Analysis and classification of phonation modes in singing

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- Neutral ♬
- Pressed ♬
- Breathy ♬
- Flow ♬

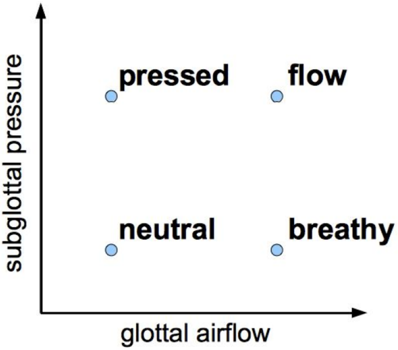


Figure: Four different phonation modes as defined by Sundberg [5]

Related work: Physiology

Laryngeal Resistance as predictor of phonation mode

- Laryngeal Pressure different in each phonation mode
  - Subglottal pressure divided by average airflow
- Difficult: How would this manifest acoustically?

TABLE 1.
Sample Mean, Standard Deviation, and 95% CIs That Could Cover the Population Parameter of μ for Pressed, Normal, Resonant, and Breathy Voice Qualities by LR ($cm\ H_2O/l/s$)

	Sample Mean	Standard Deviation	95% CIs
LR, pressed	766.23	69.77	614.22, 918.24
LR, normal	150.09	9.89	128.55, 171.65
LR, resonant	178.93	16.64	142.68, 215.17
LR, breathy	42.79	6.65	28.31, 57.27

Figure: Laryngeal resistance identified as different in every phonation mode [1]

Dataset

- Dataset with 900 recordings of female professional [2]
- Four phonation modes: Breathy, Neutral, Pressed, Flow
- Nine different vowels
- Pitches between A3 and G5

Related Work

Using the phonation dataset [3]

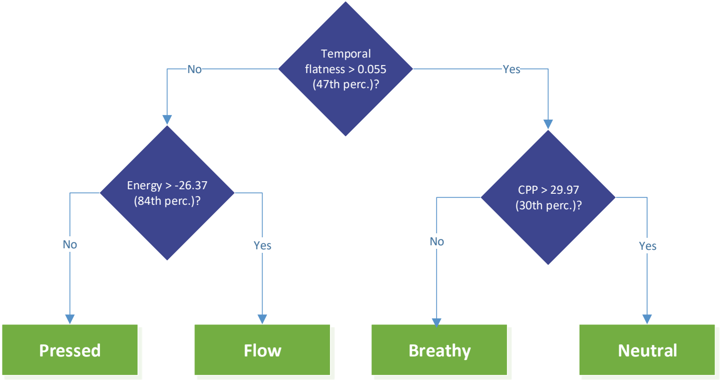
- Source-filter model for simulating the vocal tract [3]
  - Trained on each vowel individually
  - Physiologically interpretable
  - Accuracies between 60% and 75%
- Parallel work [4]
  - Focus on genre and style analysis
  - Accuracy 81.6%
  - No feature analysis

- MFCC
- Temporal flatness
- Spectral flatness
- Zero-crossing rate
- Spectral flux mean/dev.
- Spectral centroid
- High-frequency energy
- F0 mean/dev.
- Harmonic 1-6 amp.
- Harmonic-Noise Ratio
- Formant 1-4 amp./bandw./freq.

- Cepstral peak prominence (CPP)
- Normalised amplitude quotient (NAQ)
- Maxima Dispersion Quotient (MDQ)
- (Glottal) Peak Slope

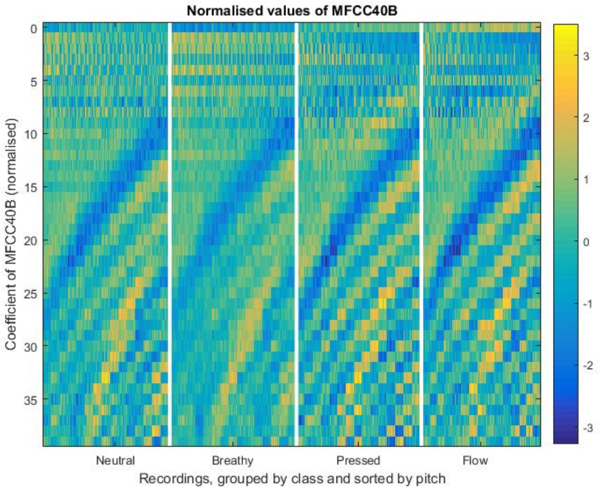
Feature analysis
Simple explanation for phonation modes

- Pruned decision tree on whole dataset:



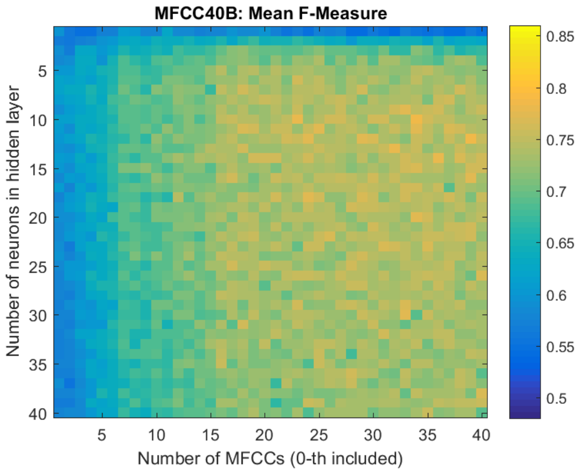
- Categorises 78% of recordings correctly

Feature Analysis
MFCC Visualisation

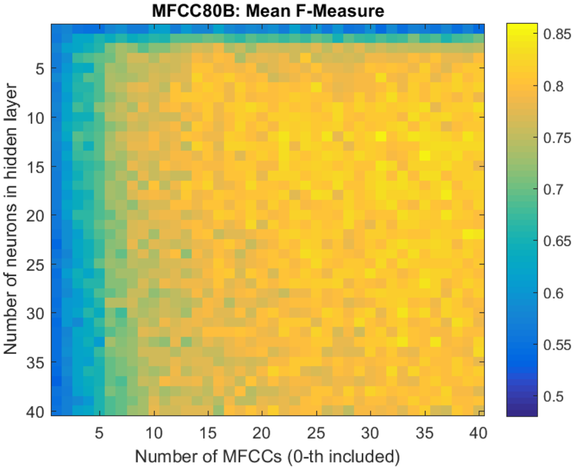


- Single-layer neural network with N hidden nodes
- 10-fold cross-validation
- Grid search optimisation: Run with $N \in \{1, \ldots, 40\}$ neurons and the first $\{1, \ldots, 40\}$ MFCCs

Classification
MFCC40B



Classification
MFCC80B



- Feature analysis to explain phonation modes as acoustic phenomenon
    - Surprisingly variable performance of specialised features
    - Simple decision tree
- MFCCs: Lowest coefficients important, higher number of bands better $\Rightarrow$ Hyperparameter
- Improved classification accuracy, but: Loudness-based classification?
- More comprehensive dataset needed

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