Vocal Fold Dynamics for Automatic Detection of Amyotrophic Lateral Sclerosis from Voice

Student Researcher: Jiayi (Maggie) Zhang, CBD | Research Mentor: Professor Rita Singh, LTI

Problem Overview

This project explores the use of estimated vocal fold dynamics for automatic detection of Amyotrophic Lateral Sclerosis (ALS) from voice recordings. The project objectives are:

- ✓ Testing the viability of proposed method of analysis.
- ✓ Devising a set of effective and reliable features for ALS detection.

Background Information

1. **Human voice** carries enormous information about the physical and physiological states of the speaker and is thus suitable for the extraction of diagnostic features.
2. **ALS** is a neuro-degenerative disease that affects the motor neurons. The complexity of current diagnostic methods calls for expedient, objective, and reliable diagnostic aids.
3. **Prior studies** on the subject showed promising results but have not indicated the existence of conclusive biomarkers for ALS diagnosis.

Data Preparation

Dataset: voice recordings of prolonged phonation of "ah" of 42 individuals (32 ALS,10 non-ALS)

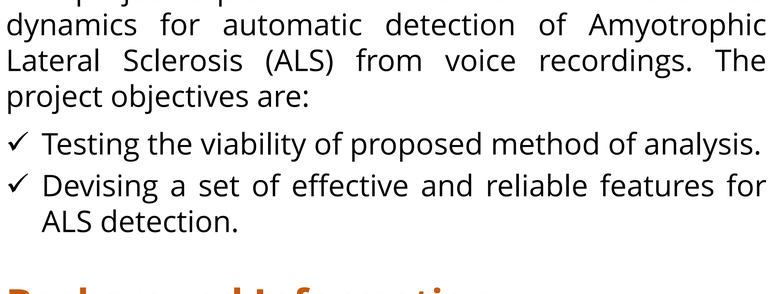

Fig. 1 Phase portraits showing estimated **vocal fold velocity vs. displacements** for 2 analysis windows of a single speaker.

Adjoint Least-Squares (ADLES) algorithm [1] based on a model of asymmetric vocal fold oscillation is used to estimate the vocal fold dynamics for each speaker.

The experiment setup: 10-way cross-validation conducted, with 70:30 train-test split. The whole dataset was used in each run; there were no overlap between training and test data.

Feature Set 1 (FS1):
Simple Statistical Measurements

20 features investigated:

- ✓ ***avg***, ***max***, ***min***, ***var*** of vocal fold displacement (*disp*);
- ✓ ***avg***, ***max***, ***min***, ***var***, ***center***, ***skew*** of max range of displacement (*MROD*)

7 features show significant separation between case and control after FDR correction (10 before correction).

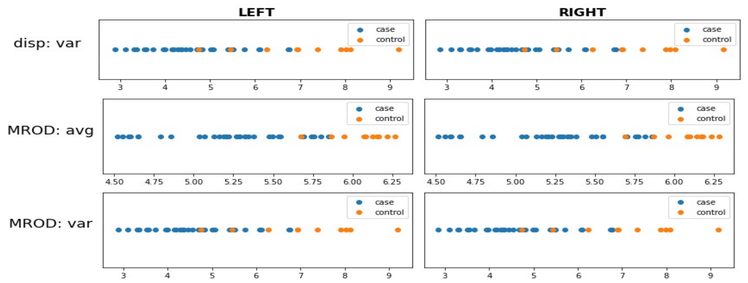

Fig. 2: Distributions of some FS1 features (significant separation after correction)

Fig. 3 Relative importance of FS1 features.
disp: var, *MROD: {var, avg}* account for 80.7% of feature weight.

Classification Results:

- ➢ Random Forest Classifiers (max-depth=2) with FS1 achieved **average AUC-ROC of 99.667%** (var=0.0001).

Feature Set 2 (FS2):
Phase-Space Characterizations

Features based on Lyapunov and Hurst exponents are extracted to measure the stability and auto-correlation of inferred dynamics.

17 features investigated:

- ✓ ***max 1-5*** among all *Lyapunov* exponents
- ✓ ***avg***, ***max***, ***var*** of *Hurst* exponents for velocity and displacement data of both sides

1 feature shows significant separation between case and control after FDR correction (12 before correction).

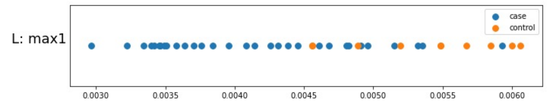

Fig. 4 Distribution of *Lyapunov: max1* (significant separation after correction)

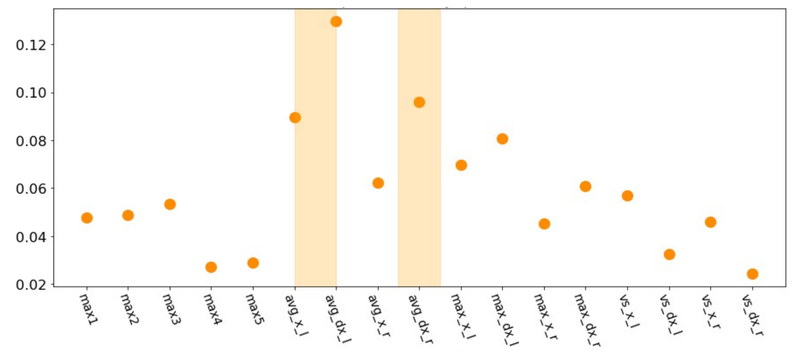

Fig. 5 Relative importance of FS2 features.
Hurst: {avg_dx_L, avg_dx_R, avg_x_L} account for 31.5% feature weight.

Classification Results:

- ➢ Random Forest Classifiers (max-depth=2) with FS2 achieved **average AUC-ROC of 82.333%** (var=0.01312).

Conclusions

- ➢ ALS decreases range of motion and capability of motion variation of the vocal folds.
- ➢ Vocal fold dynamics is useful for separating ALS from non-ALS individuals.
- ➢ It's **surprisingly easy** to detect the presence of ALS with high accuracy with proposed features!

Future Directions

- ➢ Increase cohort size; improve sample case-control, gender balance; increase sample diversity.
- ➢ Increase the complexity of the physical model of phonation.
- ➢ Relate findings (feature distributions, relative weights) with physiological and disease mechanisms.

Reference

[1] Zhao, W. and Singh, R., 2020, May. Speech-based parameter estimation of an asymmetric vocal fold oscillation model and its application in discriminating vocal fold pathologies. In *ICASSP 2020-2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)* (pp. 7344-7348). IEEE.