MODELING INSTANTANEOUS INTONATION FOR SPEAKER IDENTIFICATION
USING THE FUNDAMENTAL FREQUENCY VARIATION SPECTRUM

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Goal

Improve speaker identification by modeling **intonation bias**
(the distribution of speaker-preferred pitch change in octaves per 8 ms).

HOW?

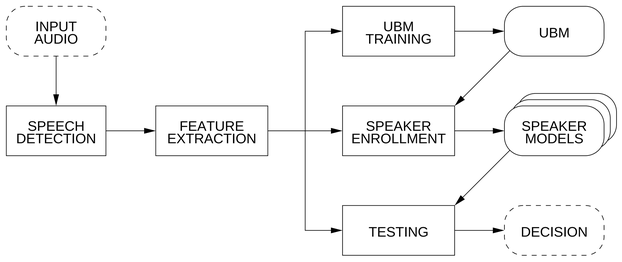
Compute the fundamental frequency variation (FFV) spectrum
and model alongside "traditional" spectral (MFCC) features, ie.

$$\log \boldsymbol{P}\left(\textsc{Mfcc13} \oplus \textsc{Ffv7} | \mathcal{M}\right) = \log \boldsymbol{P}\left(\textsc{Mfcc13}, \textsc{Ffv7} | \mathcal{M}_{\boldsymbol{stacked}}\right)$$

or

$$\log \boldsymbol{P}\left(\textsc{Mfcc13} \otimes \textsc{Ffv7} | \mathcal{M}\right) = \lambda_{\textsc{Mfcc13}} \log \boldsymbol{P}\left(\textsc{Mfcc13} | \mathcal{M}_{\textsc{Mfcc13}}\right) + \lambda_{\textsc{Ffv7}} \log \boldsymbol{P}\left(\textsc{Ffv7} | \mathcal{M}_{\textsc{Ffv7}}\right)$$

Baseline GMM-MFCC SID System



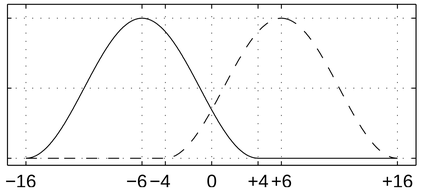
- 32 ms frames every 8 ms, low-energy frames excluded
- $\textsc{Mfcc13} \equiv \{\boldsymbol{MFCC_0}, \boldsymbol{MFCC_1}, \cdots, \boldsymbol{MFCC_{12}}\}$
- cepstral mean subtraction
- Gaussian mixture models (4096)
- ML estimation of universal background model (UBM)
- MAP estimation of speaker GMM means

Data

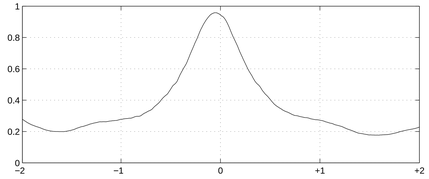
- Wall Street Journal, LDC CSR-I (WSJ0) & LDC CSR-II (WSJ1)
- read sentences and some spontaneously produced utterances
- 16 kHz wideband audio (Sennheiser HMD414)
- 102 female speakers & 95 male speakers
  TRAINSET: 5 minutes of speech per speaker
  TESTSET: 3 trials $\times$ 1 minute of speech per speaker
- UBMSET: remaining speakers' speech (70 hours)

What Is the Fundamental Frequency Variation Spectrum?

- dot product of two spectra, $\mathbf{F}_L$ and $\mathbf{F}_R$ ...



- ... after dilating one of $\mathbf{F}_L$ and $\mathbf{F}_R$ by factor $\mathbf{2}^{\rho}$
- FFV spectrum is value of dot product over range of ρ



- after 7-filter filterbank, $\textsc{Ffv7} \equiv \{\boldsymbol{FFV_{-3}}, \cdots, \boldsymbol{FFV_{+3}}\}$

Findings

1. Raw FFV7 features offer better than chance performance.
2. Sphering FFV7 features dramatically improves performance.
3. Model-space combination of MFCC13 with sphered FFV7 yields 54% and 40% relative error reductions for female and male speakers, respectively.
4. Model-space combinations of MFCC13 with FFV7 relative to that with MFCC7 yields 24–35% and 26–30% relative error reductions for female and male speakers, respectively.
5. Feature-space combinations of MFCC13 with FFV7 offer no benefit.

Experiments (identification accuracies, %)

System	Female	Male
MFCC13	82.0	92.3
MFCC7	43.8	68.8
FFV7	27.8	45.3
PCA(MFCC13)	84.3	91.2
PCA(MFCC7)	44.4	65.2
PCA(FFV7)	**62.7**	64.2
MFCC13 $\otimes$ MFCC7	86.3	92.6
MFCC13 $\otimes$ FFV7	80.7	92.3
PCA(MFCC13) $\otimes$ MFCC7	87.3	92.3
PCA(MFCC13) $\otimes$ FFV7	84.6	**92.6**
MFCC13 $\otimes$ PCA(MFCC7)	89.2	93.7
MFCC13 $\otimes$ PCA(FFV7)	**91.8**	**95.4**
PCA(MFCC13) $\otimes$ PCA(MFCC7)	86.9	93.0
PCA(MFCC13) $\otimes$ PCA(FFV7)	**91.5**	**95.1**

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