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FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
TECHNISCHE FAKULTÄT

EFFICIENT MULTICHANNEL NONLINEAR ACOUSTIC ECHO CANCELLATION BASED ON A COOPERATIVE STRATEGY

Mhd Modar Halimeh and Walter Kellermann

{mhd.m.halimeh, walter.kellermann}@fau.de

Multimedia Communications and Signal Processing, FAU Erlangen-Nürnberg, Germany

1. Outline

Goal

An efficient approach for Multichannel **N**onlinear **A**coustic **E**cho **C**ancellation (**NAEC**)

Challenges

- Simultaneously excited nonlinearities
- High dimensionality of the problem
- High computational cost

Proposed Method:

Cooperative **M**ultichannel **AEC** (**CM-AEC**)

- Decomposes the problem into multiple smaller problems
- Allows different particle filters to share their state
- Efficient model by coupling microphones
- Two variants are studied and realized

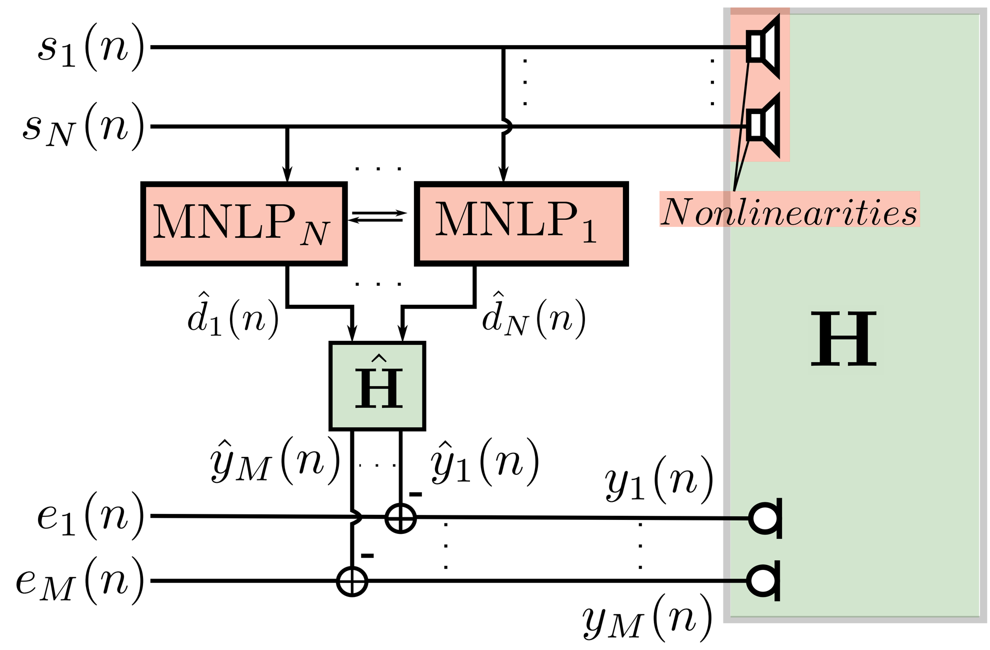
2. Problem Formulation

Echo paths

- Each loudspeaker introduces nonlinear distortions to the far-end signal $\{s_i\}_{i=1}^{N}$
- Linear transmission characteristics from the N loudspeakers to the M microphones are represented by $\mathbf{H}$

Echo paths approximation

- Each nonlinearity is approximated by a **M**emoryless **N**onlinear **P**reprocessor (**MNLP**) $\hat{d}_i(n) = \sum_{l=1}^{L_a} \hat{a}_{i,l} \cdot f_{i,l}(s_i(n)) = \hat{\mathbf{a}}_i^{\mathrm{T}} \boldsymbol{f}_i(s_i(n))$
- $\mathbf{H}$ is approximated by block matrix $\hat{\mathbf{H}}$



3. The Cooperative Multichannel AEC

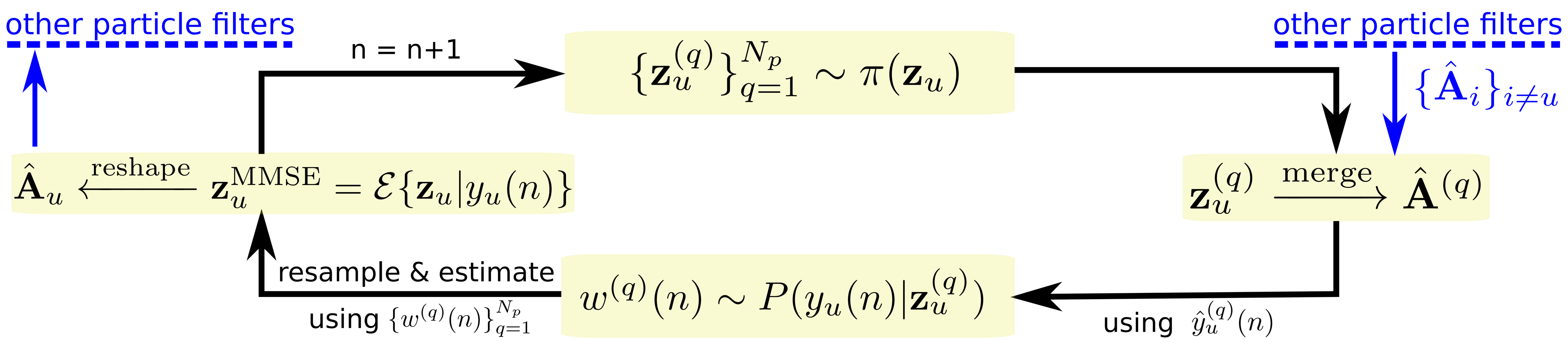
Identification of The Nonlinear Part

- Estimating the matrix $\hat{\mathbf{A}} = [\mathbf{a}_1, ..., \mathbf{a}_N] = \begin{bmatrix} \hat{a}_{1,1} & \dots & \hat{a}_{N,1} \\ \vdots & \ddots & \vdots \\ \hat{a}_{1,L_a} & \dots & \hat{a}_{N,L_a} \end{bmatrix}$ via submatrices

$$\hat{\mathbf{A}}_1 = \begin{bmatrix} \hat{a}_{i_1,1} & \dots & \hat{a}_{I_1,1} \\ \vdots & \ddots & \vdots \\ \hat{a}_{i_1,L_a} & \dots & \hat{a}_{I_1,L_a} \end{bmatrix} \quad \vdots \quad \hat{\mathbf{A}}_U = \begin{bmatrix} \hat{a}_{i_U,1} & \dots & \hat{a}_{I_U,1} \\ \vdots & \ddots & \vdots \\ \hat{a}_{i_U,L_a} & \dots & \hat{a}_{I_U,L_a} \end{bmatrix}$$

Estimating $\hat{\mathbf{A}}_u, \quad u \in \{1, ..., U\}$

- $\hat{\mathbf{A}}_u$ is arranged as $\mathbf{z}_u = [\hat{\mathbf{a}}_{i_u}^{\mathrm{T}}, ..., \hat{\mathbf{a}}_{I_u}^{\mathrm{T}}]^{\mathrm{T}}$ and adapted by a **particle filter** using $y_u(n)$ as follows:



Two variants • **CM G**aussian **P**article **F**ilter (**CM-GPF**) [1] • **CM E**litist **R**esampling **P**article **F**ilter (**CM-ERPF**) [2]

Identification of The Linear Part

- The block matrix $\hat{\mathbf{H}}$ is adapted by the **G**eneralized **F**requency **D**omain **A**daptive **F**iltering (**GFDAF**) algorithm [3]

4. Evaluation

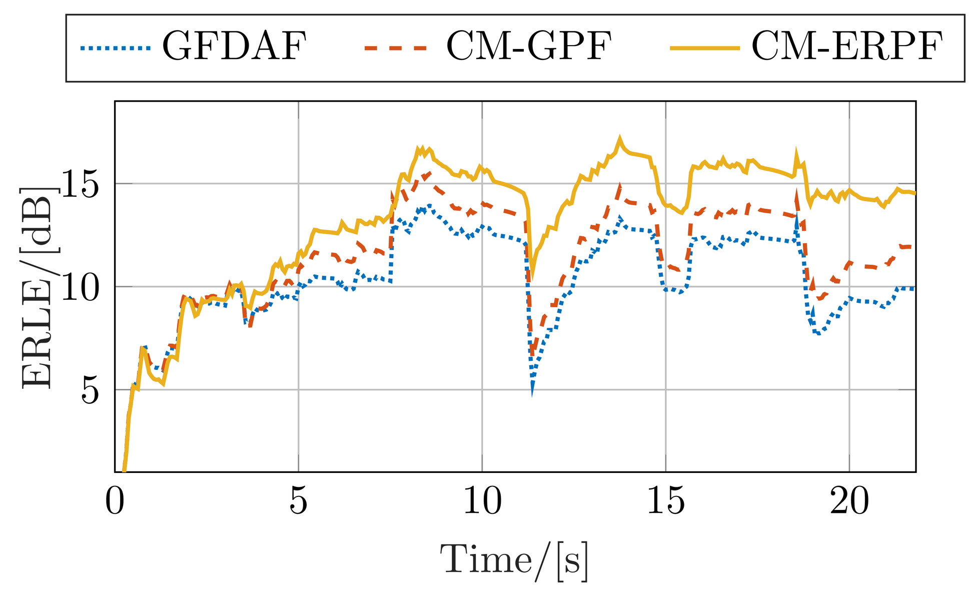
Synthesized nonlinear distortions

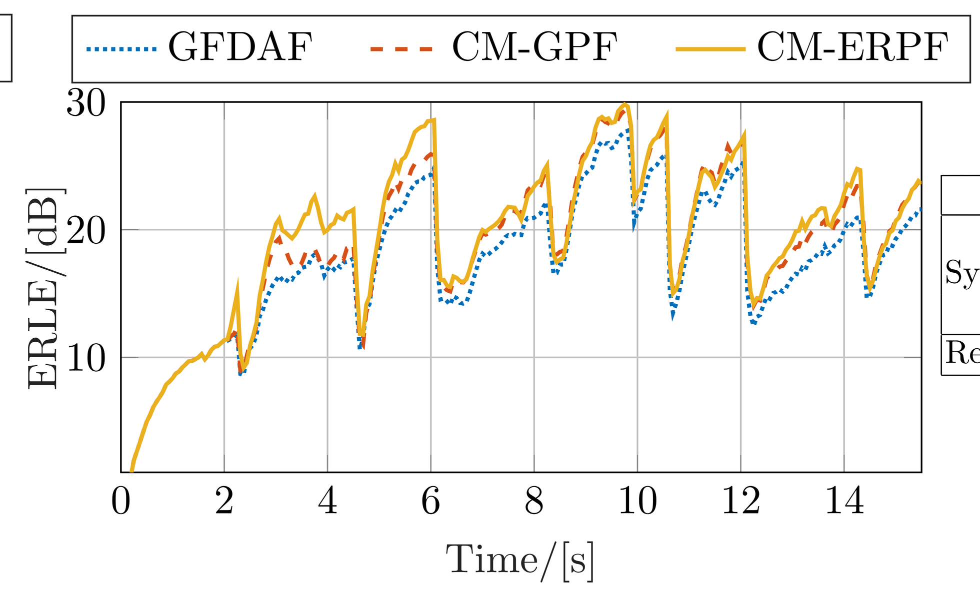
- 5 loudspeakers, 2 microphones
- Simulated soft-clipping nonlinearity
- Recorded impulse response with $T_{60} = 450\mathrm{ms}$

Real nonlinear distortions

- Smart speaker prototype: 8 loudspeakers, 7 microphones
- Recording in a room with $T_{60} = 550\mathrm{ms}$

Evaluation measure: $\mathrm{ERLE}(n) = 10\log_{10}\left(\frac{1}{M}\sum_{j=1}^{M}\frac{\mathrm{E}\{y_j^2(n)\}}{\mathrm{E}\{e_j^2(n)\}}\right)$





Average ERLE [dB]

	SNR [dB]	GFDAF	GPF	ERPF
Syn	30	10.4	11.5	13.4
	20	9.8	10.9	11.8
	10	7.1	7.4	8.1
Real	30	18.1	19.0	20.2

5. Conclusions

The CM-AEC approach

- is a new particle filter-based MIMO NLAEC method
- models the simultaneously excited nonlinearities using an efficient model
- was verified for both synthesized and real distortions using two different variants

References

[1] J. Kotecha and P. Djuric, “Gaussian particle filtering,” IEEE Trans. Signal Process., vol. 51, no. 10, pp. 2592–2601, Oct. 2003.
[2] M. M. Halimeh et al., “Nonlinear acoustic echo cancellation using elitist resampling particle filter,” in ICASSP, April 2018, pp. 236–240.
[3] M . Schneider and W. Kellermann, "The generalized frequency-domain adaptive filtering algorithm as an approximation of the block recursive least-squares algorithm", EURASIP Journal on Advances in Signal Processing. 2016.

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