals	Fine tuning neural network model parameters and improving the performance
3.	Refining EMG-UKA Trial corpus on the basis of different speech modes	Training and testing of models with our own dataset
4.	Trial dataset preparation of discretely uttered words	
5	Testing of Machine Learning algorithms	

Project Budget

S.N.	Title	Model	Quantity(pcs)	Rate (NRs.)	Price (NRs.)
1	Ag-AgCl Electrode	ECG EMG	150	10/-	1500/-
2	Instrumentation amplifier	AD620	5	114/-	570/-
3	Op-amp	OP37AJ	10	114/-	1140/-
4	Passive electronic components • Resistors • Capacitors • Header pins • Diodes	-	-	-	2000/-
5	Electrolyte	AgCl	250ml	50/-	50/-
6	Arduino	Uno	2	1000/-	2000/-
7	PCB board	Single sided	2	250/-	500/-
8	Shielded Cable	RCA	8(1m)	215/-	1720/-
9	Miscellaneous	-	-	-	3000/-
Total					12480/-

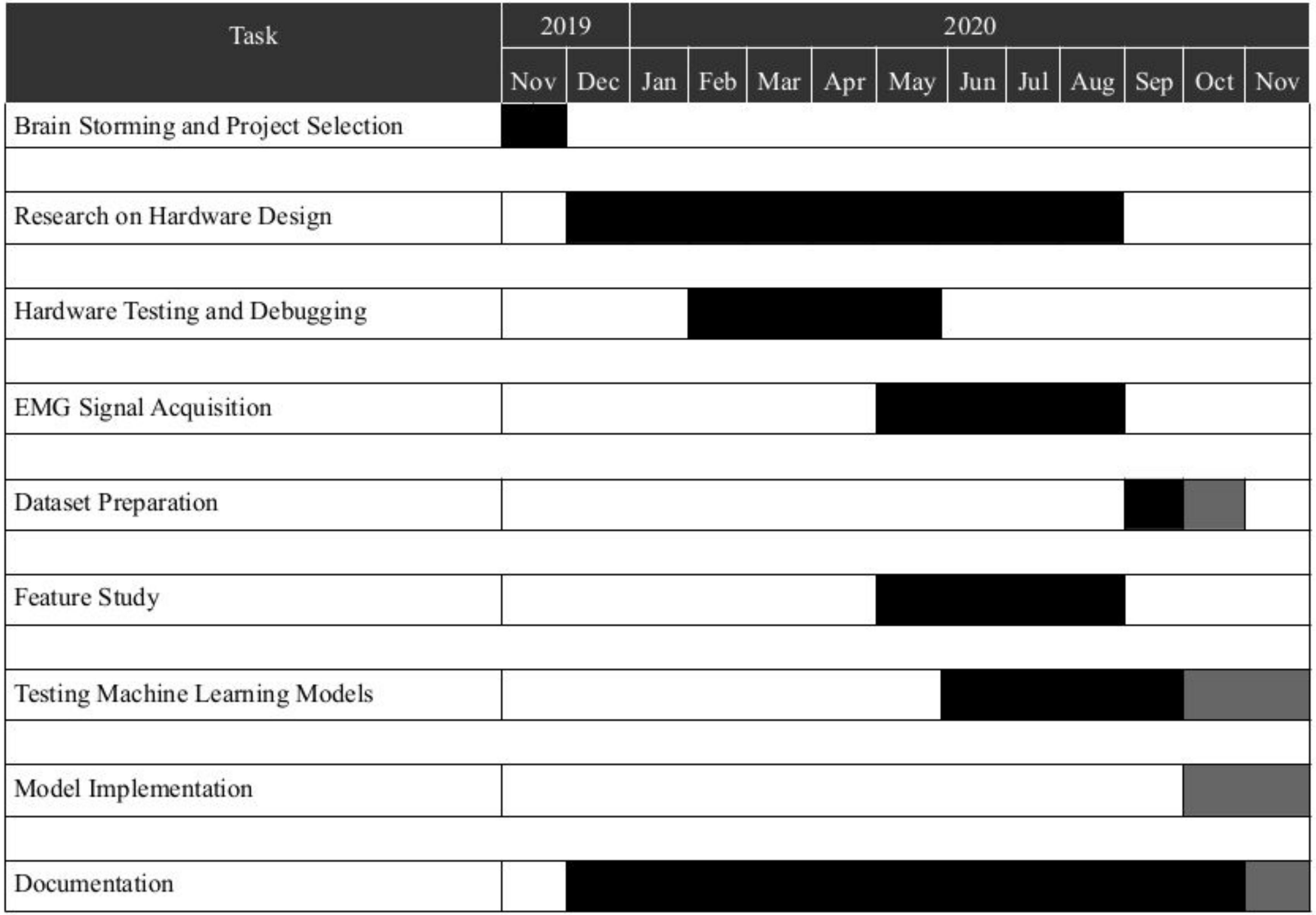
Project Timeline [Gantt Chart]

Project Start Date: 15 November 2019

Completed

Remaining

% Completed: 86.67 %
% Remaining: 13.33 %



References

[1] A. Kapur, "Human-Machine Cognitive Coalescence through an internal duplex interface," MASSACHUSETTS INSTITUTE OF TECHNOLOGY, 2018.

[2] Arnav Kapur,Shreys Kapur, Pattie Maes, "AlterEgo," *Multimodel Interface,* 2018.

[3] Michael Wand and Tanja Schultz, "SESSION-INDEPENDENT EMG-BASED SPEECH RECOGNITION," *Cognitive Systems Lab, Karlsruhe Institute of Technology, Adenauerring 4, 76131 Karlsruhe, Germany,* pp. 1-3.

References

[4] G. Kamen, David A. Gabriel, "Essentials of Electromyography," in Human Kinetics, 2010, p. 57.

[5] Chuck Jorgensen and Kim Binsted, "Web Browser Control Using EMG Based Sub Vocal Speech Recognition," in 38th Hawaii International Conference on System Sciences, IEEE, Hawaii, 2005.

[6] Jacob MIllman and Christos C. Halkias, Integrated Electronics: Analog and Digital Circuits and systems, McGraw-Hill Kogakusha. Ltd., 1972, pp. 501-534

Thank You!!