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TNO submission
NIST RT05s SAD/SPKR

Defence, Security and Safety

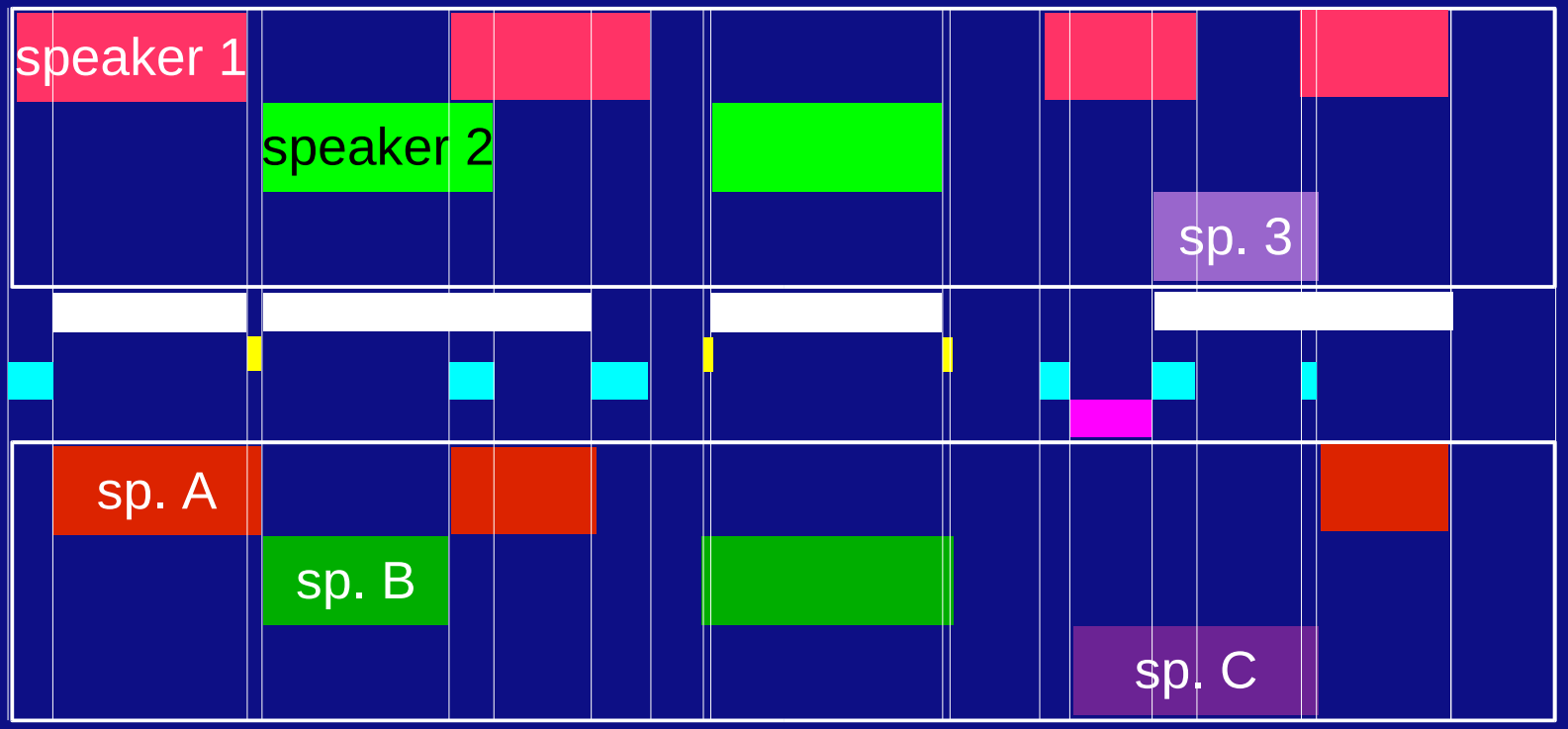
TNO | Kennis voor zaken

Reasons for TNO to join RT05s/spkr

- Running Broadcast News speaker segmentation/clustering speech recognition system for Dutch since 2001†
  - segmentation necessary for
    - on-line processing
    - feature stream time reversal in Abbot acoustic NN
    - low latency
  - poor clustering
- Active in NIST speaker recognition evaluations since 2003
- Takes part in AMI EU meeting project
  - scenarios, data collection, data processing, interpretation, presentation
    - speaker segmentation/clustering
- Problem definition
- Evaluation measures

†http://speech.tm.tno.nl/radio1/

Speaker Diarization Error rate (SDE)



Evaluation

- correct speaker time
- missed speaker time
- misclassified time
- false alarm speaker time

} *spoken* time

} speaker *error* time

Speech Activity Detection a necessity

- Speaker diarization error rate
  - Error speaker time / spoken time
- Without speech activity detection:
  - All non-speech time is *false alarm* speaker error time
  - Total time T, spoken time T_s

$$\mathrm{SDE} > \frac{T - T_s}{T_s}$$

  - typical meeting scenario $T_s/T \approx 2/3 \Longrightarrow \mathrm{SDE} > 50\,\%$
- SAD important in RT05s speaker diarization
  - ICSI offered SAD output to us
  - contrastive SPKR condition

SAD approaches

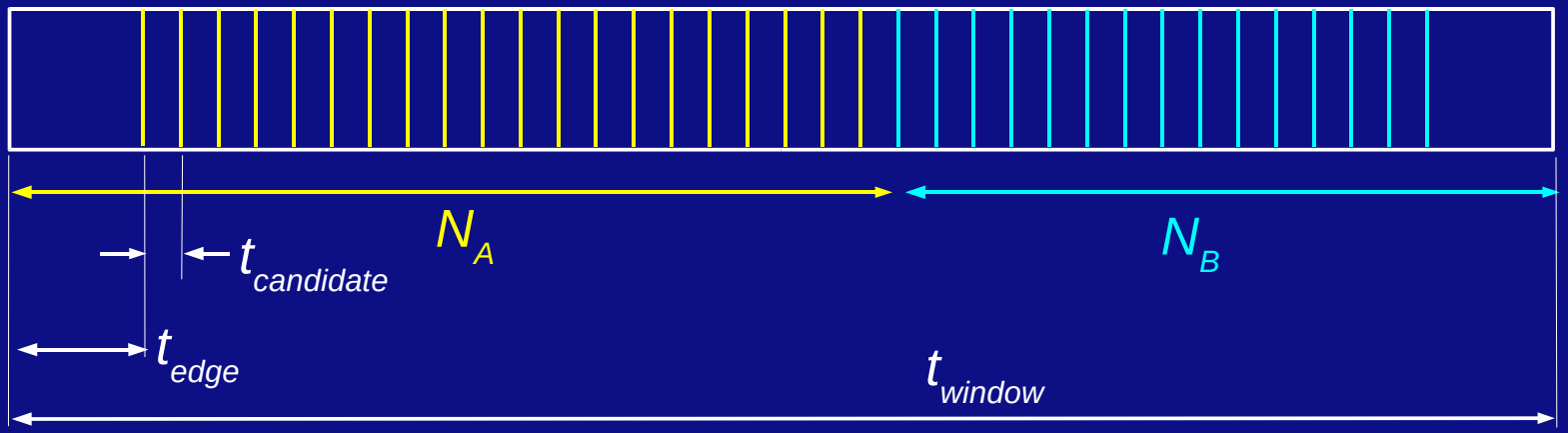
1) Energy based
   - e.g., all frames with energy > 20 dB under meeting maximum
     - works fairly well for telephone speech, speaker recognition
   - doesn't work with distant microphone
     - SAD error ≃ 50%
2) Two-phone speech recognition system
   - speech + non-speech 3-state LtoR phone models
   - Sonic decoder, 2-phone grammar
     - no output
3) Two-state Viterbi GMM decoder “ptsamiditw”
   - 16 mixtures/model
   - calculate maximum likelihood state sequence
   - apply some smoothing
   - seems to work

SAD results ptsamiditw

- GMM training, 12 PLP+energy+delta
  - 5 “train” AMI meetings from dev test
  - non/speech labels from SPKR reference files
    - thanks Xavier Anguera, ICSI
- decoder parameter tuning
  - 5 “test” AMI meetings from dev test
  - parameters
    - prior odds non/speech 0.01
    - transition probability ratio 10^{-5}
- Results SAD error rate
  - AMI dev test set 10.3 %
  - RT04s – CMU 2.8 %
  - RT05s 5.0 %

Speaker Segmentation

- Uses output from SAD, 12 PLP+energy
- Based on Bayesian Information Criterion, Chen&Gopalakrishnan†
- $$\Delta\mathrm{BIC} = \frac{1}{2}\left(N_x \log|\Sigma| - N_A \log|\Sigma_A| - N_B \log|\Sigma_B| - \lambda N_M \log N_x\right)$$
- $N_x = N_A + N_B$ number of frames considered in current "window"



- store aggregated "sufficient statistics" for covariances

† Proc. DARPA broadcast news transcription and understanding, 1998

Speaker clustering

- Uses output from speaker segmentation
- Agglomerative clustering
- Uses “Gish distance measure” for finding closest segments

$$G(c_i, c_j) = \frac{1}{2}\left((N_i + N_j)\log|\Sigma_m| - N_i \log|\Sigma_i| - N_j \log|\Sigma_j|\right)$$

- Condition for merging clusters based on BIC

$$\frac{1}{2}\lambda_c N_M \log N_x - G(c_i, c_j) > 0$$

- N_x is total number of frames in entire meeting
- Inefficient for large number of initial segments
  - but preferred over “online” version of BN system
- Tuning parameters
  - AMI “test” split development test data
  - $\lambda_{seg} = 1.5 \quad \lambda_{clust} = 14$

NIST RT05s speaker diarization results

- “Multiple distant microphones” = single distant mic
- no overlap
- SDE, in %

	SAD input to SPKR			parameters	
Test set	TNO	ICSI	perfect	optimized	
AMI dev	35.7		*45.9*	*45.3*	*?*
RT04s – CMU	35.4		31.9	25.6	
RT05s	35.1	37.1	32.3	19.0	

- RT05s speaker misses, false alarms
  - misses: 13/53 = 24.5% speakers, 0.4% speaker time
  - false alarms: 5/53 = 9.4% speakers, 6.6% speaker time

Discussion / conclusions

- SDE Evaluation measure
  - harsh on T_{FA} because $T - T_{FA}$ in denominator
  - weights long duration speakers more
    - advantageous to ignore short duration speakers
    - high λ_{clust}
- BIC segmentation / clustering
  - nice idea based on *first principles*
  - still tunable parameters λ
  - why full covariance single mixture GMMs?
    - cancellation of exponent in likelihood calculation

$$\log \prod_i N(x_i, \mu, \Sigma) = -\sum_i \log(2\pi)^{d/2} \sqrt{|\Sigma|} - \underbrace{\frac{1}{2} \sum (x-\mu)^T \Sigma^{-1} (x-\mu)}_{0}$$

  - how about diagonal covariance, multiple mixtures?

No time / plans for next evaluation

- Use decoder for clustering process
  - use diagonal covariance GMM for speaker model
  - include overlap between speakers in network
- Use multiple distant microphone data
  - SAD: results from ICSI
  - SPKR: RT05s results not hopeful
- Investigate “absolute speaker ID”
  - “speaker spotting”
  - speaker tracking
  - speaker priors and evaluation measure
    - speaker speaking time entropy?†

† Jin et al., Proc NIST RT04s, ICASSP, 2004