Echo-aware Dataset

Echo-aware datasets

⚠ Everything so far was a simulation

Echo-aware database requires:

- annotation of the echoes
- annotation of the geometry
- should cover a vast number of echo-aware applications
- expertise in signal processing, acoustics
- proper recording devices

dEchorate

Characteristics of dEchorate

- different room configurations and RT60 ($\rightarrow$ flipping wall panels)
- 6 array $\times$ 5 mics $\times$ 4 sources $\times$ 11 wall conf. $=$ **1320 annotated RIRs** at 48 kHz
- geometry annotation $\Leftrightarrow$ echo annotation in the RIRs
- real RIRs $\Leftrightarrow$ synthetic RIRs
- application to Acoustic Echo Retrieval, Room Geometry Estimation, Speech Enhancement, ...
- silence, chirps, speech, noise, diffuse bubble noise for 64 GB

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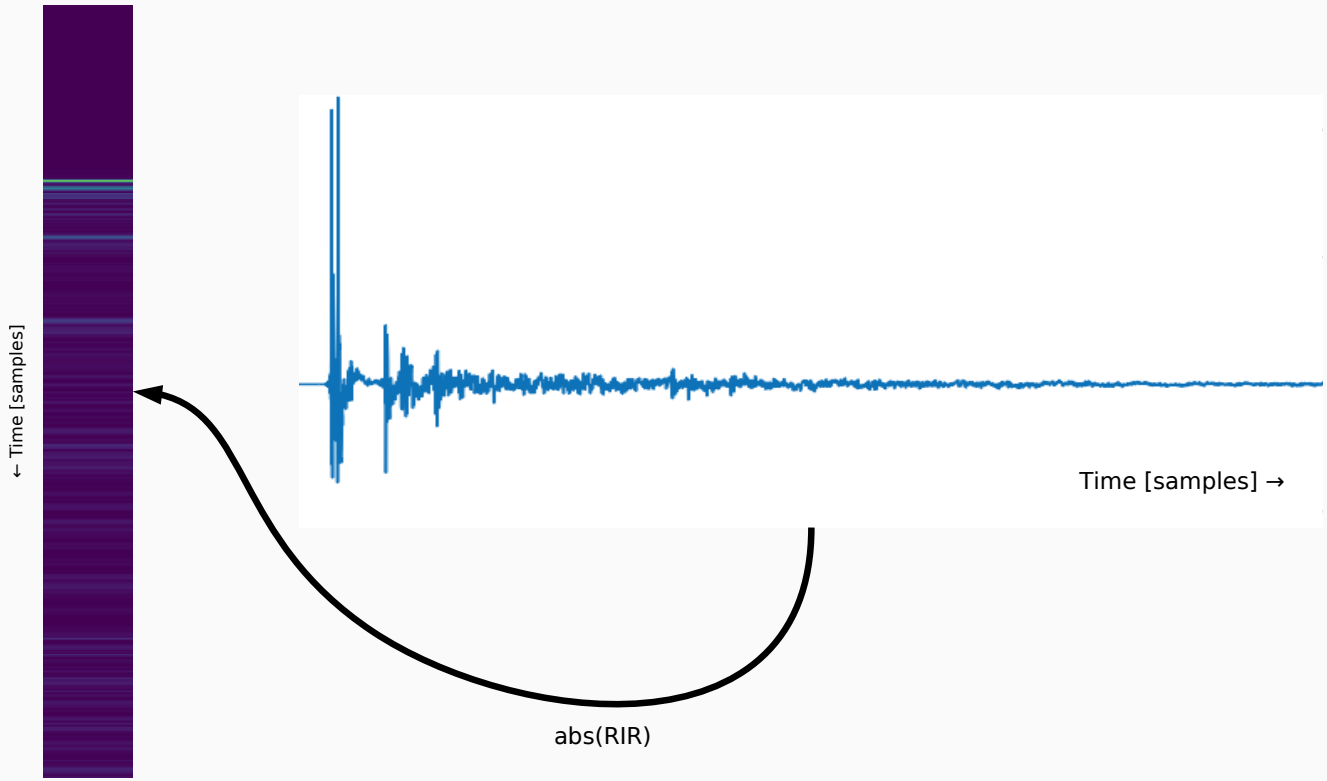
dEchorate: the skyline view



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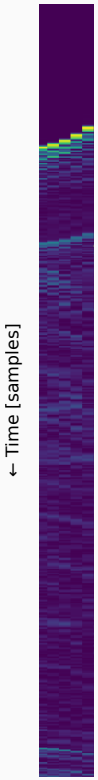

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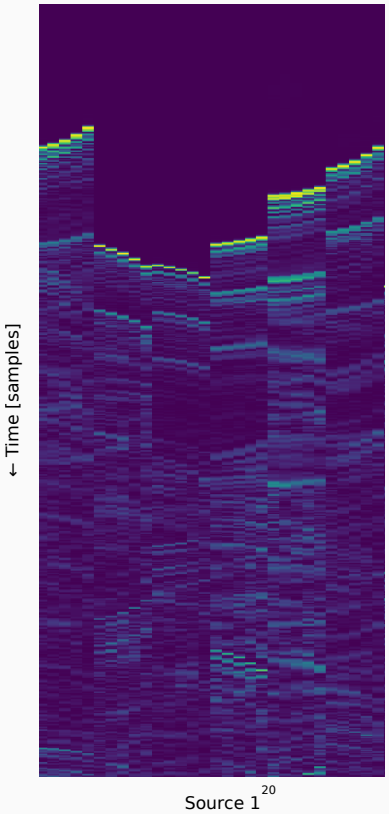

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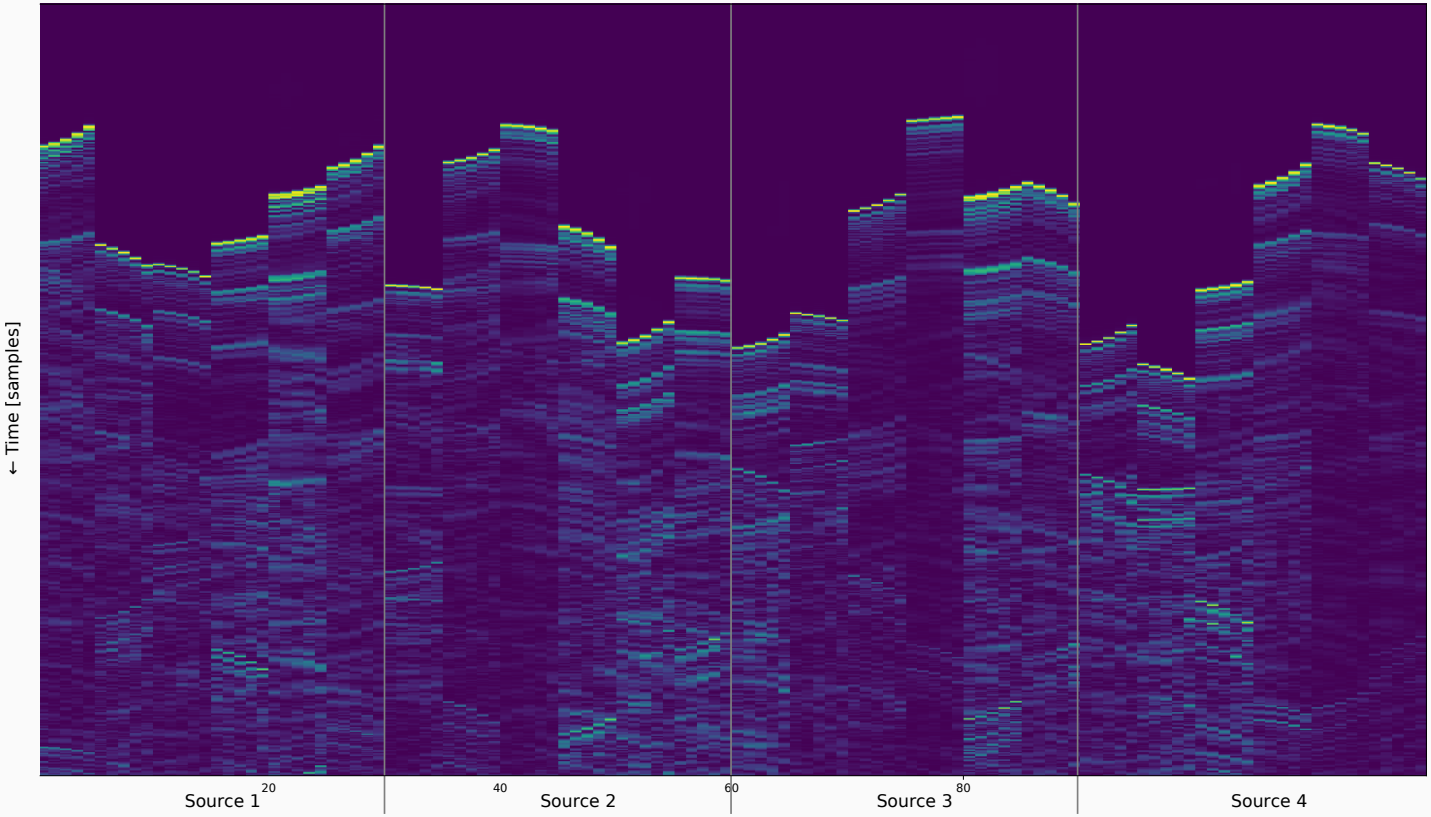

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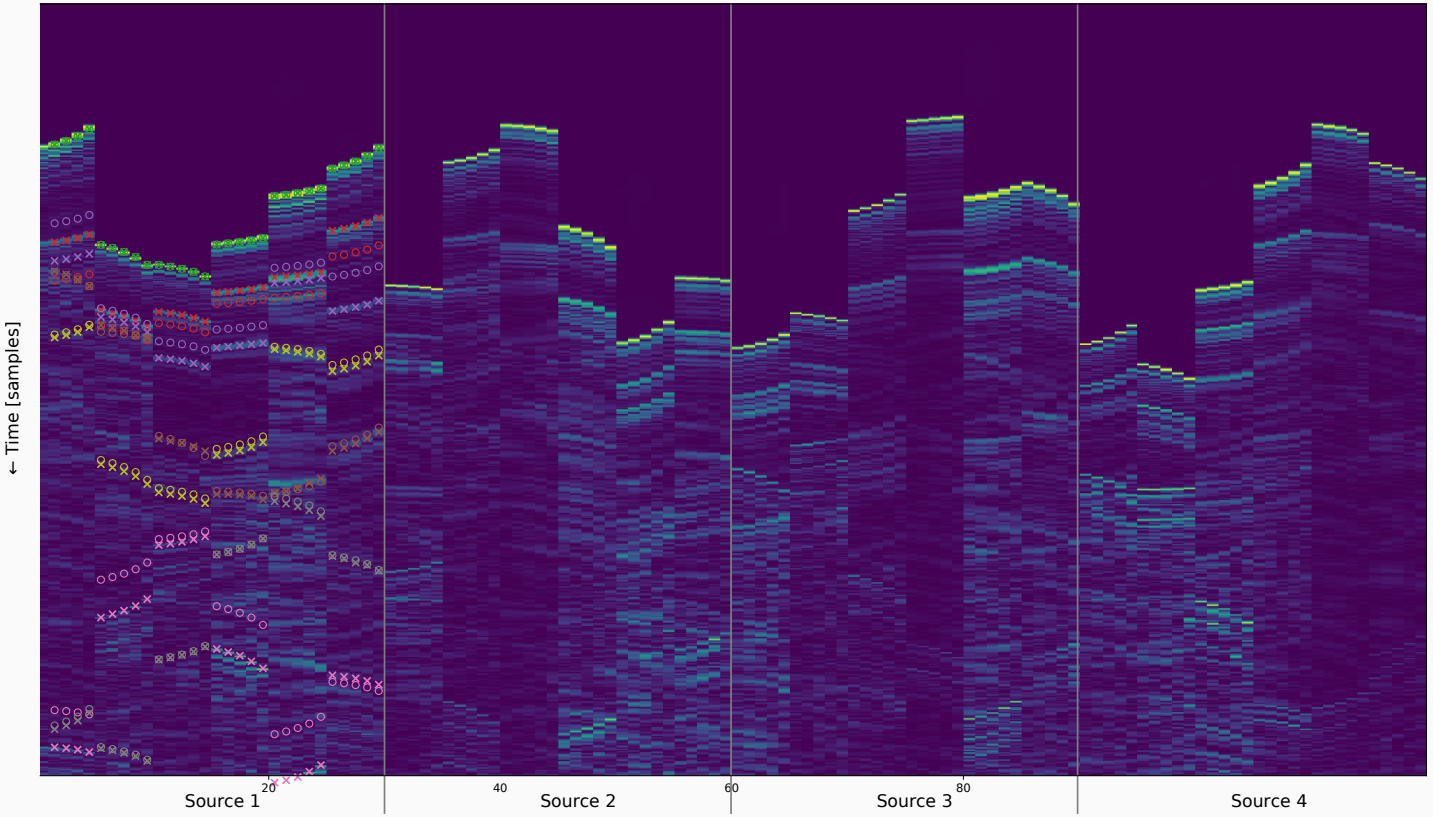

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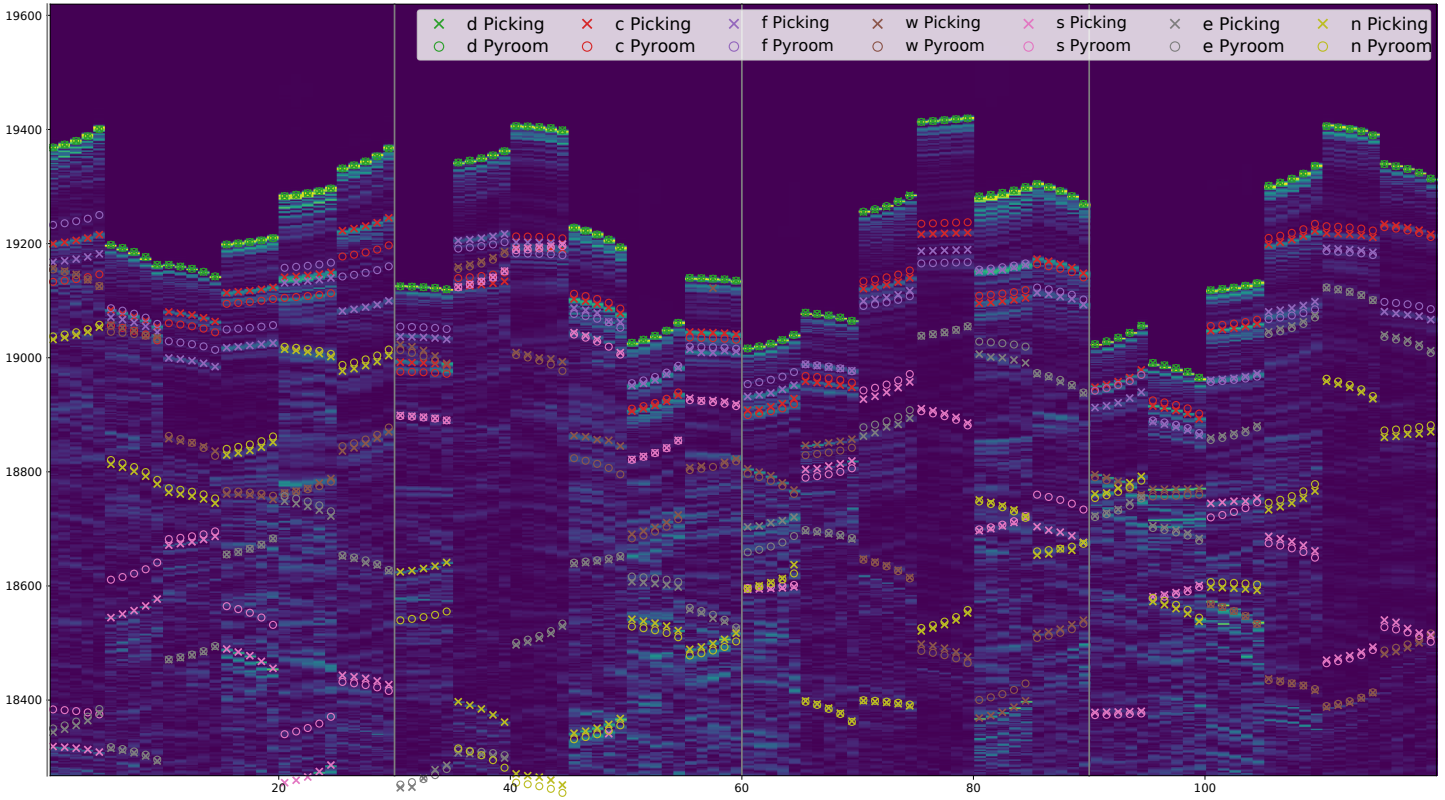

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Speech Enhancement with dEchorate

Speech Enhancement (SE)

Improve the quality of a target sound source w.r.t.:

interfering sources	+	noise	+	reverberation
↓		↓		↓
source separation		denoising		dereverberation room equalization

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SE via **linear spatial filtering** in the STFT domain

$$\mathbf{X}[f,t] = \mathbf{H}[f]\mathbf{S}[f,t] + \mathbf{N}[f,t] \in \mathbb{C}^I \quad \longrightarrow \quad \mathbf{W}^{\mathsf{H}}[f] \in \mathbb{C}^I \quad \longrightarrow \quad \mathbf{W}^{\mathsf{H}}[f]\mathbf{X}[f,t] \approx \mathbf{S}[f,t]$$

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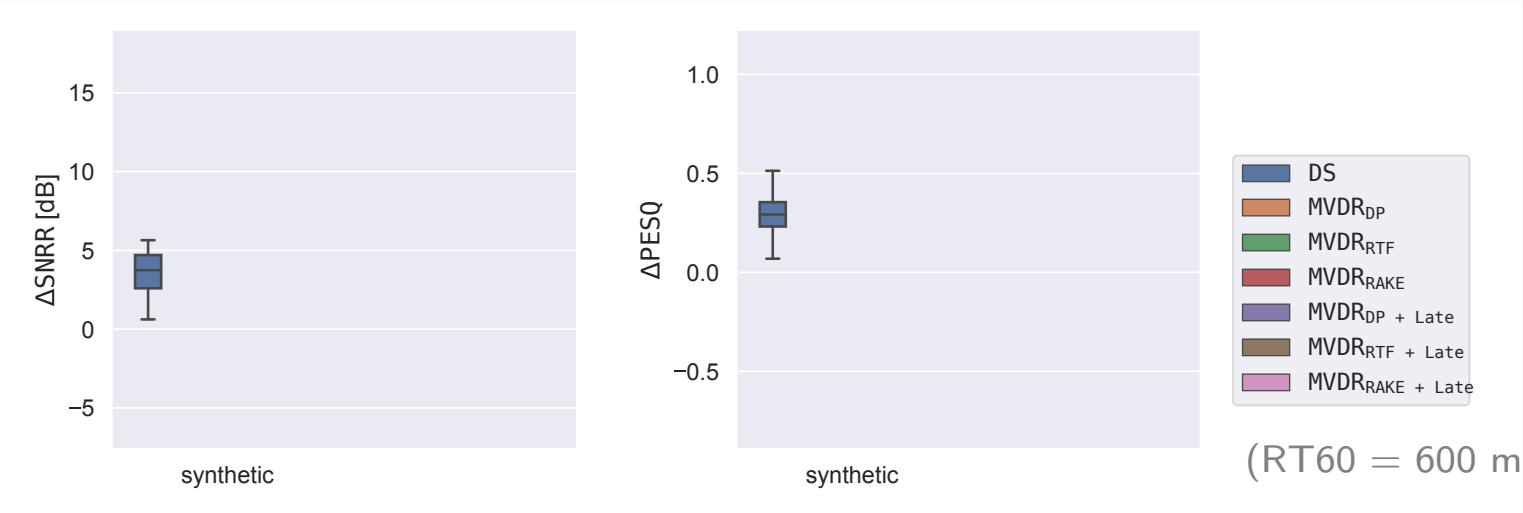
$$\widehat{\mathbf{W}} = \arg\min_{\mathbf{W}} \mathbb{E}\left\{ \left\| \mathbf{W}^{\mathsf{H}}\mathbf{X} \right\|_2^2 \right\} \quad \text{s.t.} \quad \mathbf{W}^{\mathsf{H}}\mathbf{H} = 1$$

Reducing output energy + distortionless ⇔ reduce any uncorrelated noise

Speech Enhancement with dEchorate

Methods	Noise covariance matrix	RIRs
DS	-	Direct path (AOA)

Metrics: Signal to Noise and Reverberant Ratio (SNRR) and Speech Quality (PESQ)



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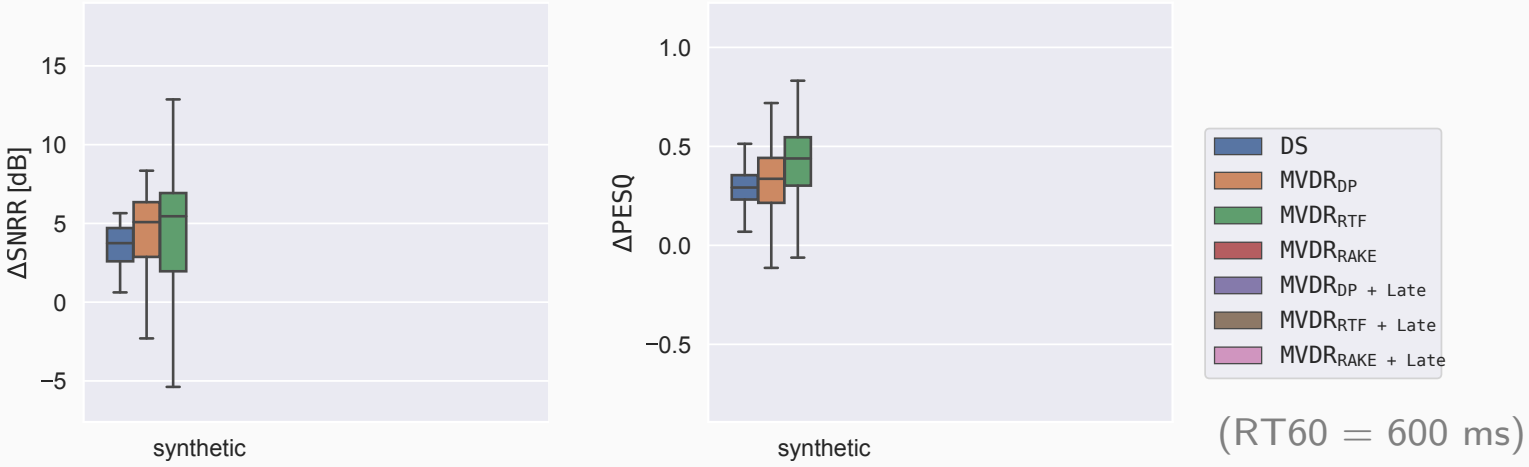

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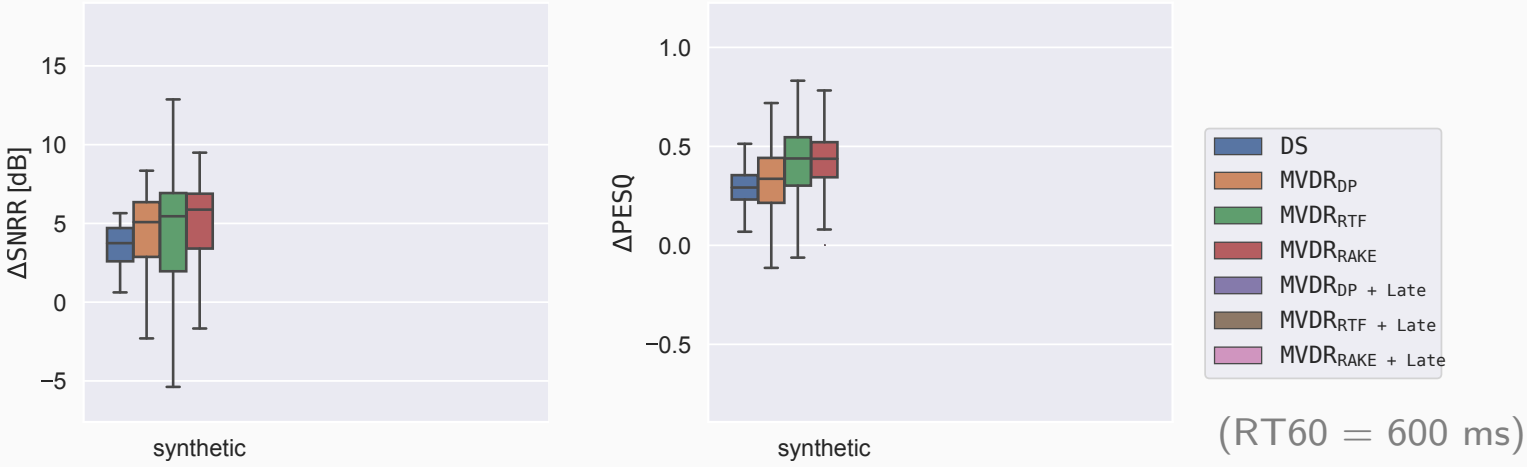

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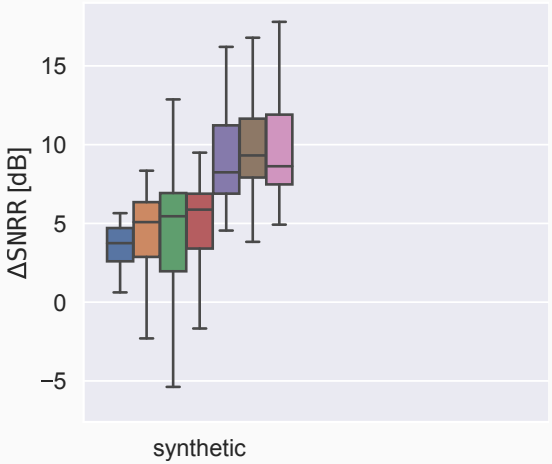

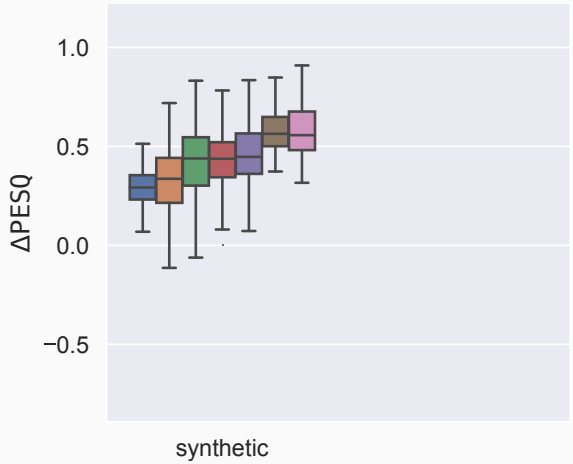

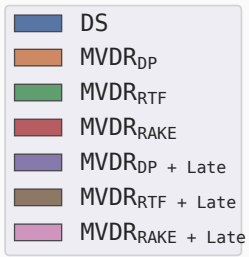

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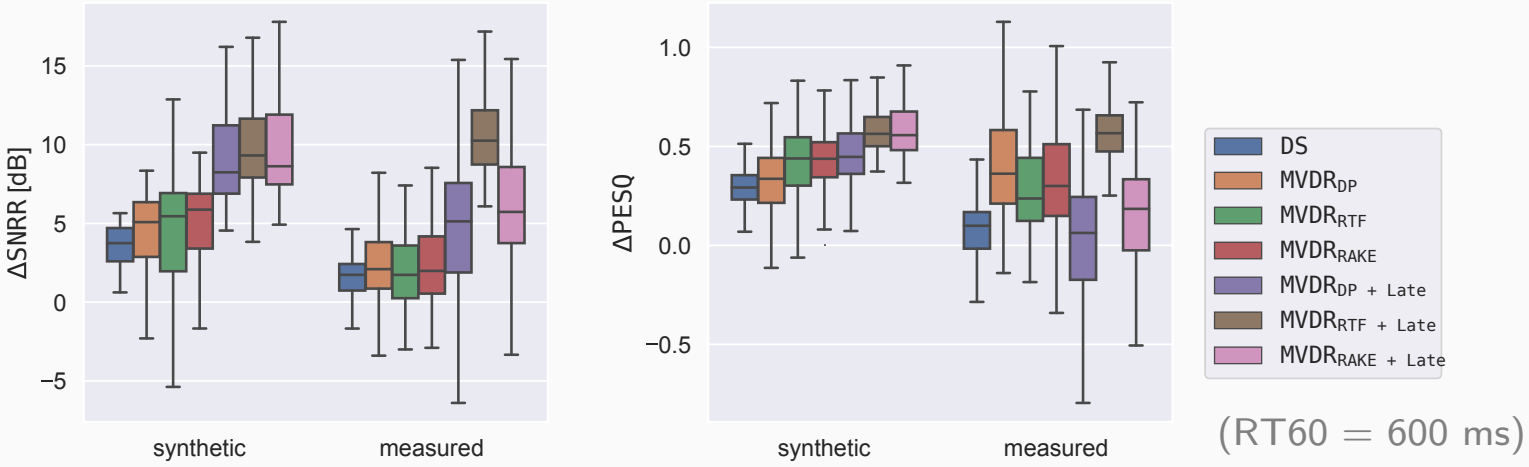

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Conclusion

Summary of contributions

How to estimate them?

In passive stereo scenario:

- Analytical method
  - ✓ direct estimation
  - ✗ depends on source and # echoes
- Learning-based method
  - ✓ estimation on first echo' TDOAs
  - ✗ only on synthetic data and noise source

How to use them?

- Source Localization
  - ✓ 2D DoA estimation with 2 mic
  - ✗ depends on the echo estimator
- Speech Enhancement
  - ✓ in theory early echoes helps
  - ✗ ... need to be accurately estimated
- Source Separation ↰
- Room Geometry Estimation ↰

Where to find them?

- `dEchorate`
  Echo-aware database for both estimation and application
  - ✓ echo annotation ⇔ geometry annotation
  - ✓ synthetic ⇔ real RIRs

Echo-aware perspective

Directions for future work:

- on **estimation**
  - develop theoretical guaranties for off-grid acoustic echo retrieval
  - for DNN: extended physics-based learning or other learning paradigm
- on **application**
  - other field of echoes: Seismology, Underwater acoustic, Volcanology, etc.
- on `dEchorate`
  - Synthetic to Real RIRs (style transfer, new type of acoustic simulator)
  - Benchmark data for echo-aware algorithms
- **"close the loop":** echo estimation $\Leftrightarrow$ audio analysis
  - in the thesis only the $\Rightarrow$

List of publications and artifacts

- On estimation
  - deep learning method in [Di Carlo et al., 2019]
  - `Blaster`: analytical method in [Di Carlo et al., 2020]
- On applications
  - `Mirage`: sound source localization in [Di Carlo et al., 2019]
  - `Separake`: sound source separation in [Scheibler et al., 2018]
- On data
  - `dEchorate`: database (journal in progress)
- Other
  - Signal Processing CUP 2019 [Deleforge et al., 2019]
  - LOCATA Challenge 2019 [Lebarbenchon et al., 2018]
  - Collaboration with Honda Research Group on multichannel `Mirage`

Code

- `dEchorate`: GUI and code for `dEchorate`
- `Risotto`: ReTF estimation
- `Brioche`: echo-aware Spatial filtering
- `pyMBSSLocate`: MBSSLocate in Python
- `Separake`: Multichannel NMF in Python

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Thank you!

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