Noise Reduction in Robot Audition

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Technical Aspects of Multimodal Systems

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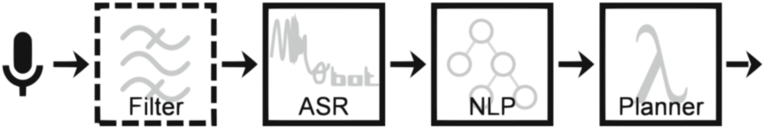
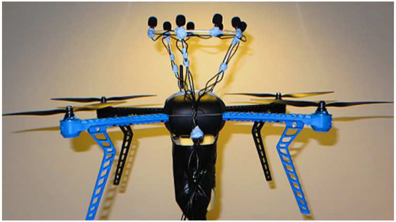
Outline

What is Robot Audition?

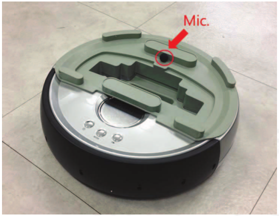


[MHP19]

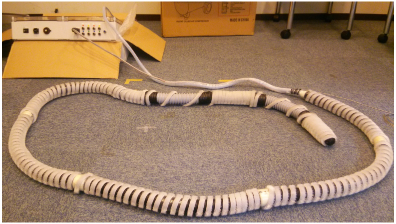
Use Cases



[WC16]



[PRS+14]



[MYM+18]

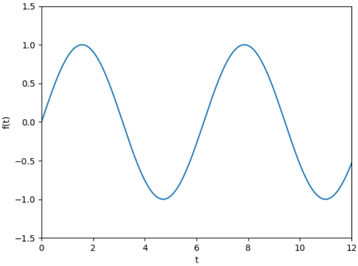
[NAO]

Main Challenges in Robot Audition

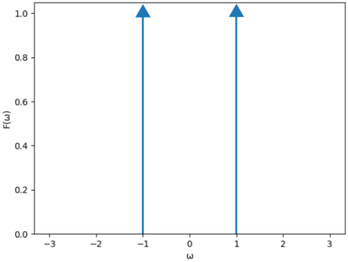
- Real-time processing
- Robustness against noise
  - Background noise
  - Reverberation
  - Ego noise

1D signal characterization:

- Amplitude
- Phase
- Frequency

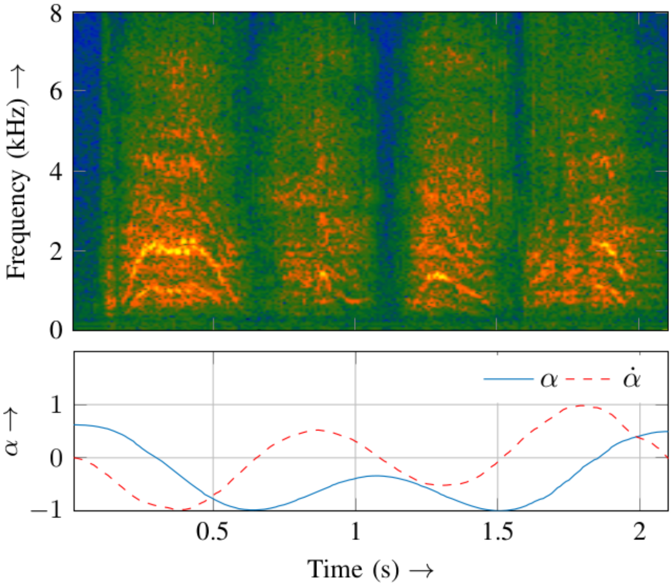


spatial



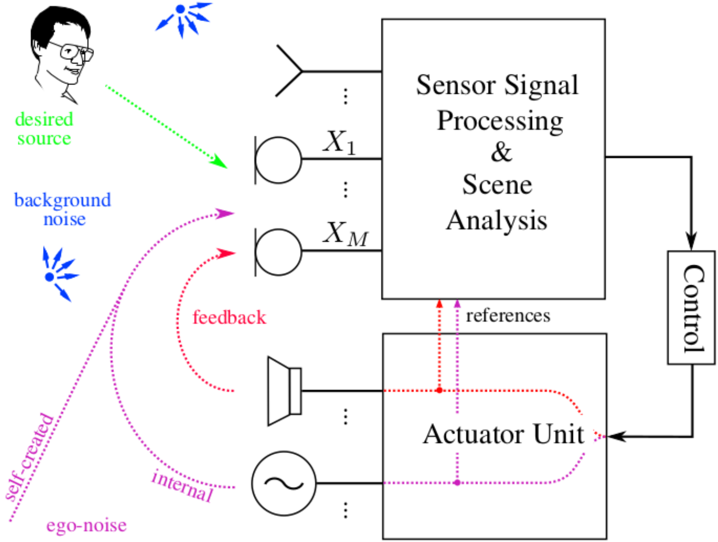
spectral

Local Analysis



[SDK16]

Typical Sound Field



[SLK18]

Presented Approaches

- Dictionary based:

  Ego-Noise Reduction Using a Motor Data-Guided Multichannel Dictionary
  Alexander Schmidt[1], Antoine Deleforge[2] and Walter Kellermann[1]
  2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)

- Matrix Factorization:

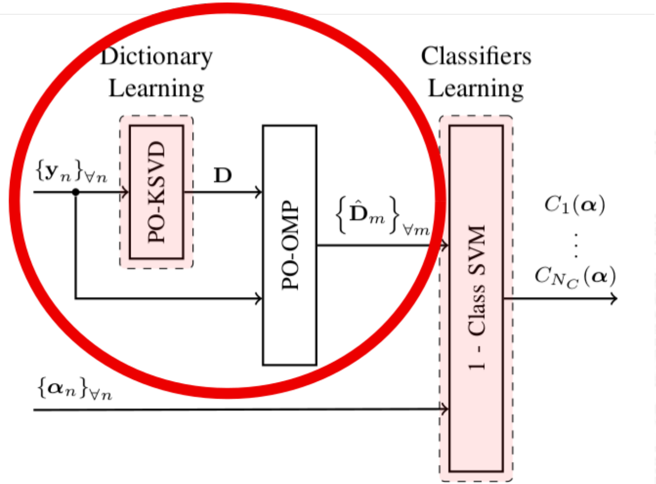
  Multichannel Nonnegative Matrix Factorization for Ego-Noise Suppression
  Thomas Haubner[1], Alexander Schmidt[1] and Walter Kellermann[1]
  2018, Speech Communication; 13th ITG-Symposium

[1]Friedrich-Alexander University, Erlangen-Nürnberg
[2]INRIA center of Rennes, France

Strategy - Dictionary based Approach

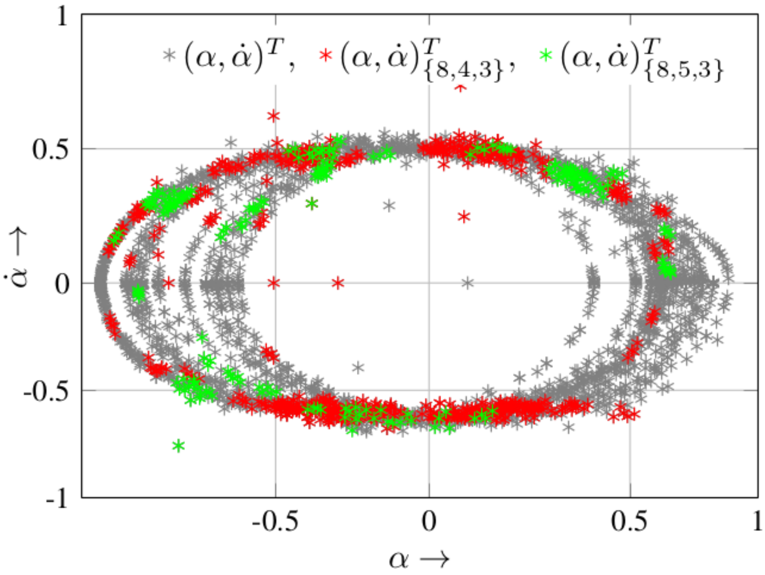
- Capture characteristics of ego noise
- Save prototype signals (atoms) in dictionaries
- Associate motor data to atoms
- Noise removal by subtracting atoms

Approach: Starting Point



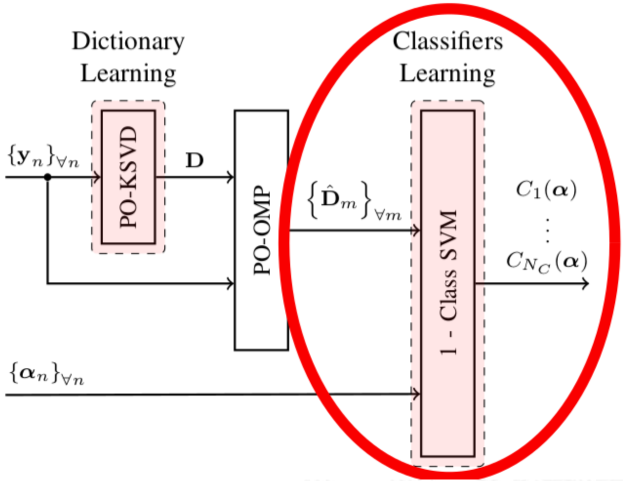
Adapted from [SDK16]

Motor Data - Atom Association



[SDK16]

Adaption



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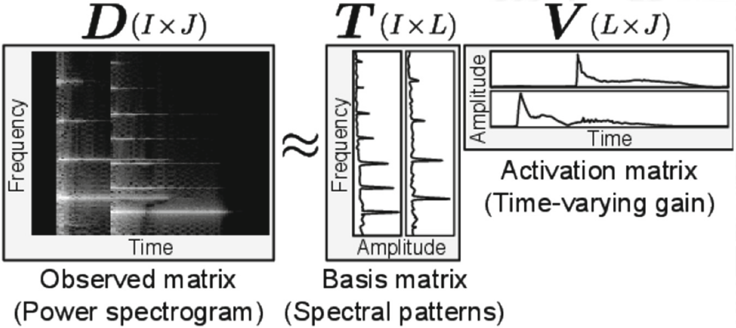
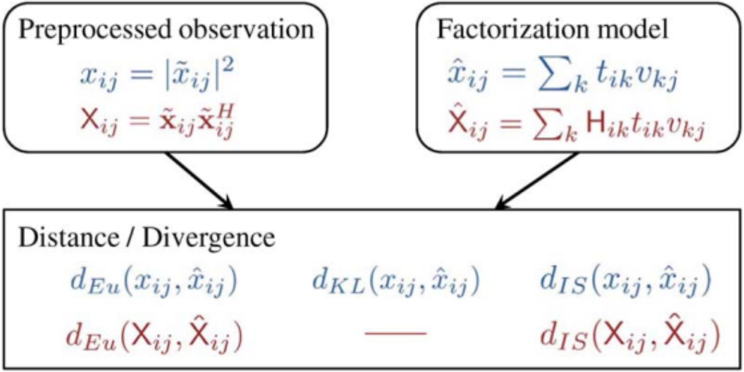
Strategy - Matrix Factorization Approach (MNMF)

- Goal: Separate target source from noise
- Approximate signal with basis and activation matrices
- Minimize difference between original and approximated signal
- Assign bases to noise or speech
- Reconstruct speech signal



[MIM+17]

General MNMF Approach

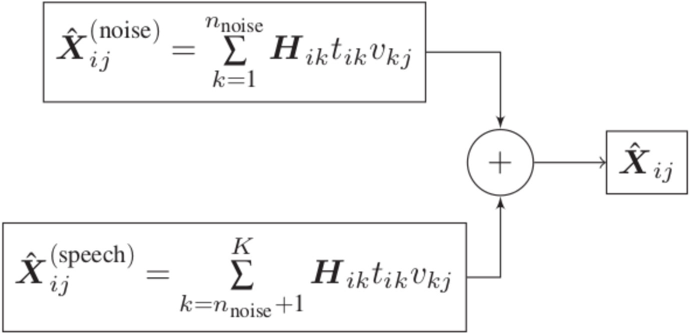


[SKAU13]

blue: single-channel NMF
red: multichannel NMF

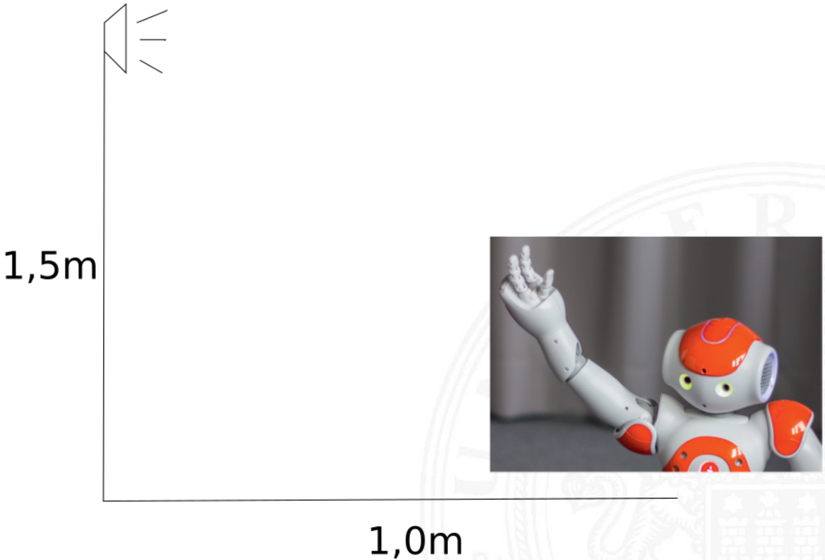
Adaption

1. Learn ego noise model
2. On input signal:
   2.1 Add bases and transfer matrices to model
   2.2 Minimize difference to real signal
   2.3 Assign bases to noise resp. speech
   2.4 Reconstruct speech signal



[HSK18]

Evaluation Experiment



Adapted from [HSK18]

Results

Dictonary based

	SIR [dB]	SDR [dB]	RR[%]
Classifier	14.71	2.64	73.0
PO-OMP	14.46	2.57	71.8
NMF	2.51	0.8	45.2
Unprocessed	-5.48	-8.15	36.1

[SDK16]

Matrix Factorization

	SDR in dB	SIR in dB	SAR in dB
Unprocessed	-2.30	-2.26	258.18
SNMF	6.77	12.59	9.31
ILRMA	8.44	10.96	12.85
Proposed	10.76	23.70	13.37

[HSK18]

SIR: Signal-to-Inference-Ratio

SDR: Signal-to-Distortion-Ratio

Conclusion

Dictionary based

- Good noise suppression
- Fast execution on input signal
- Complex training is needed

Matrix Factorization

- Stronger noise suppression
- Minimization for every incoming signal required
- Complex training is needed

Thank you for your attention.
Do you have any questions?

References

[HSK18] T. Haubner, A. Schmidt, and W. Kellermann, *Multichannel nonnegative matrix factorization for ego-noise suppression*, Speech Communication; 13th ITG-Symposium, Oct 2018, pp. 1–5.

[MHP19] Mauricio Matamoros, Karin Harbusch, and Dietrich Paulus, *From commands to goal-based dialogs: A roadmap to achieve natural language interaction in robocup@home*, RoboCup 2018: Robot World Cup XXII (Cham) (Dirk Holz, Katie Genter, Maarouf Saad, and Oskar von Stryk, eds.), Springer International Publishing, 2019, pp. 217–229.

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