Multimodal Clustering with Role Induced Constraints for Speaker Diarization

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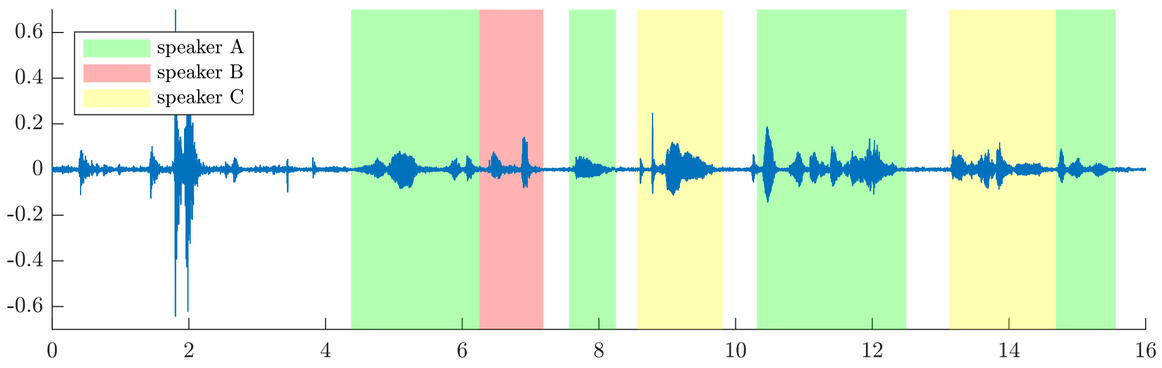
Speaker Diarization & Speaker Roles

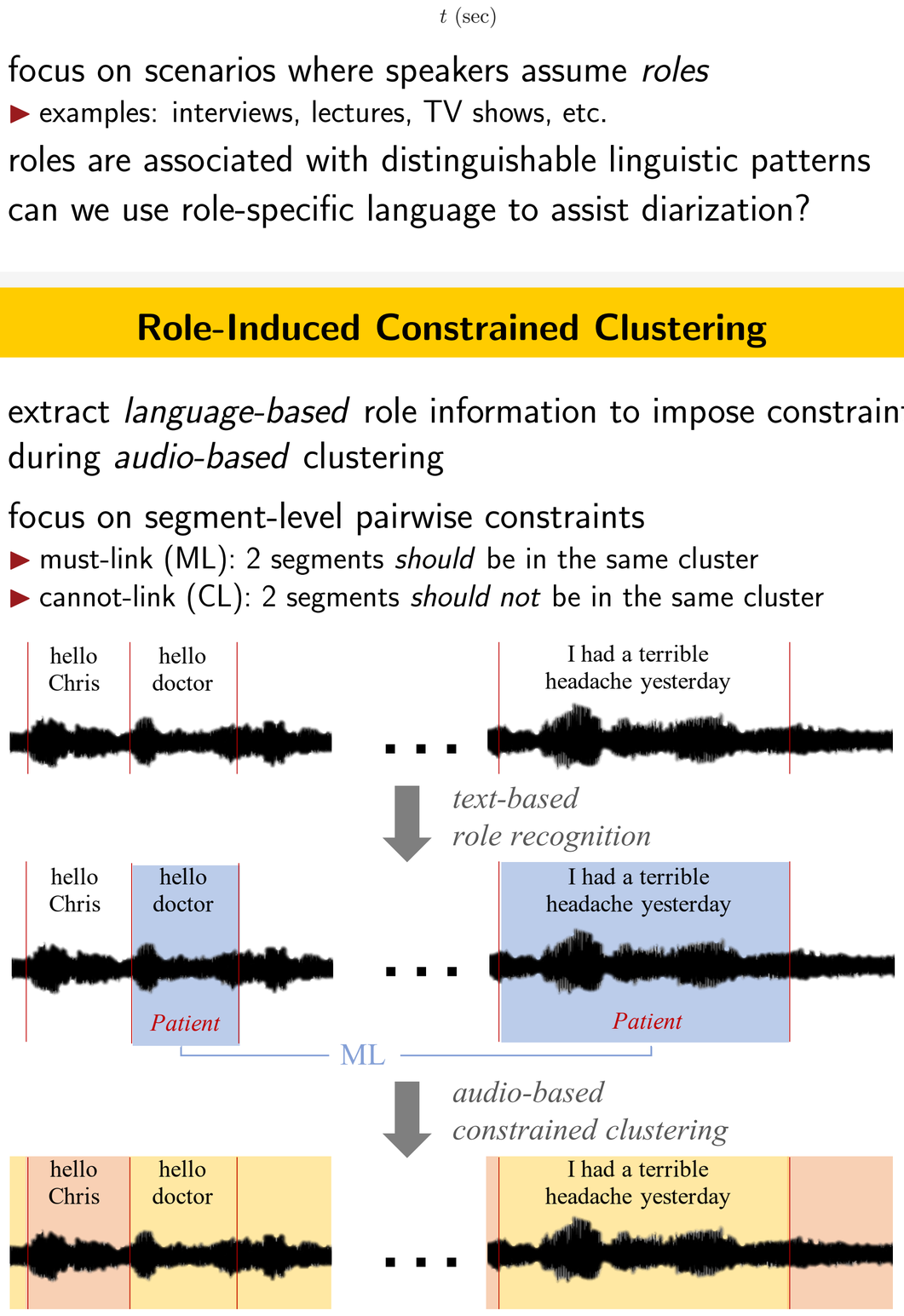
- diarization answers the question "who spoke when?"
- conventional approach:
  - speaker segmentation: find speaker change points
  - *speaker clustering*: cluster speaker-homogeneous segments



- focus on scenarios where speakers assume *roles*
  - examples: interviews, lectures, TV shows, etc.
- roles are associated with distinguishable linguistic patterns
- can we use role-specific language to assist diarization?

Role-Induced Constrained Clustering

- extract *language-based* role information to impose constraints during *audio-based* clustering
- focus on segment-level pairwise constraints
  - must-link (ML): 2 segments *should* be in the same cluster
  - cannot-link (CL): 2 segments *should not* be in the same cluster



- possible scenarios
  - different roles played by different speakers (e.g., teacher vs. students)
    ⇒ CL constraints between segments with different roles
  - different speakers play different roles (e.g., host vs. interviewer vs. host)
    ⇒ ML constraints between segments with same roles
  - every speaker mapped to a distinct role (e.g., doctor vs. patient)
    ⇒ both ML and CL constraints

Constrained Spectral Clustering

- construct pairwise similarity matrix $\mathbf{W}$
- construct role-based contraint matrix $\mathbf{Z}$ for a high-confidence subset of segments

$$\mathbf{Z}_{ij} = \begin{cases} +1, \text{ if } \exists \text{ ML constraint between } i \text{ and } j \\ -1, \text{ if } \exists \text{ CL constraint between } i \text{ and } j \\ 0, \text{ if } \nexists \text{ any constraint between } i \text{ and } j \end{cases}$$

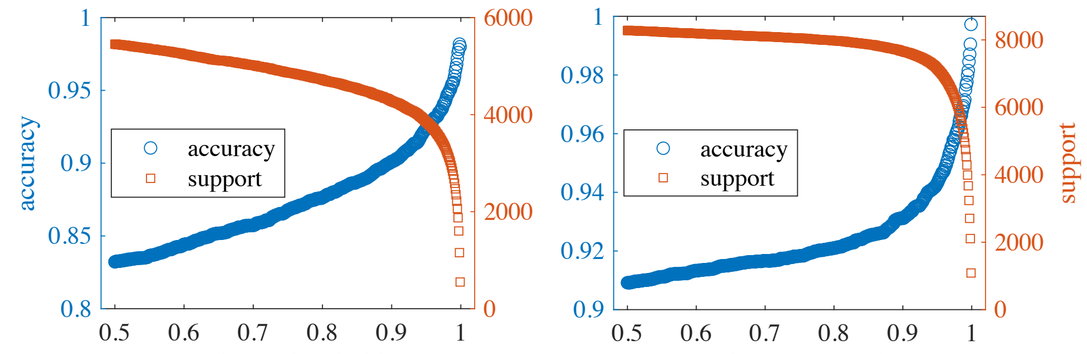
- propagate constraints via *Exhaustive and Efficient Constraint Propagation* (E^{2}CP) algorithm [1] and update $\mathbf{W}$
- apply spectral clustering

Datasets

- University Counseling Center (UCC) psychotherapy sessions
  - dyadic conversations
  - one-to-one mapping between speakers and roles
    one *therapist* vs. single *client* per session
  - apply both ML and CL constraints
  - total speaking time: therapist (26.7h) vs. client (46.7h)
- This American Life (TAL) podcast
  - multi-party conversations (18 speakers on average)
  - partial role information
    single *host* vs. multiple *non-hosts* per episode
  - apply CL constraints between segments with different roles
  - total speaking time: host (118.6h) vs. non-host (519.2h)

Extracting Role Information

- adapt a BERT model to classify the speaker roles
- make sure we don't impose wrong constraints
  - need for confidence proxy ⇒ use softmax values of classifier
  - trade-off decision: very confident or a lot of constraints?



(a) UCC data (b) TAL data

accuracy and support for the BERT-based classifier when only segments with softmax value above some threshold are taken into account

Experiments & Results

- use oracle segmentation + oracle transcriptions
  ⇒ only evaluate clustering performance
- speaker representation: x-vectors
- apply initial ML/CL constraints on ∼ 40% of the segments and integrate constraints via E^{2}CP

diarization error rate (%) – lower is better

	unconstrained clustering (audio-only)	**constrained clustering** (multimodal)	**role-based classification** (language-only)
UCC	1.38	**1.31**	10.34
TAL	42.22	**23.86**	63.01

Conclusion

- improved diarization results for both dyadic and multi-party role-playing interactions
  - improved estimation of the number of speakers in the multi-party scenario
- future work
  - focused on language-based constraints – what about other modalities?
  - can we incorporate soft constraints?

References

[1] Z. Lu, Y. Peng, "Exhaustive and efficient constraint propagation: A graph-based learning approach and its applications". Int J Comput Vis (2013)

[2] A. Tripathi, et. al., "Turn-to-diarize: Online speaker diarization constrained by transformer transducer speaker turn detection". ICASSP (2022)

[3] N. Flemotomos, P. Georgiou, S. Narayanan, "Linguistically aided speaker diarization using speaker role information". Odyssey (2020)