Modified prior i-Vector Estimation for Language Identification of Short Duration Utterances

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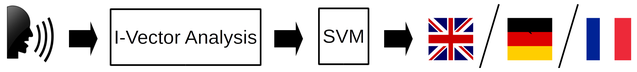
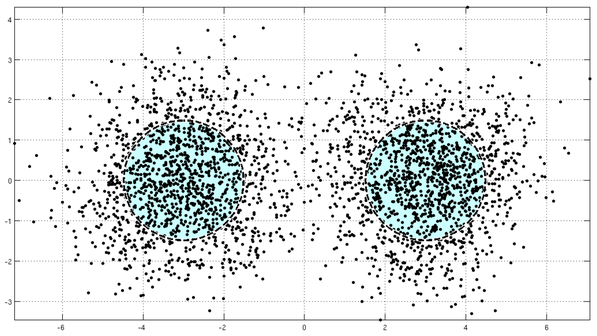
Introduction

- **Goal** : Identify spoken language from utterances
- **Challenge** : Short and noisy utterances
- **Framework** : Total Variability i-Vector Modeling + SVM

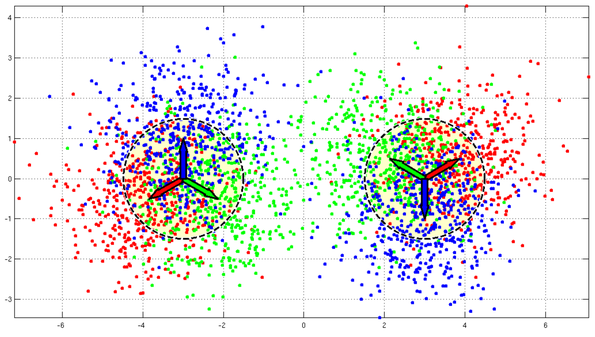


Total Variability i-Vector Modeling

- **Complete data distribution** :
  Gaussian Mixture Model, denoted as **UBM**



- **Utterance-specific data distribution** :
  GMM, with UBM component means shifted *slightly*



- **Model Assumption** :
  Shift in UBM mean supervector is *low-dimensional*

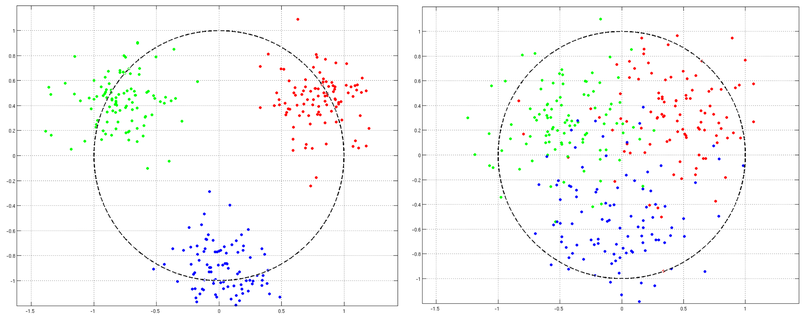
$$\mathbf{M_U} = \mathbf{M_0} + \mathbf{Tx}, \quad P(\mathbf{x}) = \mathcal{N}(\mathbf{0}, \mathbf{I})$$

- **i-Vector** is the **MAP estimate** of $\mathbf{x}$ given statistics $\mathbf{F}, n$:

$$E\left[\mathbf{x}|\boldsymbol{F}\right] = \left(\mathbf{I} + \mathbf{T}^t\boldsymbol{\Sigma}^{-1}n\mathbf{T}\right)^{-1}\mathbf{T}^t\boldsymbol{\Sigma}^{-1}n\boldsymbol{F}$$

Effect of reducing duration

- **Variance** of the i-Vector estimate increases
- Decisions become error-prone
- Estimate is driven by the **nature of the prior**



Prior Modification

- **Motivation and hypothesis** :
  - **Observation** :
    i-Vectors estimated from ample data form clusters
  - **Standard normal prior** :
    Penalizes probability of *large magnitude* i-Vector estimates
  - **Hypothesis** :
    Better to penalize deviation from cluster centers
  - **Gaussian Mixture** prior is better suited to this purpose

- **Proposed Prior** : GMM, with one component per class

$$P(\mathbf{x}) = \sum_{i=1}^{M} P_C(i)\mathcal{N}\left(\mu_i, \mathbf{C}_i\right)$$

- **i-Vector estimate with GMM Prior** :

$$E\left[\mathbf{x}|\mathbf{F}\right] = \sum_{i=1}^{M} P_C(i)\, \boldsymbol{l}_i^{-1}\mathbf{b}_i$$

$$\mathbf{b}_i = \mathbf{T}^t\boldsymbol{\Sigma}^{-1}n\mathbf{F} + \mathbf{C}_i^{-1}\mu_i, \;\; \boldsymbol{l_i} = \mathbf{C}_i^{-1} + \mathbf{T}^t\boldsymbol{\Sigma}^{-1}n\mathbf{T}$$

- **Prior re-weighting** :
  Provide a parameter(λ) to tune weight of prior relative to data :

$$\mathbf{b}_i = \lambda\mathbf{T}^t\boldsymbol{\Sigma}^{-1}n\mathbf{F} + \mathbf{C}_i^{-1}\mu_i, \;\; \boldsymbol{l_i} = \mathbf{C}_i^{-1} + \lambda\mathbf{T}^t\boldsymbol{\Sigma}^{-1}n\mathbf{T}$$

Proposed Variants

- **GMM i-Vector** : Use i-Vector estimates from long duration utterances to set parameters $P_C(i)$ and $\mu_\mathbf{i}, \mathbf{C}_i$ for the prior.
- **GMM Re-estimation** : Use i-Vector estimates from long duration utterances only to set $\mu_\mathbf{i}, \mathbf{C}_i$ for the prior. Set $P_C(i)$ by first-pass SVM classification.
- **Score Re-estimation** :
  - i-Vector estimates under GMM prior are linear combinations of i-Vector estimates under individual component Gaussian priors
  - Try combining scores after classification as opposed to combining i-Vector estimates before classification

Database and System Description

- **Database : DARPA RATS**
  - Noisy audio recordings from **six** classes :
    - Five **target** languages
    - A class corresponding to 10 **non-target** languages
  - Audio utterances of length : 120s, 30s, 10s, 3s
- **System Description**
  - **UBM Size** : 2048 Components
  - **i-Vector dimension** : 400
  - **Inter-session variability compensation** : WCCN
  - **SVM** : Fifth order polynomical kernel
  - **Utterance duration** :
    - **i-Vector Model $(\mathbf{T}, \boldsymbol{\Sigma})$ Estimation** : 30 s
    - **SVM training and Test** : 3 s

Results

System	*EER*	*DCF*	P_{miss}^{10}	*Accuracy*
Baseline	15.40	15.21	22.19	69.74
GMM i-Vector	15.27	**14.98**	**20.76**	69.44
GMM Re-estimation	16.32	15.82	22.32	**70.11**
Score Re-estimation	**15.14**	15.07	21.28	69.96

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