NEUROTONE.AI

Diversifying detection of parkinson's disease through multilingual non-invasive audio data

LITERATURE REVIEW

Early diagnosis in PD, does it even make a difference?

Voice problems are typically the first to occur, while other disorders, such as prosody, articulation and fluency, appear later and gradually [7]–[9]. The majority of the individuals developing the disease are aged, but the disease sometimes develops in young people. Given that the disease progression is relatively slow, the chance that these individuals could maintain a good quality of life is increased by their improvement in the communication ability. Therefore, the value of an effective treatment for disordered communication is high.

lion people in North America alone [3]. Moreover, an aging population means this number is expected to rise as studies suggest rapidly increasing prevalence rates after the age of 60 [4]. In addition to increased social isolation, the financial burden of PD is significant and is estimated to rise in the future [5]. Currently, there is no cure, although medication is available offering significant alleviation of symptoms, especially at the early stages of the disease [6]. Most *people with Parkinson's* (PWP) disease will

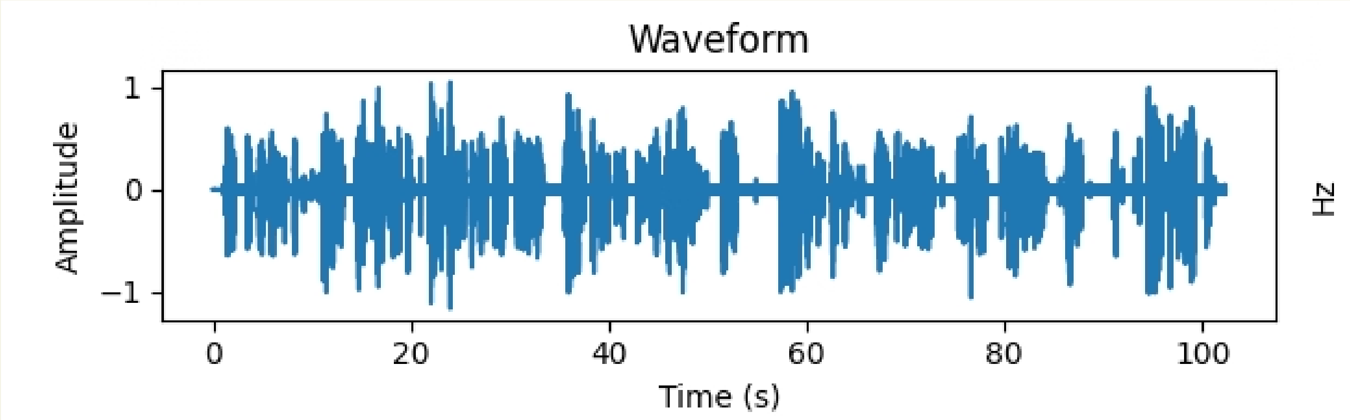
In essence Early diagnosis enables:

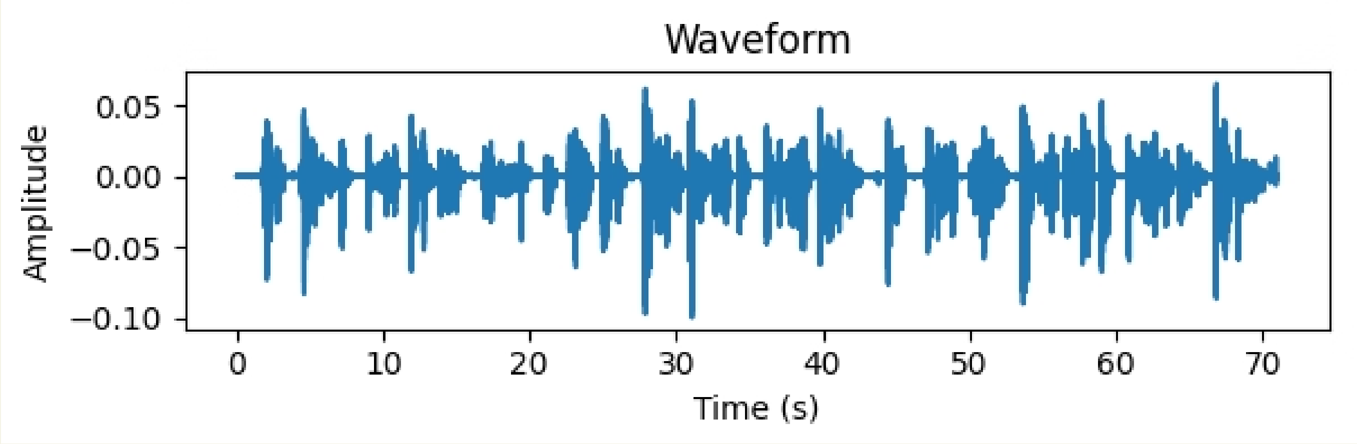
1. Better Quality of Life
2. Lowering Financing burden
3. Prepares us for an aging population
4. Prevents progression of disease

LITERATURE REVIEW

Why Sound and How?

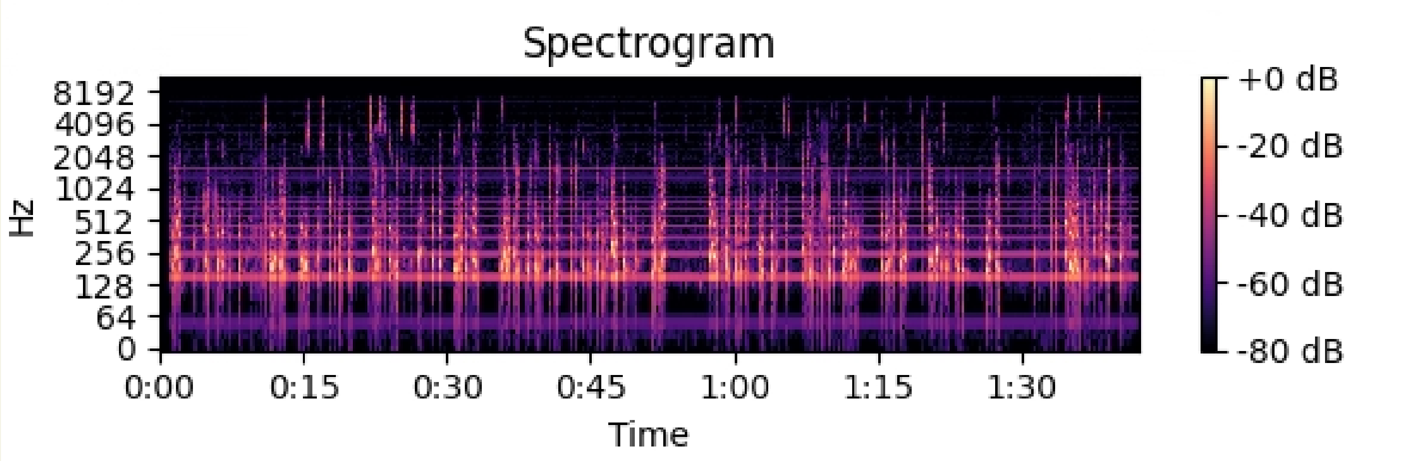
diagnose PD at the preclinical stage, biomarkers are usually searched in BF in untreated PD patients at the clinical stage. Although dozens of studies have attempted to identify biomarkers in BF, most of the results are contradictory. Nevertheless, some changes in the level

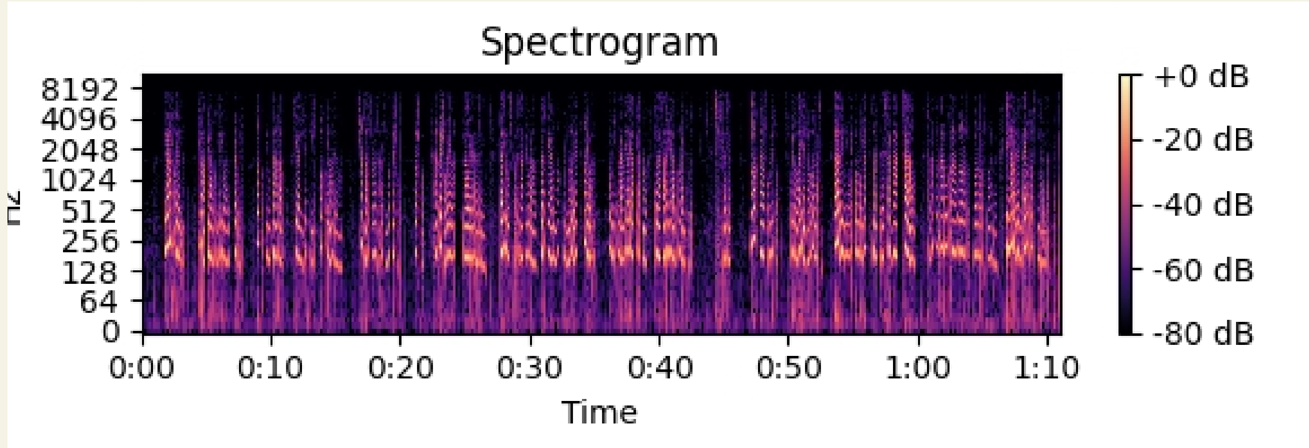




Acoustic data collection is:

1. Non invasive
2. Cheap
3. Prevalent in 90% of the pateints





PROBLEM STATEMENT

AI models currently, diagnose Parkinson but they only do so for monolingual data. hence, creating a lack of diversity in their use case

PRE MIDSEM DEVELOPMENT

OUR DATASET

1. Two Datasets
2. Sustained Phonetics technique
3. Demographics:
   a. 81 italians
   b. 31 English speakers
4. Control and Diagnosed
   a. 23 ENG PD
   b. 28 ITA PD
5. 25 Features
6. Datapoints: 978*

Second Dataset

f. 15 Young Healthy Control (Running Speech data is available)
g. 22 Health Elderly Control (Both Running Speech and Sustained Data is present)
h. 28 people with Parkinson's disease (Both Running Speech and Sustained Data is present)

LIST OF SUBJECTS WITH SEX, AGE, PARKINSON'S STAGE, AND NUMBER OF YEARS SINCE DIAGNOSIS

Subject code	Sex	Age	Stage (H&Y)	Years since diagnosis
S01	M	78	3.0	0
S34	F	79	2.5	¼
S44	M	67	1.5	1
S20	M	70	3.0	1
S24	M	73	2.5	1
S26	F	53	2.0	1½
S08	F	48	2.0	2
S39	M	64	2.0	2
S33	M	68	2.0	3
S32	M	50	1.0	4
S02	M	60	2.0	4
S22	M	60	1.5	4½
S37	M	76	1.0	5
S21	F	81	1.5	5
S04	M	70	2.5	5½
S19	M	73	1.0	7
S35	F	85	4.0	7
S05	F	72	3.0	8
S18	M	61	2.5	11
S16	M	62	2.5	14
S27	M	72	2.5	15
S25	M	74	3.0	23
S06	F	63	2.5	28
S10 (healthy)	F	46	n/a	n/a
S07 (healthy)	F	48	n/a	n/a
S13 (healthy)	M	61	n/a	n/a
S43 (healthy)	M	62	n/a	n/a
S17 (healthy)	F	64	n/a	n/a
S42 (healthy)	F	66	n/a	n/a
S50 (healthy)	F	66	n/a	n/a
S49 (healthy)	M	69	n/a	n/a

FEATURE EXTRACTION

FEATURE EXTRACTION

Calculate fundamental frequency (F0)

1. Average, maximum, and minimum F0
2. Jitter (percent and absolute)
3. Relative Amplitude Perturbation (RAP)
4. Pitch Period Perturbation Quotient (PPQ)

Extract F0 contour and calculate:

1. Spread 1 and Spread 2 (quantile differences)
2. Pitch Period Entropy (PPE)
3. Calculate RPDE and D2 from F0 contour

Calculate amplitude envelope and related features:

1. Shimmer (APQ3, APQ5, MDVP)
2. Jitter (DDP)
3. Amplitude Perturbation Quotient (APQ)
4. Shimmer Dda
5. Noise-to-Harmonic Ratio (NHR) and Harmonic-to-Noise Ratio (HNR)

DATA PRE PROCESSING

Person	Wav file	MDVP:Fo(Hz)	MDVP:Fhi(Hz)	MDVP:Flo(Hz)	MDVP:Jitter(%)	MDVP:Jitter(Abs)	MDVP:RAP	MDVP:PPQ	Shimmer:APQ3	Shimmer:APQ5
Giulia P	GLL63F10022017	200.403	308.791	75.0	14.667	6.302	6.302	8.604	0.001	0.003
Giulia P	GLL63F1002201	238.239	245.087	232.672	1.115	0.474	0.474	0.811	0.005	0.007
Giulia P	JGLL63F1002201	196.541	250.816	75.0	30.619	1.149	1.149	1.785	0.001	0.003
Giulia P	JGLL63F1002201	205.433	240.877	180.454	2.778	1.244	1.244	1.43	0.005	0.013

name	rep	MDVP:Fo(Hz)	MDVP:Fhi(Hz)	MDVP:Flo(Hz)	MDVP:Jitter(%)	MDVP:Jitter(Abs)	MDVP:RAP	MDVP:PPQ	Jitter:DDP	MDVP:Shimmer
phon_R01_S01	1	119.992	157.302	74.997	0.008	0.0	0.004	0.006	0.011	0.044
phon_R01_S01	2	122.4	148.65	113.819	0.01	0.0	0.005	0.007	0.014	0.061
phon_R01_S01	3	116.682	131.111	111.555	0.01	0.0	0.005	0.008	0.016	0.052
phon_R01_S01	4	116.676	137.871	111.366	0.01	0.0	0.005	0.007	0.015	0.055

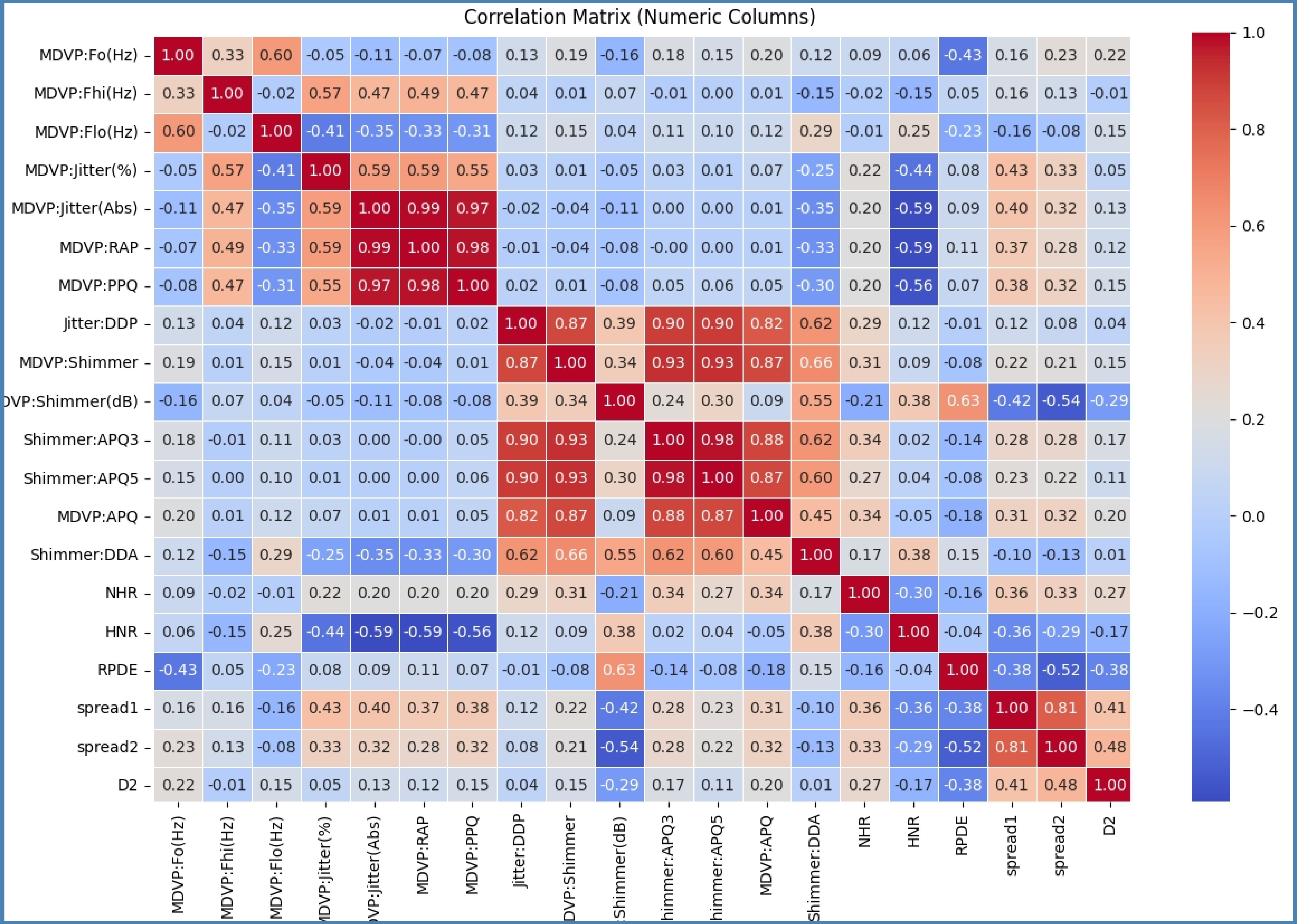
DATA COMBINING

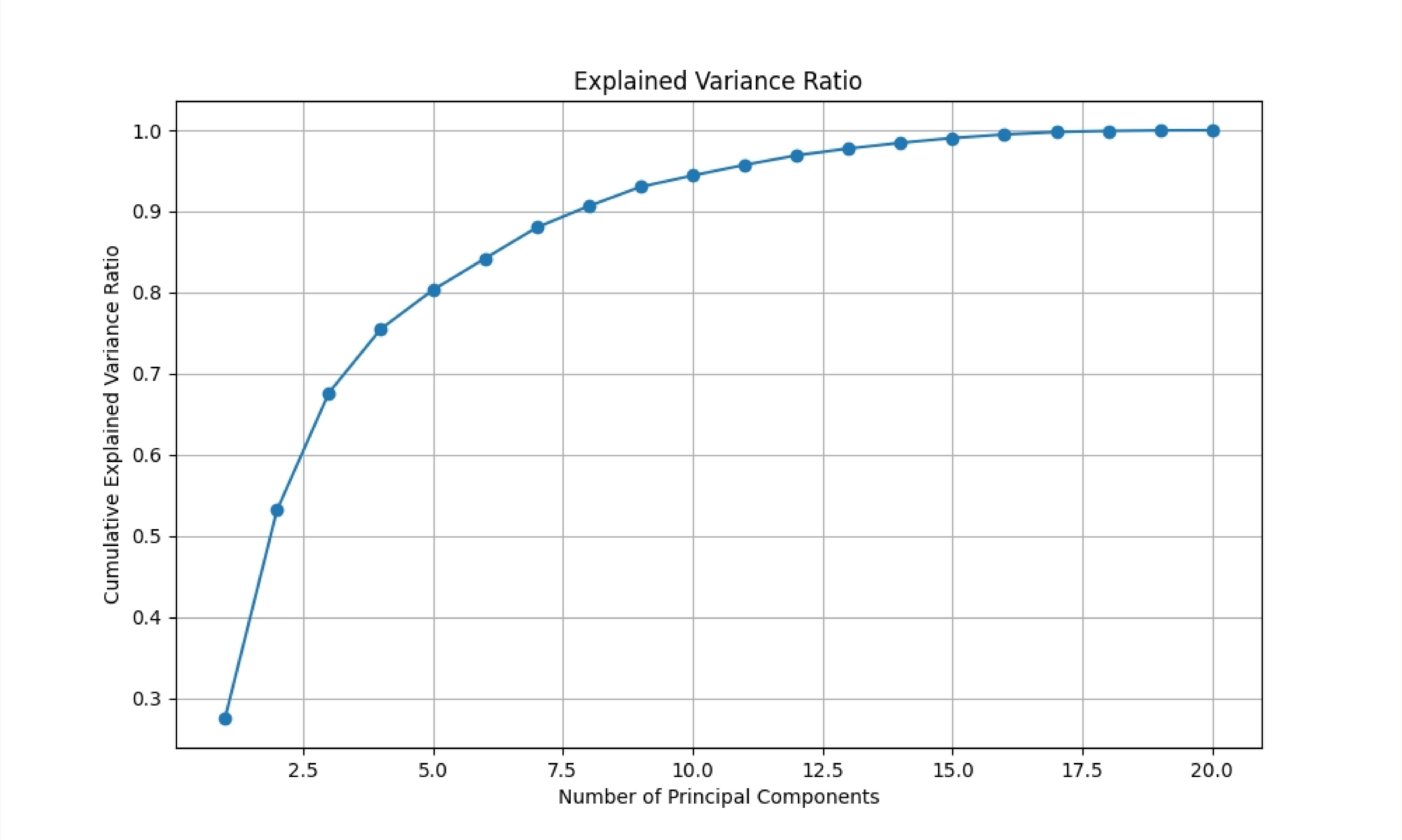
Shimmer:DDA	NHR	HNR	status	RPDE	spread1	spread2	D2	Language
.33258441391706	)6830696756533	).5117451028204	1	.36915542219557	.56987520957057	.58576512936186	.39066128438146	English
.51604827320580	)5933093548079	.43257742014142	1	).4708304847858	.70327699403701	.74133704321517	.47314522027094	English
.44331749903710	)3959639685520	.49622043404047	1	).4044159680433	.63674469842719	.68637091164493	).4088193790738	English
.47547823854153	)4099691249960	.49593595058115	1	.41625503697084	.69562749855223	.73808864546541	.43697717125738	English

.25723494712373	1871497459318E	.75335957189575	0	1	)1089159070027	).0102017330069	)0329700403551	Italian
.69046639666154	3580651284006E	.82113378433232	0	1	)0871572692921	)0788445904606	)0306578557694	Italian
.69001707686022	5610239278084E	.73832116189538	0	1	)0882517835645	)0766417180344	)0285253858471	Italian
0	)0439746132623	)5067742510048	0	1	)5053649318806	)3696840656772	.12171065337609	Italian
.34451734936113	7482841901068E	).7472438382537	0	1	)0935264955046	.00806842931848	)0320306482026	Italian

Try Pitch

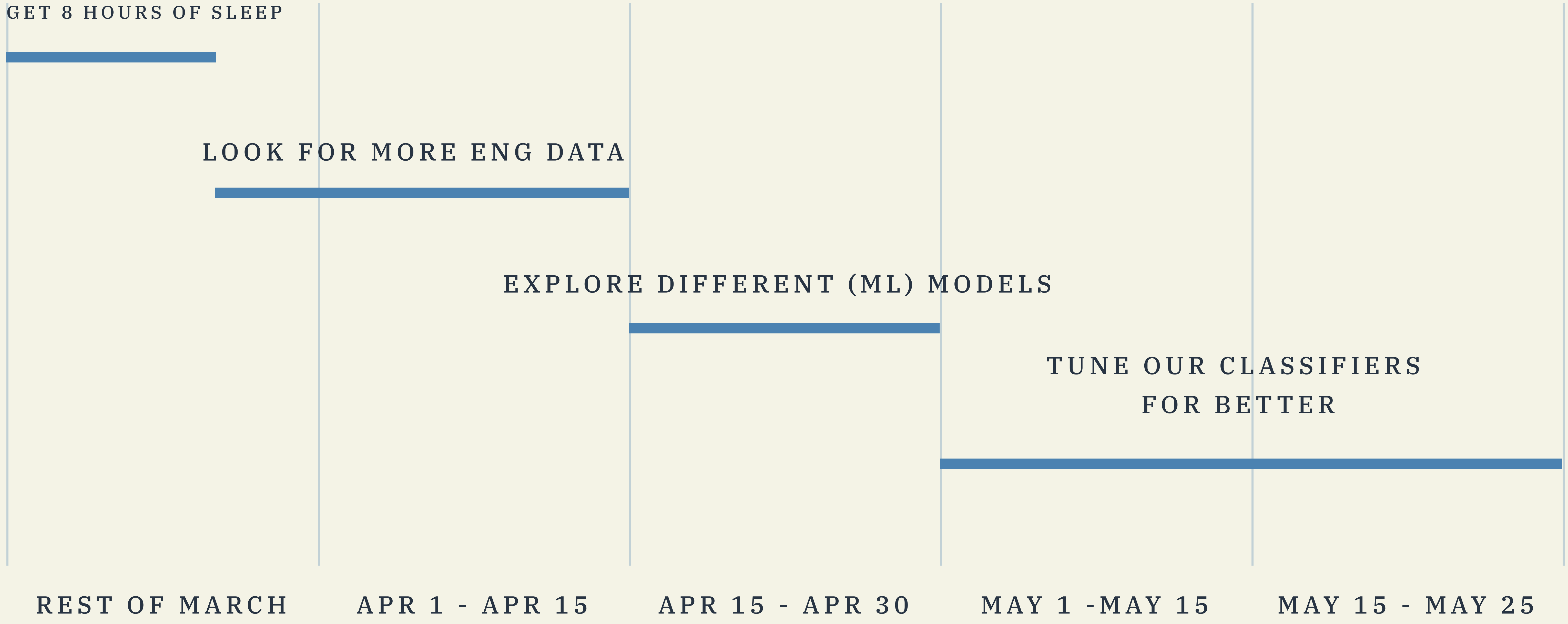
ANALYSIS


Correlation Matrix (Numeric Columns)
MDVP:Fo(Hz) 1.00 0.33 0.60 -0.05 -0.11 -0.07 -0.08 0.13 0.19 -0.16 0.18 0.15 0.20 0.12 0.09 0.06 -0.43 0.16 0.23 0.22
MDVP:Fhi(Hz) 0.33 1.00 -0.02 0.57 0.47 0.49 0.47 0.04 0.01 0.07 -0.01 0.00 0.01 -0.15 -0.02 -0.15 0.05 0.16 0.13 -0.01
MDVP:Flo(Hz) 0.60 -0.02 1.00 -0.41 -0.35 -0.33 -0.31 0.12 0.15 0.04 0.11 0.10 0.12 0.29 -0.01 0.25 -0.23 -0.16 -0.08 0.15
MDVP:Jitter(%) -0.05 0.57 -0.41 1.00 0.59 0.59 0.55 0.03 0.01 -0.05 0.03 0.01 0.07 -0.25 0.22 -0.44 0.08 0.43 0.33 0.05
MDVP:Jitter(Abs) -0.11 0.47 -0.35 0.59 1.00 0.99 0.97 -0.02 -0.04 -0.11 0.00 0.00 0.01 -0.35 0.20 -0.59 0.09 0.40 0.32 0.13
MDVP:RAP -0.07 0.49 -0.33 0.59 0.99 1.00 0.98 -0.01 -0.04 -0.08 -0.00 0.00 0.01 -0.33 0.20 -0.59 0.11 0.37 0.28 0.12
MDVP:PPQ -0.08 0.47 -0.31 0.55 0.97 0.98 1.00 0.02 0.01 -0.08 0.05 0.06 0.05 -0.30 0.20 -0.56 0.07 0.38 0.32 0.15
Jitter:DDP 0.13 0.04 0.12 0.03 -0.02 -0.01 0.02 1.00 0.87 0.39 0.90 0.90 0.82 0.62 0.29 0.12 -0.01 0.12 0.08 0.04
MDVP:Shimmer 0.19 0.01 0.15 0.01 -0.04 -0.04 0.01 0.87 1.00 0.34 0.93 0.93 0.87 0.66 0.31 0.09 -0.08 0.22 0.21 0.15
DVP:Shimmer(dB) -0.16 0.07 0.04 -0.05 -0.11 -0.08 -0.08 0.39 0.34 1.00 0.24 0.30 0.09 0.55 -0.21 0.38 0.63 -0.42 -0.54 -0.29
Shimmer:APQ3 0.18 -0.01 0.11 0.03 0.00 -0.00 0.05 0.90 0.93 0.24 1.00 0.98 0.88 0.62 0.34 0.02 -0.14 0.28 0.28 0.17
Shimmer:APQ5 0.15 0.00 0.10 0.01 0.00 0.00 0.06 0.90 0.93 0.30 0.98 1.00 0.87 0.60 0.27 0.04 -0.08 0.23 0.22 0.11
MDVP:APQ 0.20 0.01 0.12 0.07 0.01 0.01 0.05 0.82 0.87 0.09 0.88 0.87 1.00 0.45 0.34 -0.05 -0.18 0.31 0.32 0.20
Shimmer:DDA 0.12 -0.15 0.29 -0.25 -0.35 -0.33 -0.30 0.62 0.66 0.55 0.62 0.60 0.45 1.00 0.17 0.38 0.15 -0.10 -0.13 0.01
NHR 0.09 -0.02 -0.01 0.22 0.20 0.20 0.20 0.29 0.31 -0.21 0.34 0.27 0.34 0.17 1.00 -0.30 -0.16 0.36 0.33 0.27
HNR 0.06 -0.15 0.25 -0.44 -0.59 -0.59 -0.56 0.12 0.09 0.38 0.02 0.04 -0.05 0.38 -0.30 1.00 -0.04 -0.36 -0.29 -0.17
RPDE -0.43 0.05 -0.23 0.08 0.09 0.11 0.07 -0.01 -0.08 0.63 -0.14 -0.08 -0.18 0.15 -0.16 -0.04 1.00 -0.38 -0.52 -0.38
spread1 0.16 0.16 -0.16 0.43 0.40 0.37 0.38 0.12 0.22 -0.42 0.28 0.23 0.31 -0.10 0.36 -0.36 -0.38 1.00 0.81 0.41
spread2 0.23 0.13 -0.08 0.33 0.32 0.28 0.32 0.08 0.21 -0.54 0.28 0.22 0.32 -0.13 0.33 -0.29 -0.52 0.81 1.00 0.48
D2 0.22 -0.01 0.15 0.05 0.13 0.12 0.15 0.04 0.15 -0.29 0.17 0.11 0.20 0.01 0.27 -0.17 -0.38 0.41 0.48 1.00
MDVP:Fo(Hz) MDVP:Fhi(Hz) MDVP:Flo(Hz) MDVP:Jitter(%) VP:Jitter(Abs) MDVP:RAP MDVP:PPQ Jitter:DDP DVP:Shimmer Shimmer(dB) himmer:APQ3 himmer:APQ5 MDVP:APQ Shimmer:DDA NHR HNR RPDE spread1 spread2 D2
1.0 0.8 0.6 0.4 0.2 0.0 −0.2 −0.4


Explained Variance Ratio
Cumulative Explained Variance Ratio
Number of Principal Components
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0

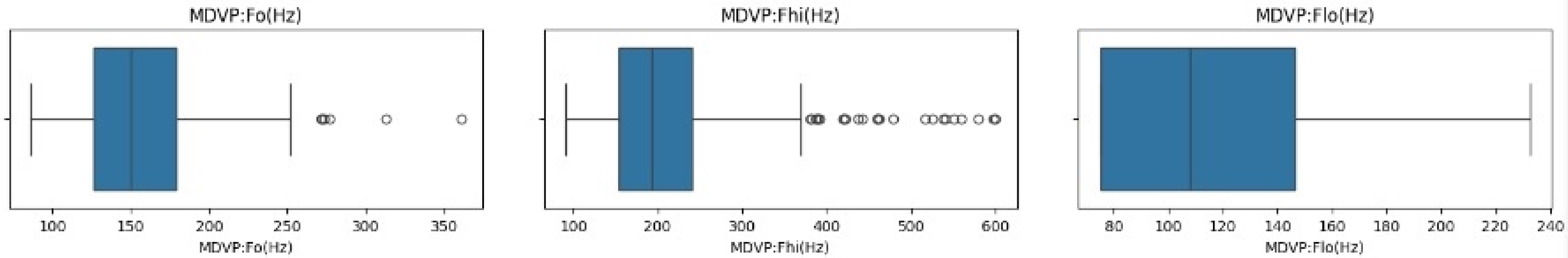
Timeline for the semester

- THROW COLORS ON PEOPLE WALKING BY
- EAT HOMECOOKED FOOD
- FINALLY GET 8 HOURS OF SLEEP

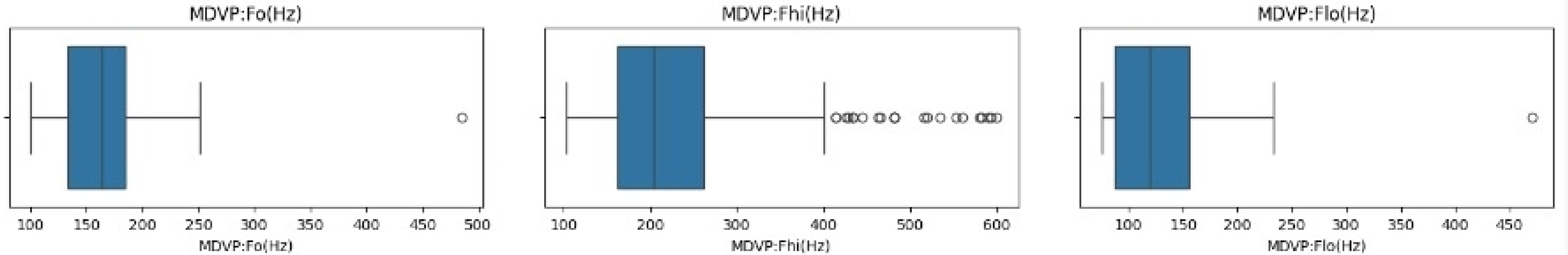


POST MIDSEM DEVELOPMENT

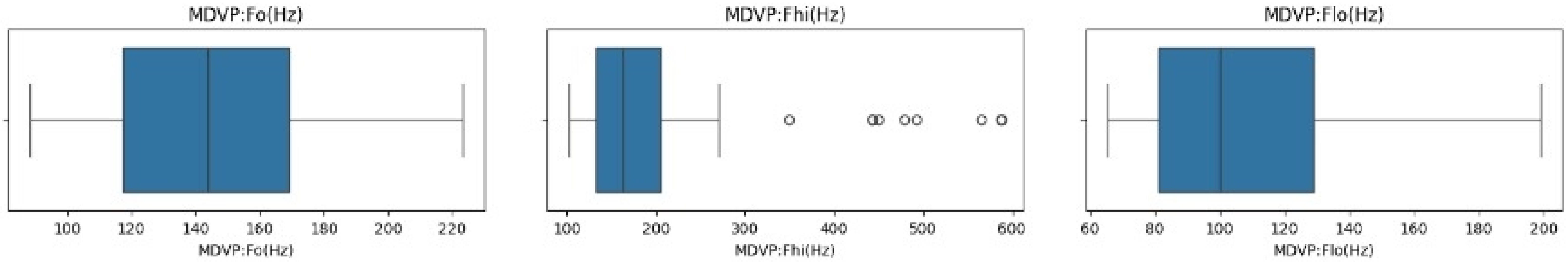
Outliers for Italian Data with parkinson:



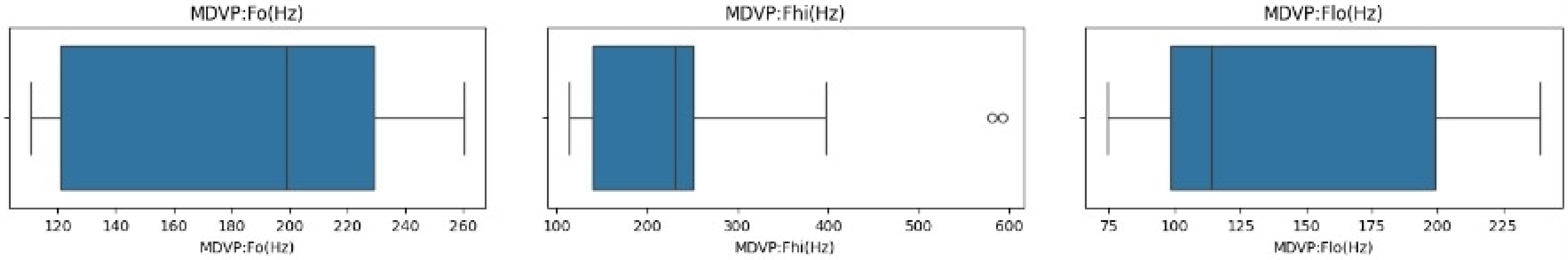
Outliers for Italian Data without parkinson:

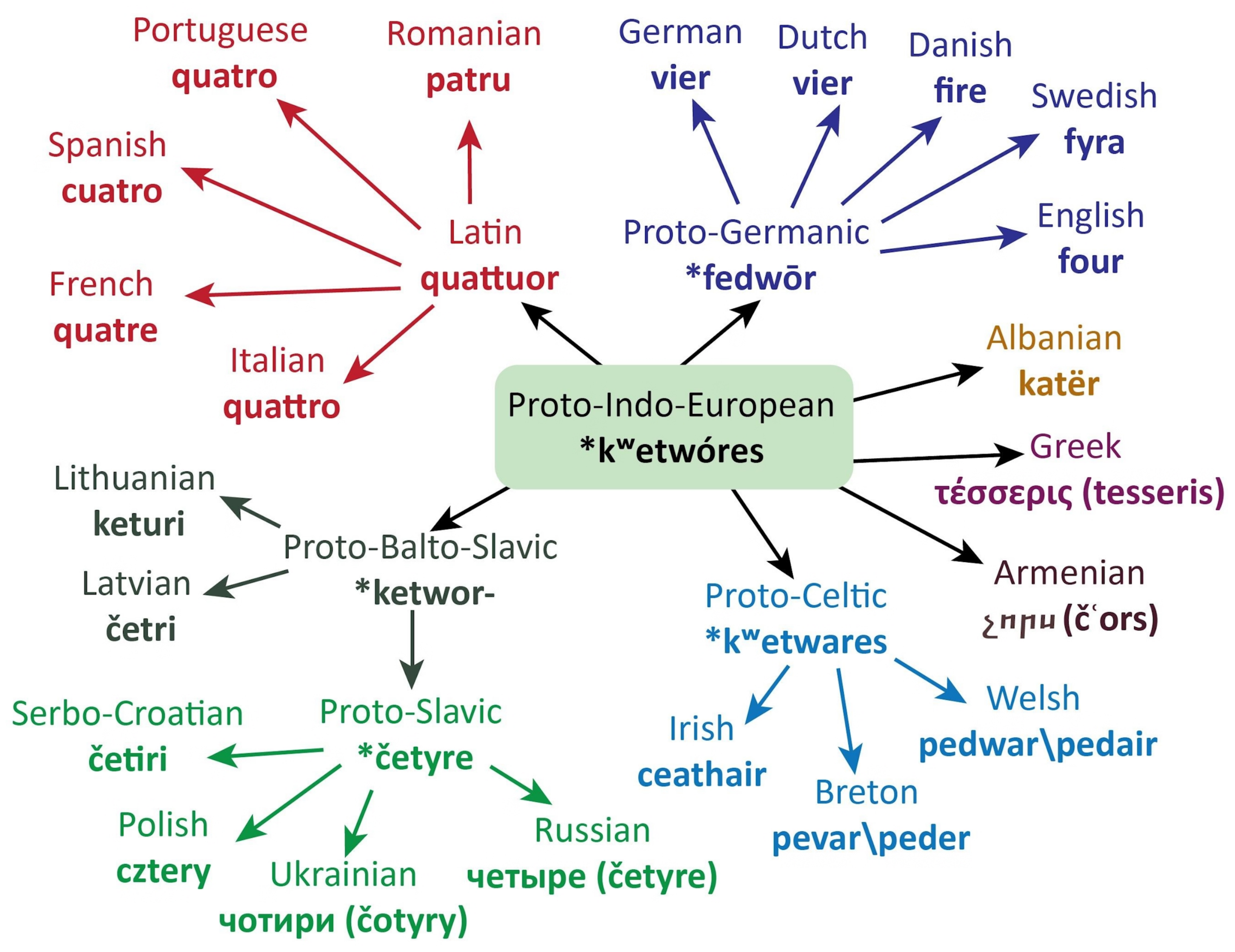


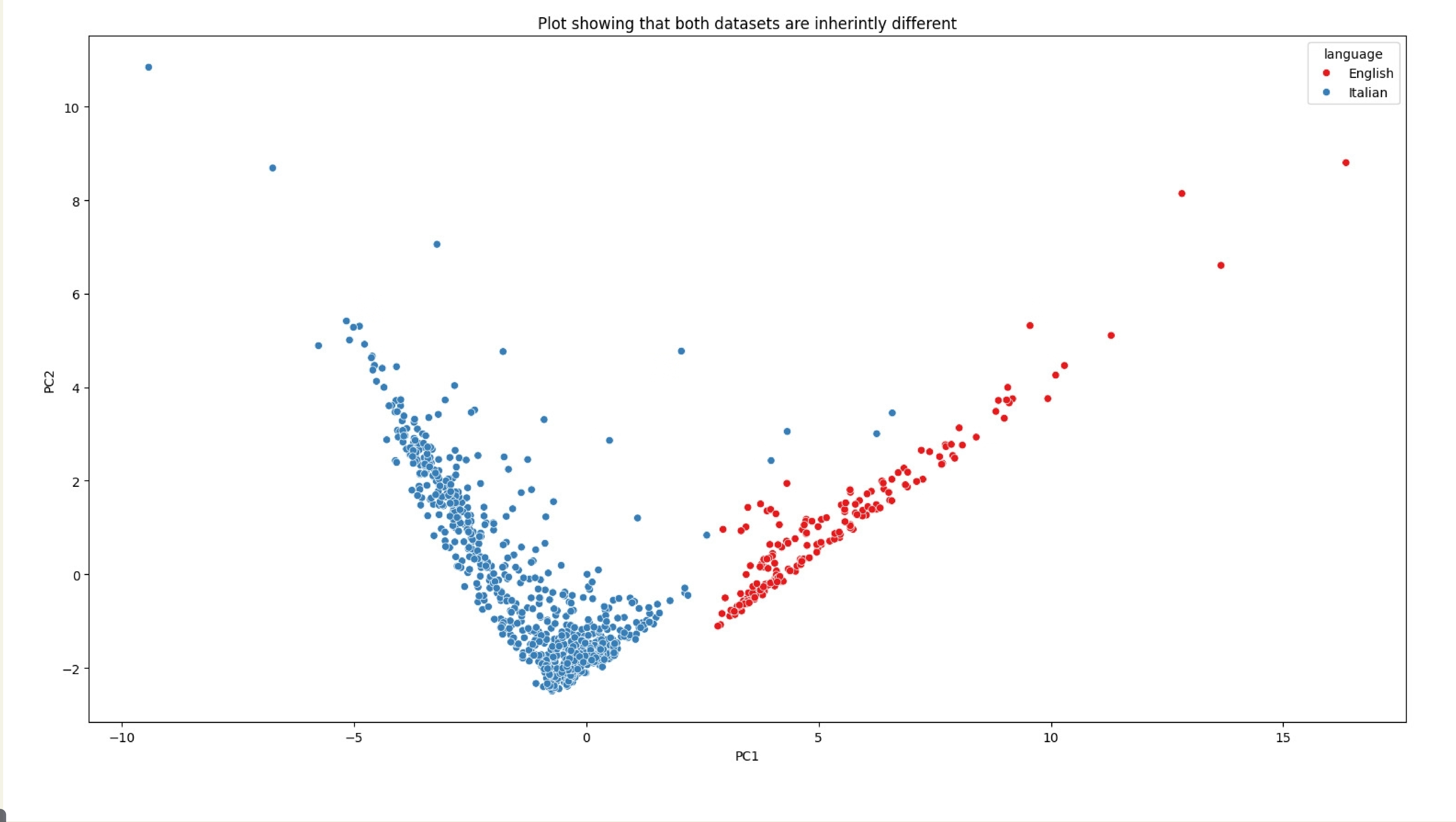
Outliers for English Data with parkinson:



Outliers for English Data without parkinson:




Portuguese
quatro
Romanian
patru
German
vier
Dutch
vier
Danish
fire
Swedish
fyra
Spanish
cuatro
Latin
quattuor
Proto-Germanic
*fedwōr
English
four
French
quatre
Italian
quattro
Albanian
katër
Proto-Indo-European
*kʷetwóres
Greek
τέσσερις (tesseris)
Lithuanian
keturi
Proto-Balto-Slavic
*ketwor-
Latvian
četri
Armenian
չորս (čʿors)
Proto-Celtic
*kʷetwares
Serbo-Croatian
četiri
Proto-Slavic
*četyre
Welsh
pedwar\pedair
Irish
ceathair
Breton
pevar\peder
Polish
cztery
Ukrainian
чотири (čotyry)
Russian
четыре (četyre)


Plot showing that both datasets are inheritntly different
language
English
Italian
PC2
PC1
10
8
6
4
2
0
−2
−10
−5
0
5
10
15

Early Diagnosis of Parkinson's Disease via Machine Learning on Speech Data

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***Abstract*— Using two distinct data sets (from the USA and Germany) of healthy controls and patients with early or mild stages of Parkinson's disease, we show that machine learning tools can be used for the early diagnosis of Parkinson's disease from speech data. This could potentially be applicable before physical symptoms appear. In addition, we show that while the training phase of machine learning process from one country can be reused in the other; different features dominate in each country; presumably because of languages differences. Three results are presented: (i) separate training and testing by each country (close to 85% range); (ii) pooled training and testing (about 80% range) and (iii) cross-country (training in one and testing in the other) (about 75% ranges). We discovered that different feature sets were needed for each country (language).**

***Index Terms*- Parkinson Disease, Early Diagnosis, Classification, Machine Learning, Speech Data, Pattern Matching, SVM.**

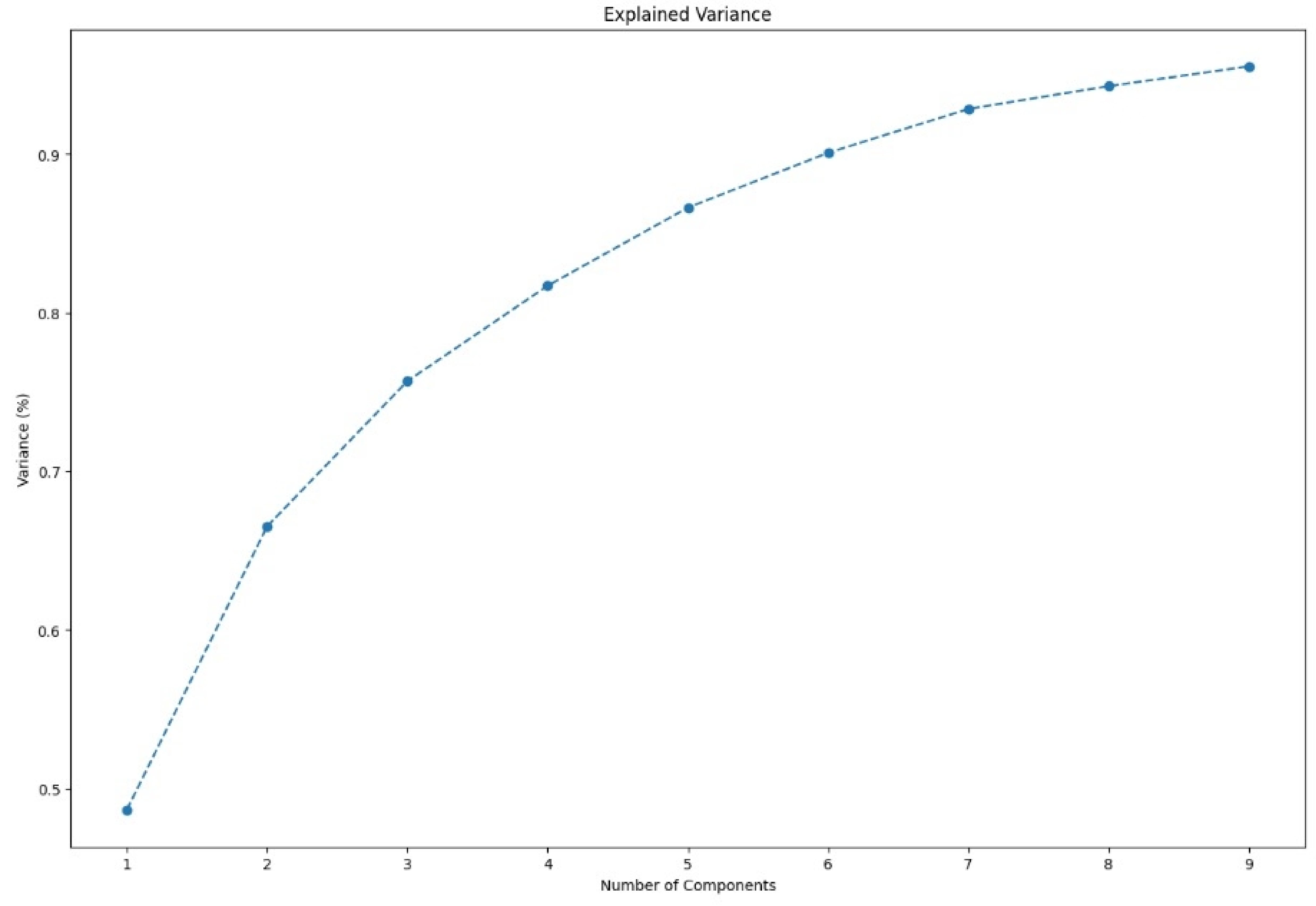
vowels /i/, /u/, and /a/ , and various ratios of these vowel formants. The reason for using such acoustic analysis is that the F1 and F2 of these vowels reflect the movements of the tongue, lips, and jaw [5], [7].

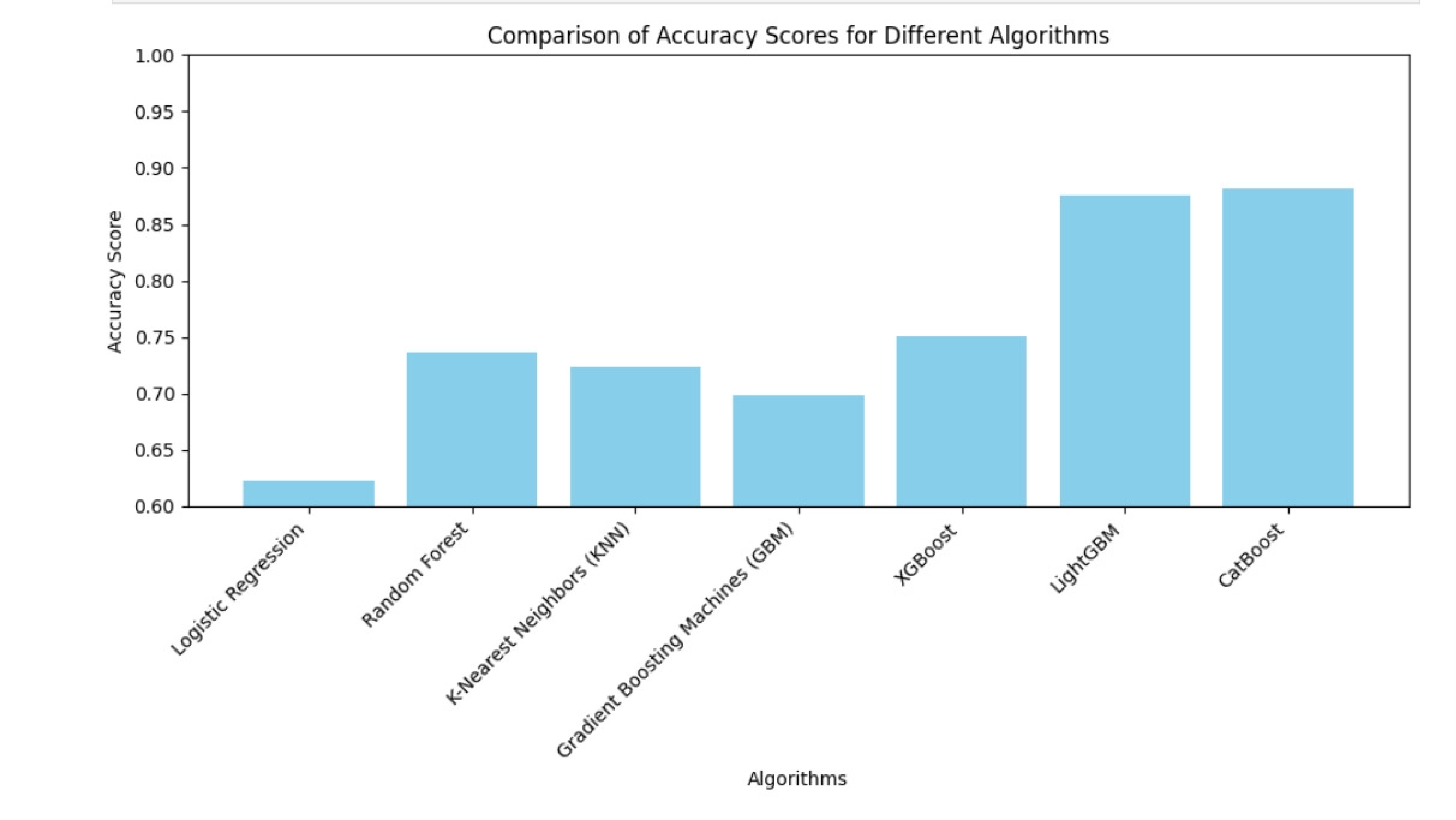
Specifically, F2 increases and F1 decreases in formant frequency as the tongue moves forward (as in the case of the vowel /i/), and, respectively, F2 decreases and F1 increases in frequency when the tongue moves backwards (as in the vowel /u/). Also, F1 formant frequency decreases when the tongue goes up (e.g., for the vowels /i/ and /u/) and increases as the tongue goes down, along with the jaw (e.g., for the vowel /a/). Furthermore, Both F1 and F2 decrease when the lips are rounded (e.g., for the vowel /u/) and increase when the lips are unrounded or detracted (as in the vowels /i/ and /a/).

In PD the movements of the speech articulators (lips, tongue, jaw) are restricted in range (hypokinetic), and as a

Try Pitch

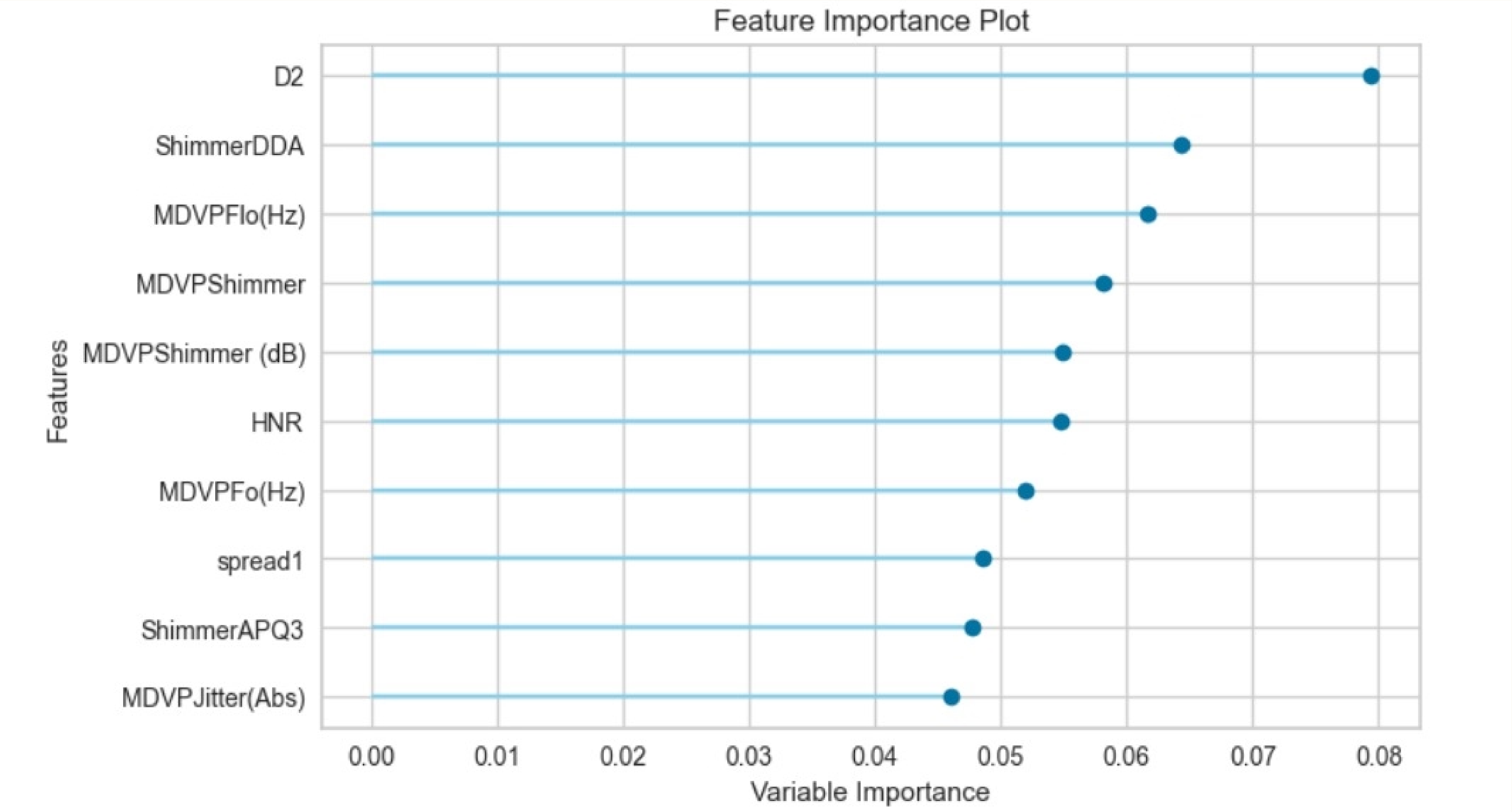
VARIANCE PLOT



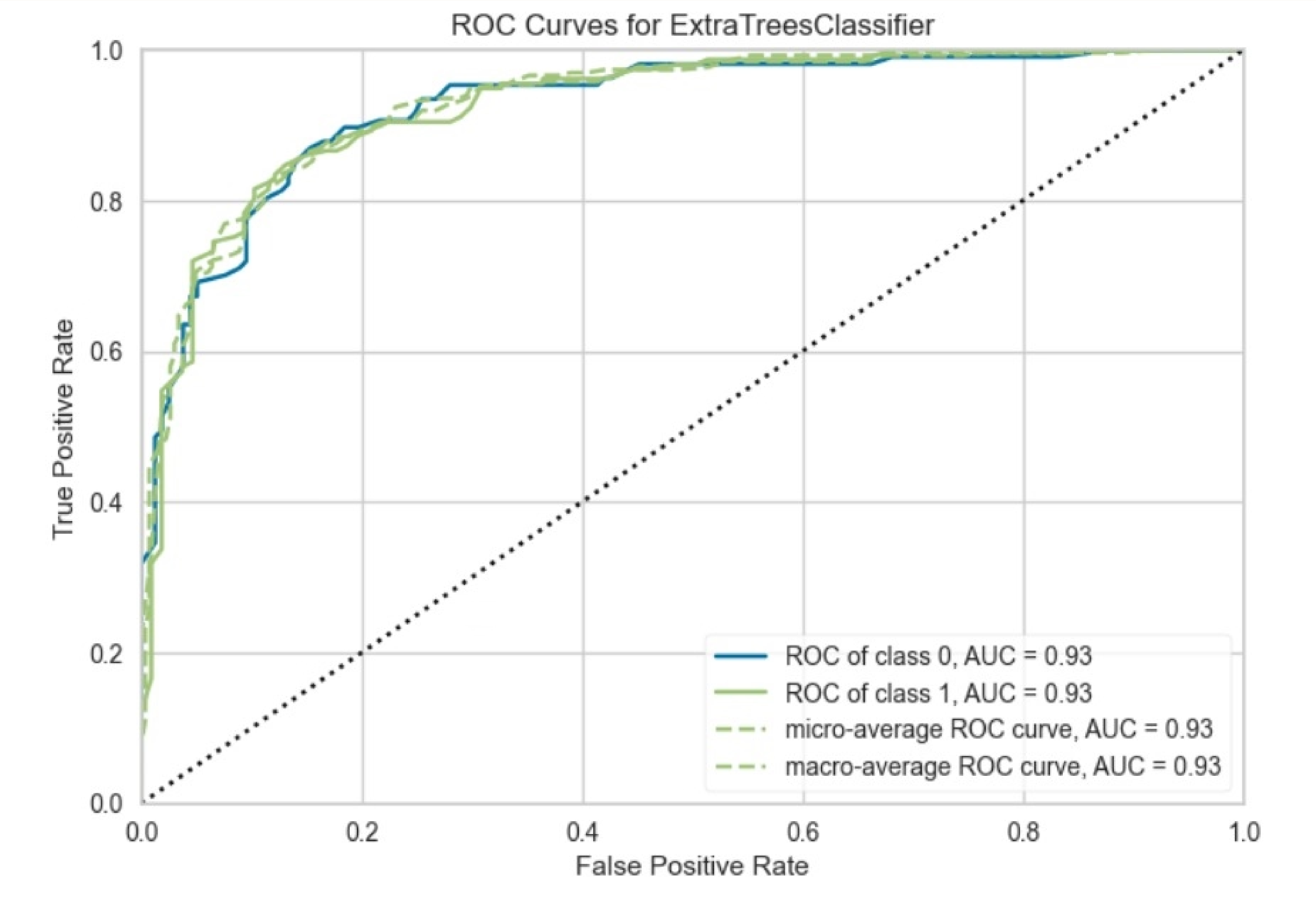

Comparison of Accuracy Scores for Different Algorithms
Accuracy Score
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
Logistic Regression
Random Forest
K-Nearest Neighbors (KNN)
Gradient Boosting Machines (GBM)
XGBoost
LightGBM
CatBoost
Algorithms

	Model	Accuracy	AUC	Recall	Prec.	F1	Kappa	MCC
et	Extra Trees Classifier	0.8539	0.9307	0.8640	0.8908	0.8760	0.6980	0.7012
rf	Random Forest Classifier	0.8327	0.9227	0.8453	0.8744	0.8577	0.6548	0.6595
lightgbm	Light Gradient Boosting Machine	0.8231	0.9119	0.8396	0.8629	0.8501	0.6342	0.6367
xgboost	Extreme Gradient Boosting	0.8229	0.9140	0.8505	0.8545	0.8515	0.6321	0.6340
gbc	Gradient Boosting Classifier	0.8085	0.8971	0.8209	0.8567	0.8365	0.6054	0.6100
ada	Ada Boost Classifier	0.7889	0.8576	0.7962	0.8445	0.8176	0.5672	0.5717
dt	Decision Tree Classifier	0.7694	0.7653	0.7878	0.8241	0.8037	0.5240	0.5282
lda	Linear Discriminant Analysis	0.7316	0.7866	0.7038	0.8268	0.7588	0.4598	0.4697
ridge	Ridge Classifier	0.6813	0.7569	0.6708	0.7691	0.7157	0.3565	0.3623
lr	Logistic Regression	0.6765	0.7543	0.6571	0.7686	0.7077	0.3502	0.3566
knn	K Neighbors Classifier	0.6608	0.7321	0.6870	0.7274	0.7042	0.3063	0.3093
svm	SVM - Linear Kernel	0.5353	0.6266	0.4446	0.6354	0.5003	0.1134	0.1106
nb	Naive Bayes	0.5276	0.6799	0.2637	0.8354	0.3960	0.1574	0.2307
qda	Quadratic Discriminant Analysis	0.4026	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
dummy	Dummy Classifier	0.4026	0.5000	0.0000	0.0000	0.0000	0.0000	0.0000

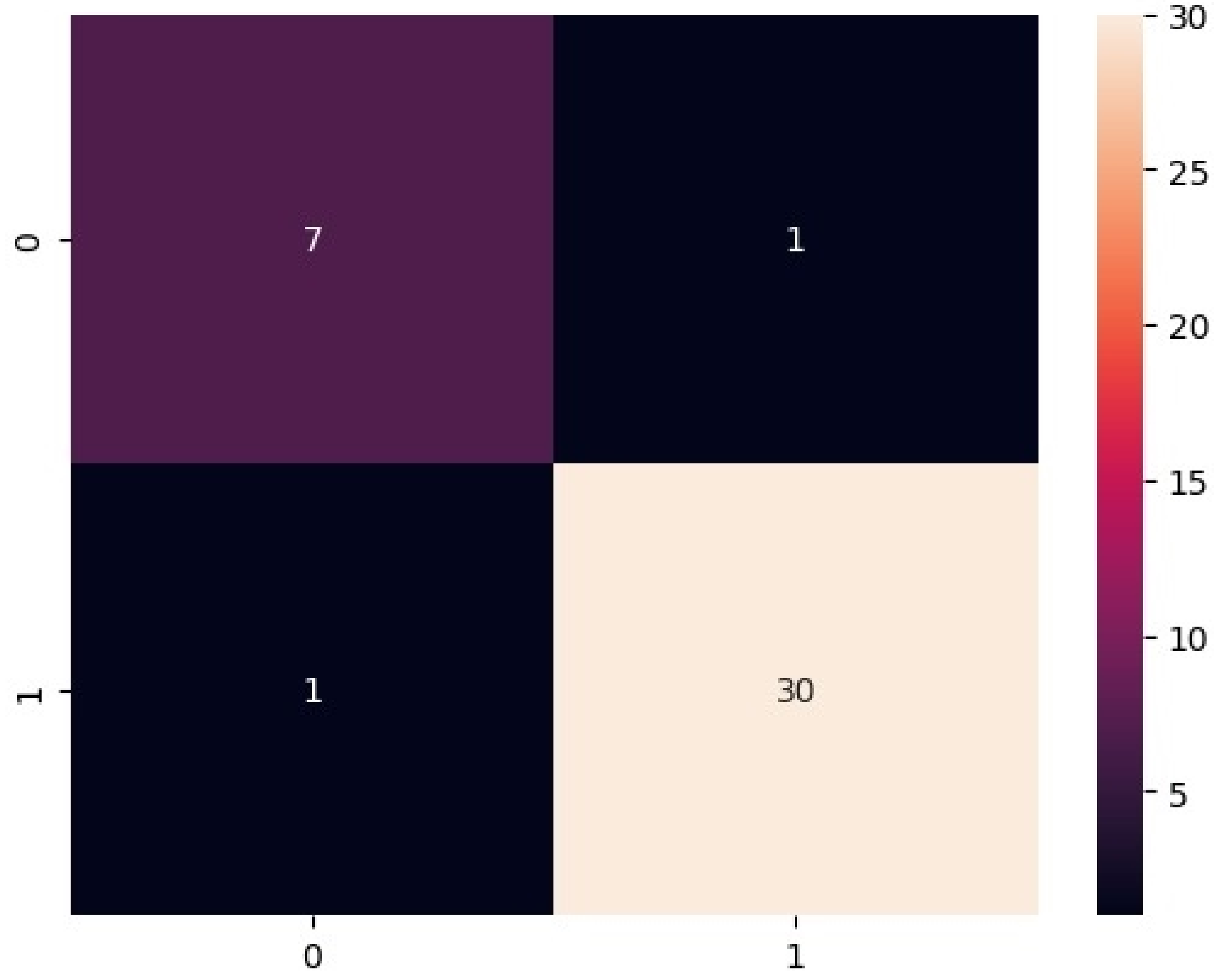
EXTRA TREES


Feature Importance Plot
D2
ShimmerDDA
MDVPFlo(Hz)
MDVPShimmer
MDVPShimmer (dB)
HNR
MDVPFo(Hz)
spread1
ShimmerAPQ3
MDVPJitter(Abs)
Features
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Variable Importance

EXTRA TREES

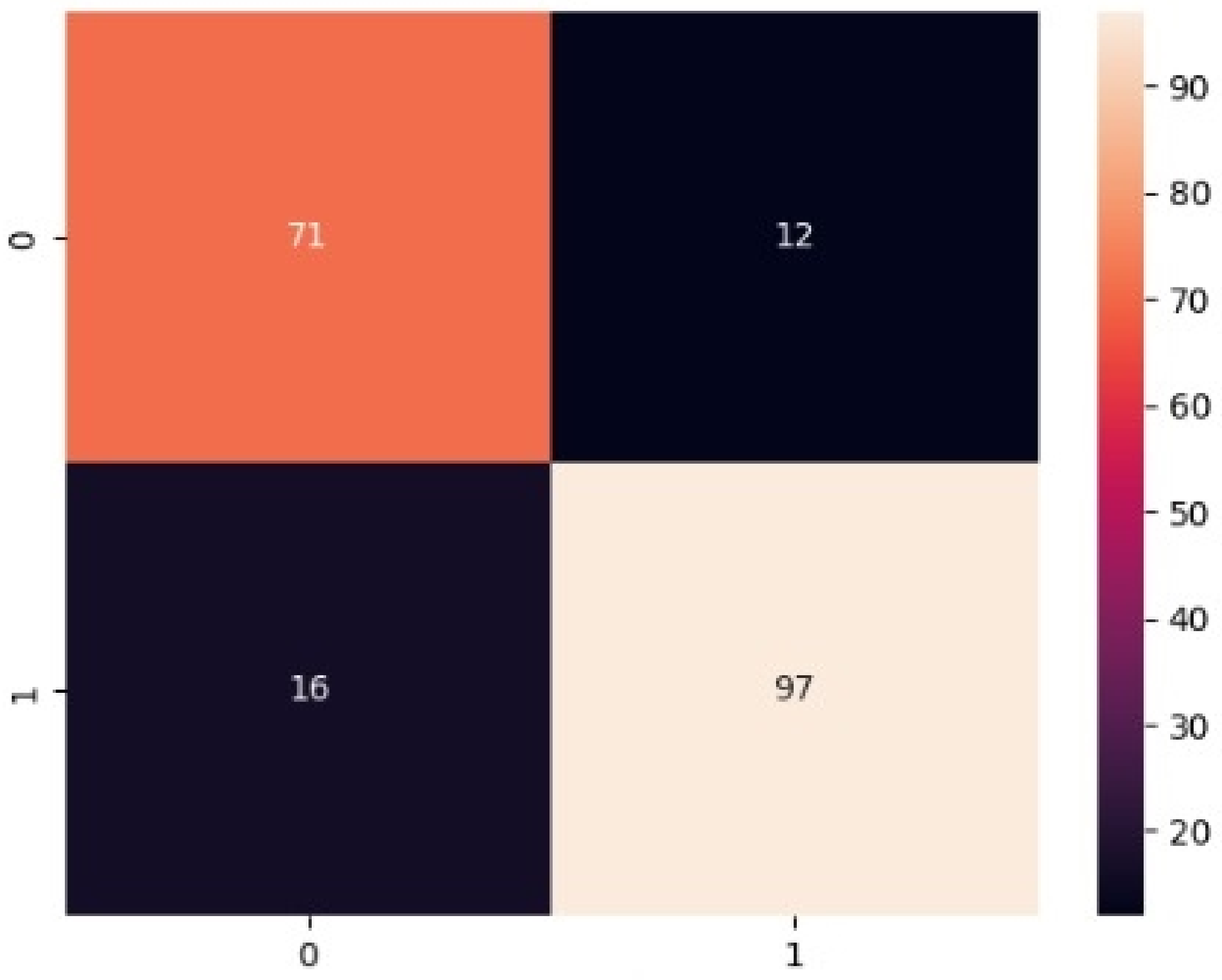

ROC Curves for ExtraTreesClassifier
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC of class 0, AUC = 0.93
ROC of class 1, AUC = 0.93
micro-average ROC curve, AUC = 0.93
macro-average ROC curve, AUC = 0.93

Extra Trees Evaluation for English data:



	precision	recall	f1-score	support
0.0	0.88	0.88	0.88	8
1.0	0.97	0.97	0.97	31
accuracy			0.95	39
macro avg	0.92	0.92	0.92	39
weighted avg	0.95	0.95	0.95	39

Extra Trees Evaluation for Merged data:

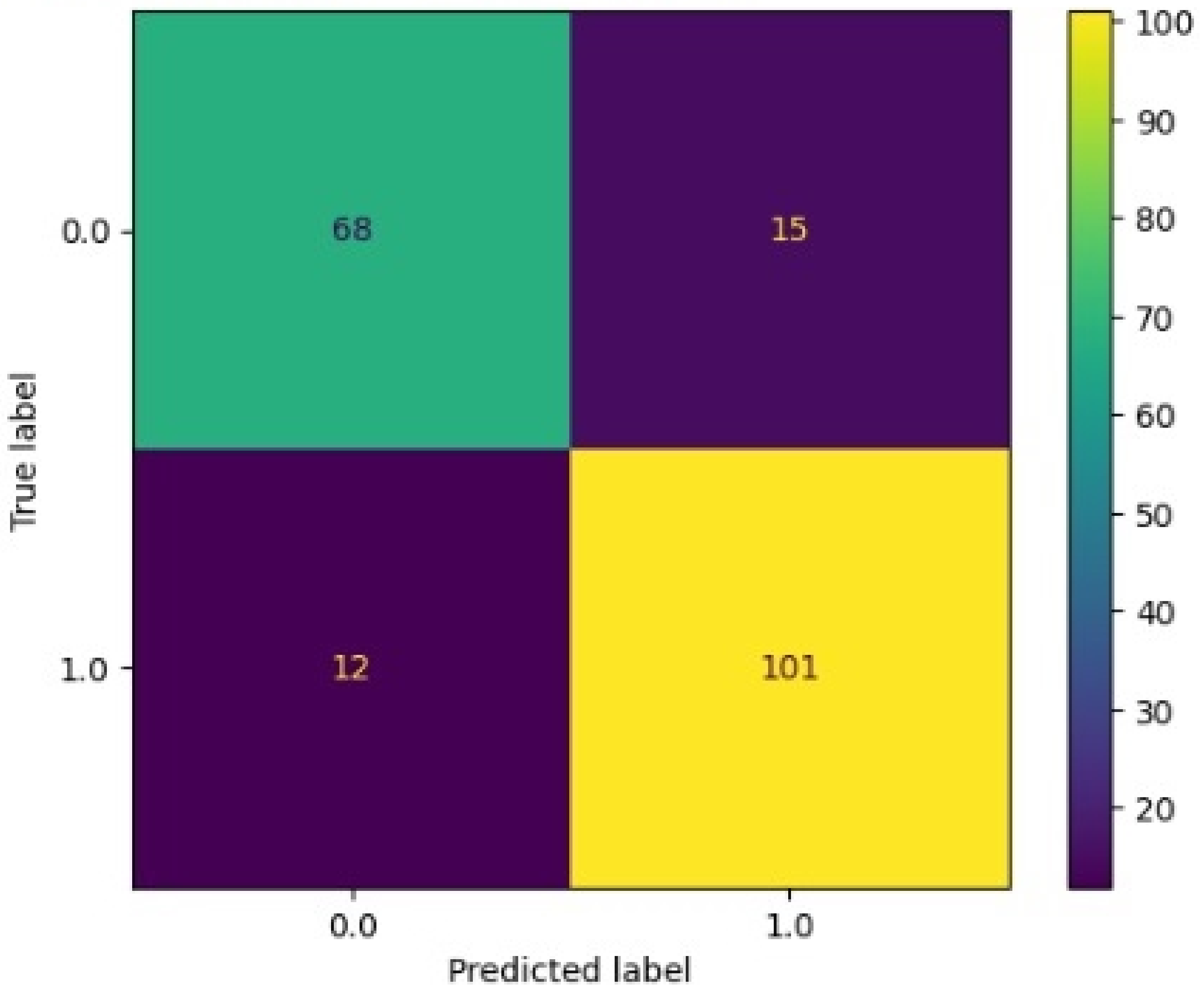


	precision	recall	f1-score	support
0.0	0.82	0.86	0.84	83
1.0	0.89	0.86	0.87	113
accuracy			0.86	196
macro avg	0.85	0.86	0.85	196
weighted avg	0.86	0.86	0.86	196

Mean Cross-Validation Accuracy: 0.8996682681308625
Test Accuracy: 0.8673469387755102

STACKING CLASSIFIER

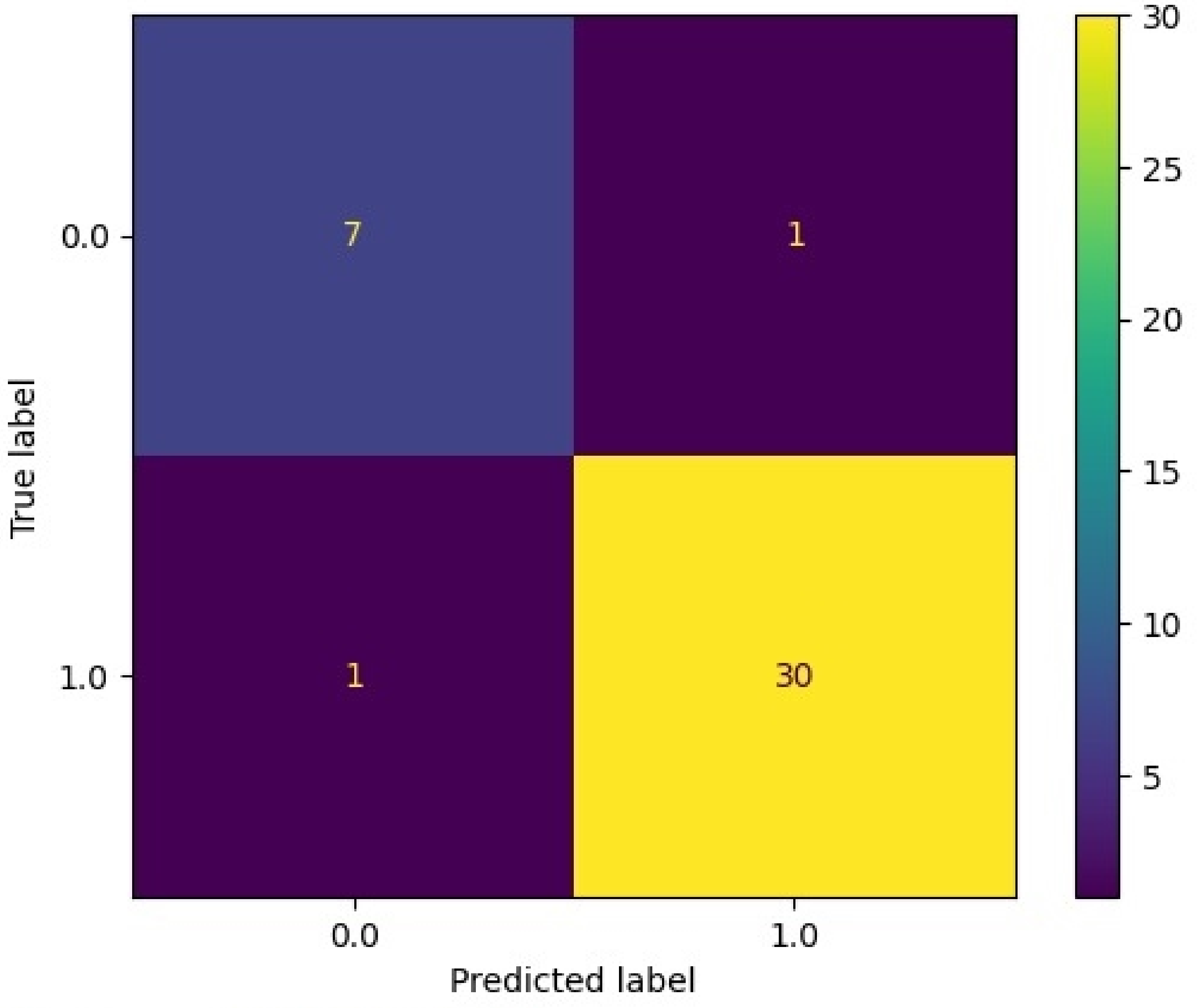
Train on Merged Data, Test on Merged Data:



Accuracy: 0.8622448979591837
Precision: 0.8619282195636875
Recall: 0.8622448979591837
F1 Score: 0.8618795389669786

Stacking Classifier Evaluation:

Train on English Data, Test on English Data:

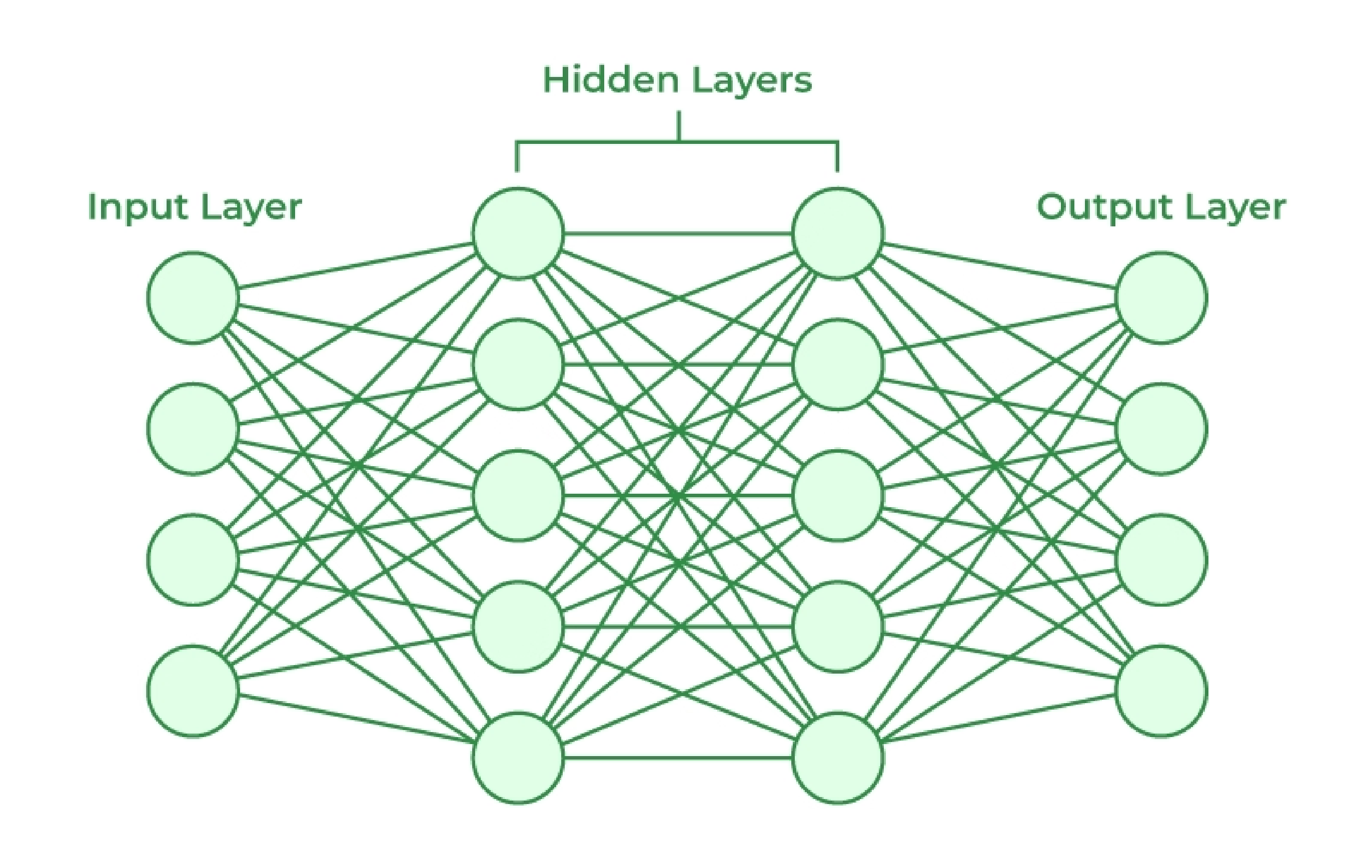


Accuracy: 0.9487179487179487
Precision: 0.9487179487179487
Recall: 0.9487179487179487
F1 Score: 0.9487179487179487

WE ALSO TRAINED A DNN

- Epochs Variation: 1000,5000,10000
- Hidden Layers: 2,3,4

```
Accuracy on test data: 72.45%
Confusion Matrix:
[[50 29]
 [25 92]]
Precision: 0.7603305785123967
Recall: 0.7863247863247863
F1 Score: 0.773109243697479
```



WHERE DOES THIS LEAD US?

v Accuracy/ Model ->	Anglo-German	Anglo-Italian
Merge Train Merge Test	~80%	**86.2%**
Single Train Single Test	~85%	**94.8%**

CHALLENGES & FUTURE DEVELOPMENT

- LESS DATA FOR ENGLISH LANGUAGE
- NORMALIZATION BLACKBOXES
- LANGUAGES OF DIFFERENT ORIGINS

- OBTAIN MORE DATA
- TRAIN BETTER NEURAL NETWORK
- MAKE A 2+ LANGUAGE MODEL WITH >85% ACCURACY

TEAM

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References

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