Audio Segmentation and its Applications in Speaker Characterization

Paula López Otero

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- Division of a signal into homogeneous segments
    - Speaker segmentation

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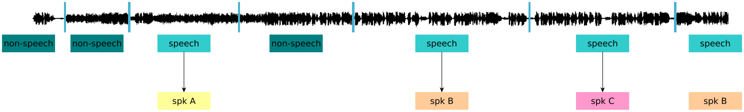
  - Speaker segmentation

- Speaker diarization ("who spoke when")
- Indexing of multimedia information
  - classification of music (song title, genre...)
- Automatic speech recognition (ASR)
  - Removal of non-speech segments
  - When we know "who spoke when" ⇒ Speaker adaptation



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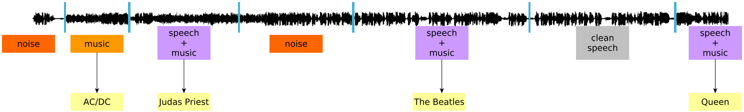

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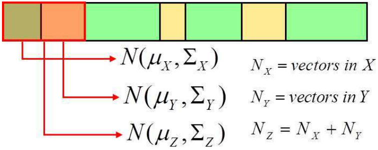
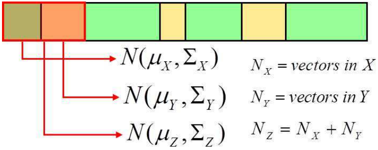
The BIC algorithm



- A window of data (Z) is taken and divided into two sub-windows (X, Y) at frame i
- X, Y and Z are modelled with a multivariate Gaussian
- A hypothesis test is applied for acoustic change detection
  - H_0: No acoustic change in window Z
  - H_1: The window contains an acoustic change at point i

G. Schwarz, "Estimating the dimension of a model"

The BIC algorithm



- BIC: The maximum likelihood ratio between H_0 and H_1

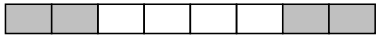
$$R(i) = L_X + L_Y - L_Z = N_Z \log|\Sigma_Z| - N_X \log|\Sigma_X| - N_Y \log|\Sigma_Y|$$

$$\Delta BIC(i) = BIC(H_1) - BIC(H_0) = R(i) - \lambda \frac{1}{2}(d + \frac{1}{2}d(d+1))log(N_Z)$$

- Decision:
  - $\Delta BIC(i) > 0$
  - λ must be tuned for each dataset

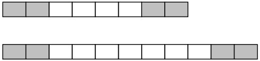
G. Schwarz, "Estimating the dimension of a model"

Segmentation Strategy



M. Cettolo, M. Vescovi, "Efficient Audio Segmentation Algorithms based on the BIC"

Segmentation Strategy



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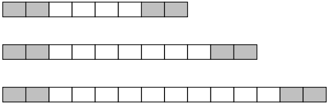

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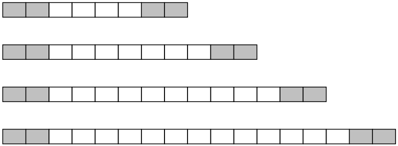

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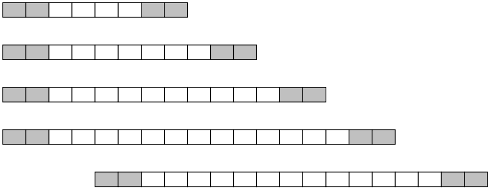

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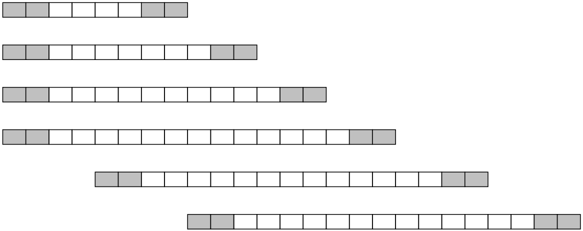

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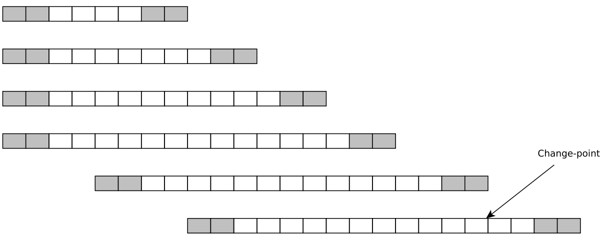

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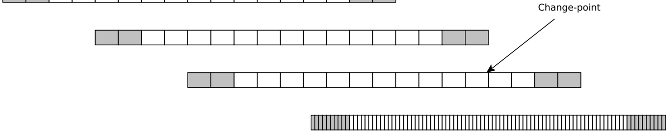

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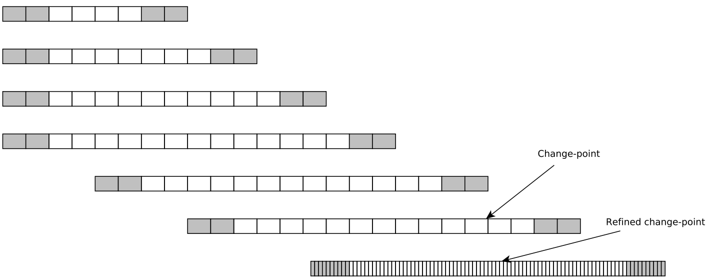

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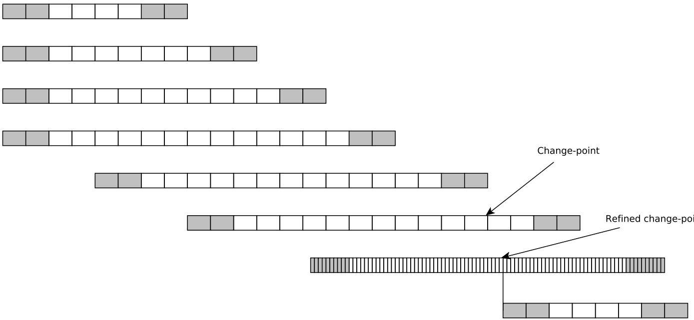

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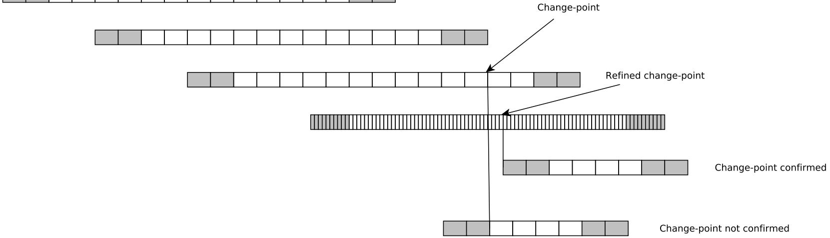

M. Cettolo, M. Vescovi, "Efficient Audio Segmentation Algorithms based on the BIC"

Issue: sensitivity

Too sensitive ⇒ false alarms

Too little sensitive ⇒ deletions

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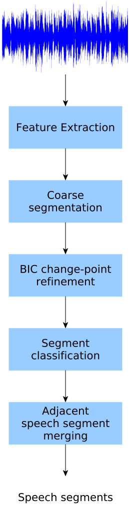
Reducing the false alarm rate

Baseline System



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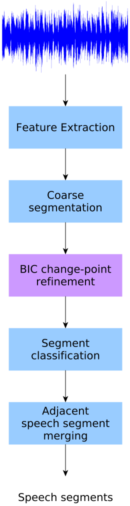

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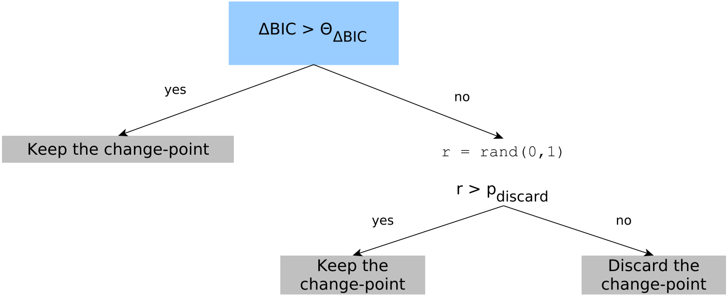

Adaptive Strategy

- $p_{discard}$ and Θ_{BIC} increase when the system is accepting too many false alarms
- $p_{discard}$ and Θ_{BIC} decrease when the system is not accepting false alarms
- Initially: $p_{discard} = 0$, $\Theta_{BIC} = 0$

Poisson-based Strategy

- $p_{discard}$ follows a Poisson cumulative density function
- $p_{discard}$ depends on the expected number of change-points (mean of the distribution)
- Initially: $p_{discard} = 0$

Uniform-based Strategy

- $p_{discard}$ is constant
  - $p_{discard} \downarrow$: high tolerance to false alarms
  - $p_{discard} \uparrow$: low tolerance to false alarms

L. Docio-Fernandez, P. Lopez-Otero, C. Garcia-Mateo, "An Adaptive Threshold Computation for Unsupervised Speaker Segmentation"

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P. Lopez-Otero, L. Docio-Fernandez, C. Garcia-Mateo, "Novel Strategies for Reducing the False Alarm Rate in a Speaker Segmentation System"

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Adaptive Strategy

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Database

- TC-STAR 2006 ASR evaluation campaign
- Spanish parliament sessions

Metrics

$$\text{Precision: } P = \frac{c}{c+i} \times 100$$

$$\text{Recall: } R = \frac{c}{c+d} \times 100$$

$$\text{F-score: } F = \frac{2PR}{P+R}$$

Results

System	P	R	F
Baseline	57.46	85.59	65.99
Adaptive	66.98	85.59	73.17
Uniform	80.97	81.75	81.22
Poisson	76.21	83.09	79.05

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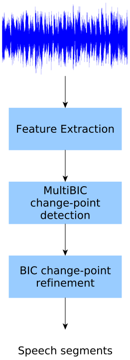
MultiBIC Strategy



BIC

$$\Delta BIC(i) = L_i - \lambda P$$

$$P = \frac{1}{2}(d + \frac{1}{2}d(d+1))logL$$

$$L_i = \frac{L}{2}log|\Sigma| - \frac{L_1}{2}log|\Sigma_1| - \frac{L_2}{2}log|\Sigma_2|$$

MultiBIC

$$\Delta MultiBIC(i,j) = L_{ij} - \lambda P$$

$$P = d + \frac{1}{2}d(d+1)logL$$

$$L_{ij} = \frac{L}{2}log|\Sigma| - \frac{L_1}{2}log|\Sigma_1| - \frac{L_2}{2}log|\Sigma_2| - \frac{L_3}{2}log|\Sigma_3|$$

P. Lopez-Otero, L. Docio-Fernandez, C. Garcia-Mateo, "MultiBIC: an Improved Speaker Segmentation Technique for TV Shows"

Database

- TV shows
  - *sit-coms*: canned laughter, jingles
  - drama series: background music

Metrics

$$\text{Precision: } P = \frac{c}{c+i} \times 100$$

$$\text{Recall: } R = \frac{c}{c+d} \times 100$$

$$\text{F-score: } F = \frac{2PR}{P+R}$$

Results

Test		c	d	i	P	R	F
1	BIC	466	158	6	98.06	66.13	78.98
	MultiBIC		96	2	99.46	79.28	88.21
2	BIC	497	169	5	98.66	66.36	79.34
	MultiBIC		82	4	99.17	83.50	90.67
3	BIC	402	147	0	100	63.43	77.63
	MultiBIC		61	0	100	84.83	91.79

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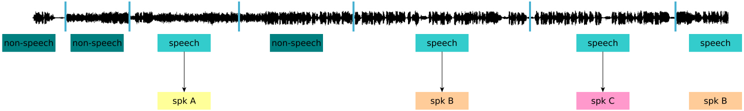
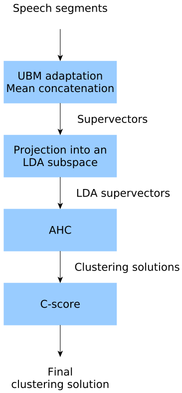
Speaker Diarization



- Audio and speaker segmentation
  - Non-speech segments are removed
  - Speech segments of different speakers are divided
- Clustering
  - Agglomerative hierarchical clustering
  - How many clusters?

Applications: Speaker Diarization

The C-score Technique



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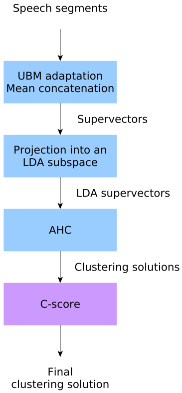
Speech segments
UBM adaptation
Mean concatenation
Supervectors
Projection into an
LDA subspace
LDA supervectors
AHC
Clustering solutions
C-score
Final
clustering solution

- A number of clusters n^* is selected such that:
  - Intra-cluster similarity (I_n) is minimized
  - Extra-cluster similarity (E_n) is maximized

$$C\text{-}score_n = \frac{2I_n(1-E_n)}{I_n + (1-E_n)}$$

$$n^* = \underset{i=n_{min},\ldots,n_{max}}{\arg\max}\; C\text{-}score_i$$

Database

- Albayzin 2010 speaker diarization evaluation database
- Broadcast news programmes

Metrics

- Speaker error rate (SPKE)
- False alarm rate (FAS)
- Missed speech (MISS)

Results

Segmentation	Method	FAS	MS	SPKE (%)
Manual	C-score	0 %	0 %	16.1 ± 0.9
	BIC			29.0 ± 1.1
Automatic	C-score	2.2 %	7.3 %	15.0 ± 0.7
	BIC			19.4 ± 0.8

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Database

- Transcrigal-DB
- Broadcast news programmes in Galician language

Metrics

$$WER = \frac{S + D + I}{W}$$

Results

	Speakers	Substitutions	Deletions	Insertions	WER
Manual segmentation	All	14.9 %	4.9 %	4.4 %	24.2 %
	Habitual	12.1 %	3.4 %	4.6 %	18.3 %
	Others	18.2 %	5.9 %	4.3 %	28.4 %
Automatic segmentation	All	14.9 %	6.5 %	3.6 %	25.0 %
	Habitual	10.6 %	4.5 %	3.6 %	18.7 %
	Others	17.9 %	7.8 %	3.7 %	29.4 %
Automatic segmentation and clustering	All	13.7 %	6.2 %	3.3 %	23.1 %
	Habitual	9.9 %	4.3 %	3.3 %	17.6 %
	Others	16.4 %	7.5 %	3.3 %	27.2 %

P. Lopez-Otero, L. Docio-Fernandez, C. Garcia-Mateo, A. Cardenal-Lopez, "On the Influence of Automatic Segmentation and Clustering in Automatic Speech Recognition"

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Ongoing work: Emotion Recognition

- Automatic estimation of speaker's affect and depression level
- Application of speaker verification techniques to emotion recognition
    - Feature dimensionality reduction
    - Emotional characterization of speech segments

E. Sanchez-Lozano, P. Lopez-Otero, L. Docio-Fernandez, E. Argones-Rua, J.L. Alba-Castro, "Audiovisual Three-Level Fusion for Continuous Estimation of Russell's Emotion Circumplex"

Thank you for your attention

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