MULTISTREAM DIARIZATION FUSION USING THE MINIMUM VARIANCE BAYESIAN INFORMATION CRITERION

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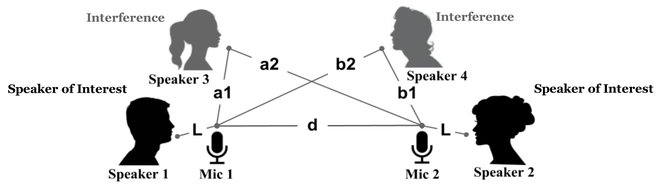
Introduction

- ***Motivation:***
  - Different features for diarization are reliable under different acoustic conditions.
- ***Goal:***
  - Improve the performance of diarization system by fusing two diarization streams in the clustering phase
- ***Approach:***
  - Propose Minimum Variance Bayesian Information Criterion (MVBIC) to estimate the proper ratio to fuse two diarization streams

Open Source USCDiarLibri

- ***USCDiarLibri2,4 Dataset:***



  - The speech data comes from the LibriSpeech ASR corpus
  - Assumes 2 speakers of interest among 4 speakers
  - Models reverberation, overlap, and interfering sources:

$$x_{\text{mic}}[t] = \frac{1}{r}\,\bar{H}[t] * x_{\text{source}}\left[t - r\frac{f_s}{v_s}\right]$$

- **Overlap :** Randomly chosen
- **Interfering sources:** Active at random intervals with overlap
- **Time delay:** Calculated according to the position of each speaker
- **Reverberation:** Impulse Response (IR) is simulated according to the distance to model acoustic degradation in real life

Single Stream Speaker Diarization

- ***Features:***
  - Diarization stream 1: Root Mean Square Energy (RMSE)
  - Diarization stream 2: 13 Mel Frequency Cepstral Coefficients (MFCC)
- ***Segmentation:***
  - KL-distance based speaker change detection
- ***Clustering:***
  - Distance Measure: Bayesian Information Criterion (BIC)
  - Clustering algorithm: Agglomerative hierarchical clustering
- ***Evalutation:***
  - Diarization Error Rate (DER): speaker error, false alarm speech, missed speech and overlap speaker

Proposed Diarization Fusion Framework

- ***Two BIC streams:***
  - N_S : Number of segments in a session
  - $N_S\mathbf{C}2$ (Choose 2 segments out of N_S segments) BIC distances from both RMSE and MFCC
  - An $N_S\mathbf{C}2$ by 2 matrix is used to calculate weight based on MVBIC
- ***MVBIC:***
  - Optimizes the weighted sum of BIC distances in the minimum variance sense
  - Efficiently weights BIC distances according to their reliability
- ***Noisy BIC model:*** Correct BIC stream through a noisy channel
  - The hidden, correct BIC streams: b
  - Two observed, noisy BIC streams: $\tilde{b}_i$

$$\tilde{b}_i = b + n_i \tag{1}$$

- ***Estimated BIC value:*** Obtain the optimal fusion weights

$$\hat{b} = \sum_{i=1}^{M} \omega_i\, b_i = \mathbf{w}^T\mathbf{b}$$
$$Var\left[\hat{b}\right] = \mathbf{w}^T\Sigma_b\mathbf{w} \tag{2}$$

- ***Assumption:*** Mean zero and uncorrelated noise random variables

$$\sigma_{b,i}^2 = \sigma^2 + \sigma_{n,i}^2$$
$$\sigma_{b,ij} = \sigma_{b,ji} = \sigma^2$$
$$\text{where } i \neq j \text{ and } i, j \in [1, M] \tag{3}$$

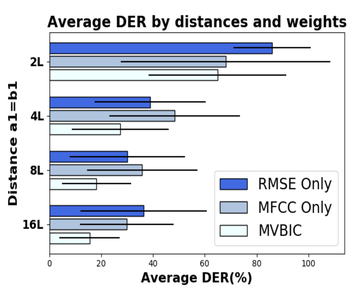
- ***Minimize Noise:*** Set the sum of weights to 1 to keep the signal variance intact and only minimize the variance of noise

$$Var[\hat{b}] \;=\; \left(\sum_{i=1}^{M}\omega_i\right)^2\sigma^2 + \sum_{i=1}^{M}\omega_i^2\,\sigma_{n,i}^2 \;=\; \sigma^2 + \sum_{i=1}^{M}\omega_i^2\,\sigma_{n,i}^2 \tag{4}$$

- ***Minimization problem:***

$$\begin{aligned}&\text{Minimize:} && Var\left[\hat{b}\right] = \mathbf{w}^T\Sigma_b\mathbf{w} \qquad \widehat{\mathbf{w}} = \frac{\Sigma_b^{-1}\mathbf{1}}{\mathbf{1}^T\Sigma_b^{-1}\mathbf{1}}\\ &\text{Subject to:} && \mathbf{w}^T\mathbf{1} = 1\end{aligned} \tag{5}$$

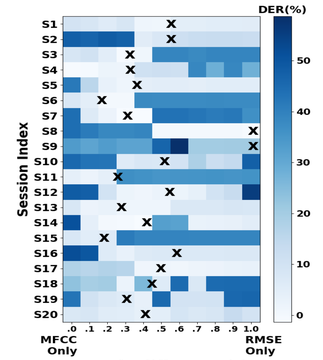
Experimental Results: USCDiarLibri2,4



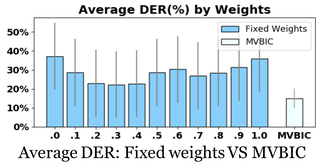
Average DER by distances of interfering speakers

- ***Objective of the Experiment:***
  - Test the effect of the distances from interfering speakers to microphones
- ***Experiment Setup:***
  - Fix distance between primary speakers to 5L
  - Vary distances a1 and b1, keeping a1 = b1
- ***Results:***
  - MVBIC gives lower DER than both of single stream diarization systems.
  - Both features perform worse when interfering speakers are near the primary speakers.

Experimental Results: USCDiarLibri2,4



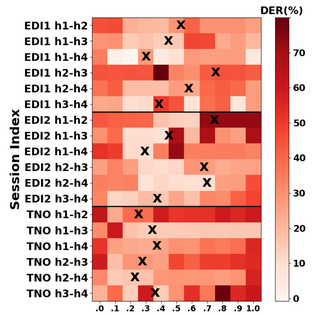
DER for different weights
X Marks MVBIC optimal weight



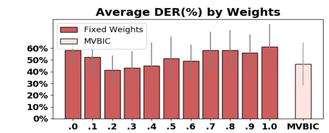
Average DER: Fixed weights VS MVBIC

- ***Objective of the Experiment:***
  - MVBIC vs. fixed BIC weights
  - Evaluated on USCDiarLibri2,4
- ***Experiment Setup:***
  - Random distances [2L, 20L]
- ***Improvement with MVBIC method:***
  - lower DER for each session
  - lower overall DER over fixed BIC weight

Experimental Results: RT06



Estimated weights (X) and DER for RT06S.



Average DER by fixed weights and MVBIC for subset of RT06S dataset.

- ***Objective of the Experiment:***
  - Same test on real-life data (RT06S)
- ***Experiment Setup:***
  - Speech recorded with head-set microphones
- ***Improvement with MVBIC method:***
  - Real-life data shows more irregularity
  - MVBIC method :46.5% fixed BIC method: 41.5%.

Conclusions

- ***Contributions:***
  - Open source data generation framework that models various acoustic conditions
  - Propose MVBIC method to combine two diarization streams without using dev-set data
- ***Further work:***
  - Multiple streams; including i-vector, DNN embeddings

Acknowledgments

http://scuba.usc.edu

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