Pattern Recognition Lab

sivantos the hearing company

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

Deep Neural Networks for Noise Reduction under Hearing Aid Side Conditions

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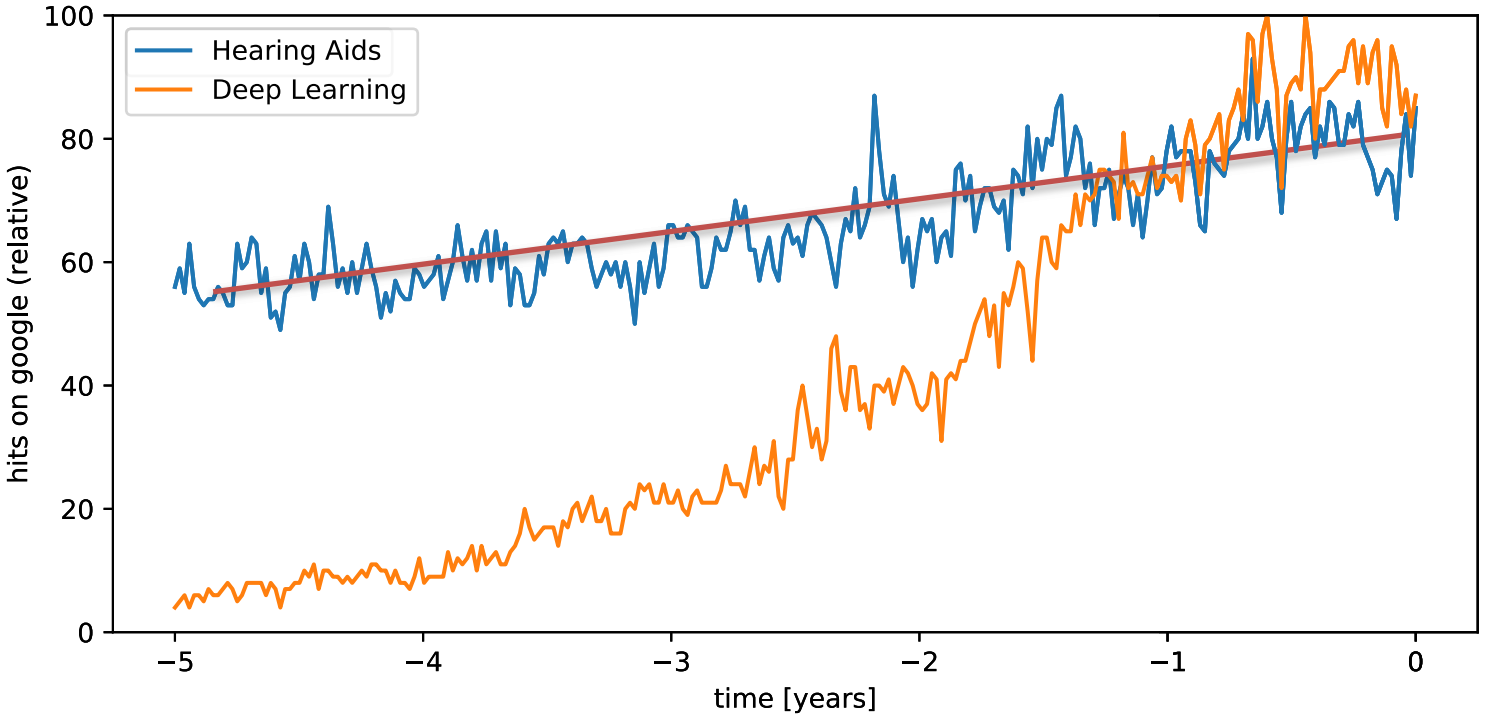
IHCON 2018, Lake Tahoe, CA, United States

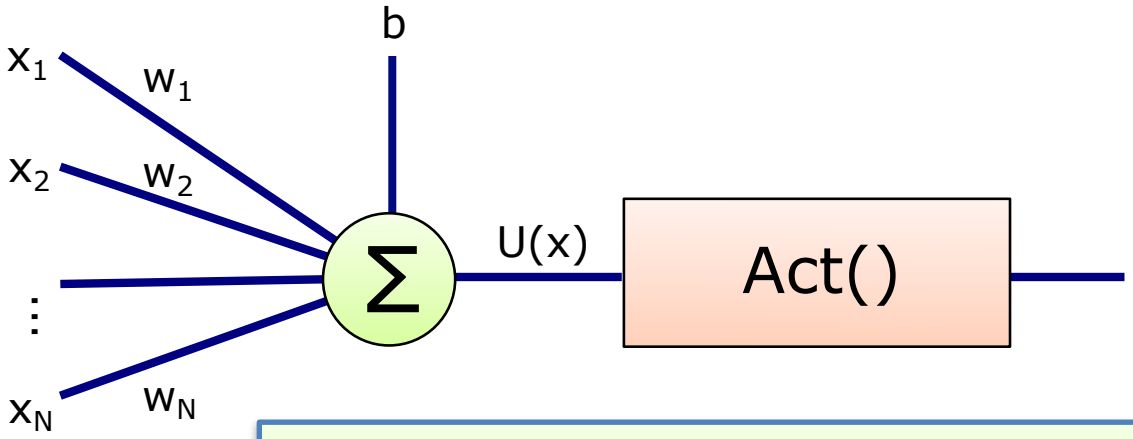
Image by the_tahoe_guy@flickr.com

Attention



[google trends: "hearing aids" vs. "deep learning"]

What is deep learning anyway?

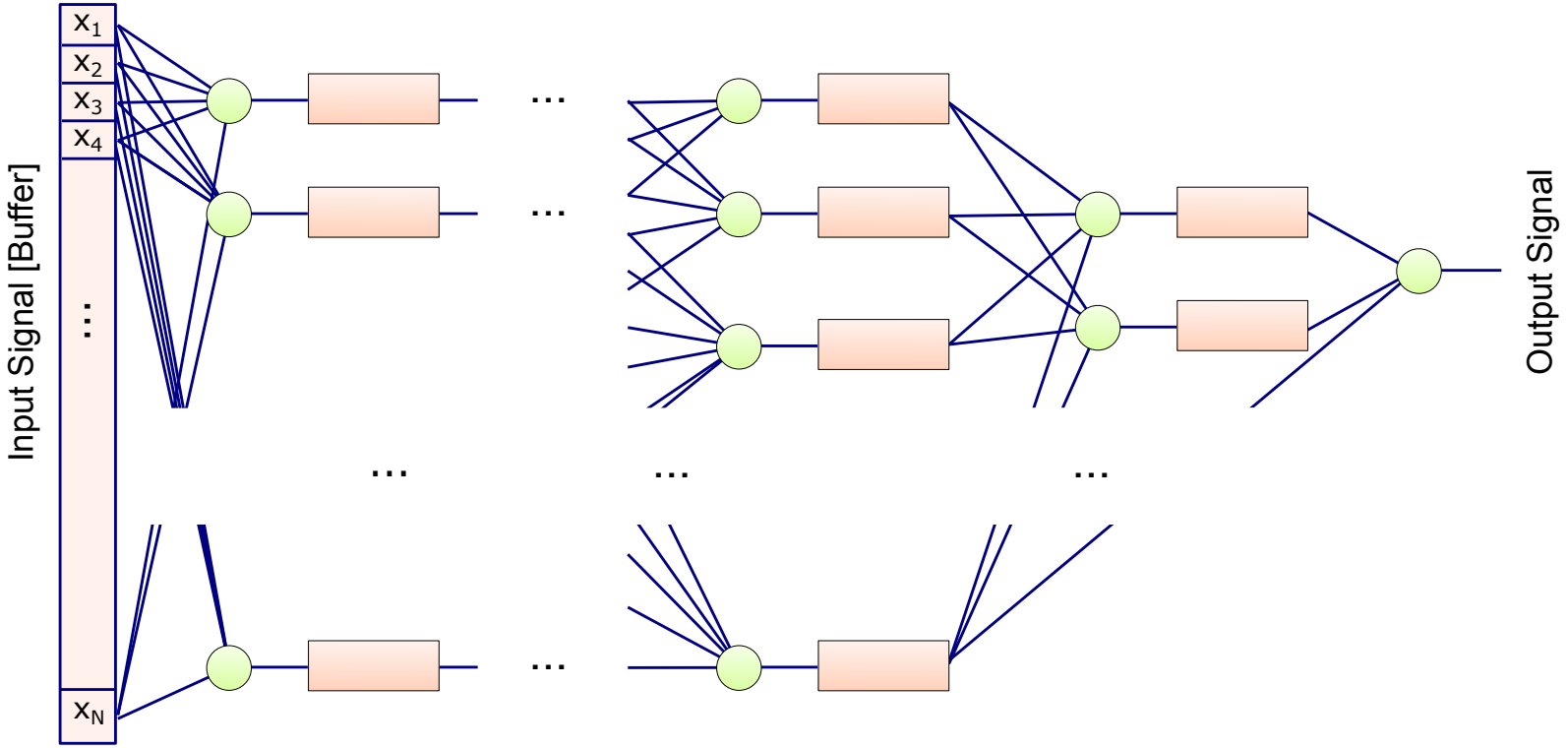


$$U(X) = b + x_1 \cdot w_1 + x_2 \cdot w_2 + \ldots + x_N \cdot w_N$$

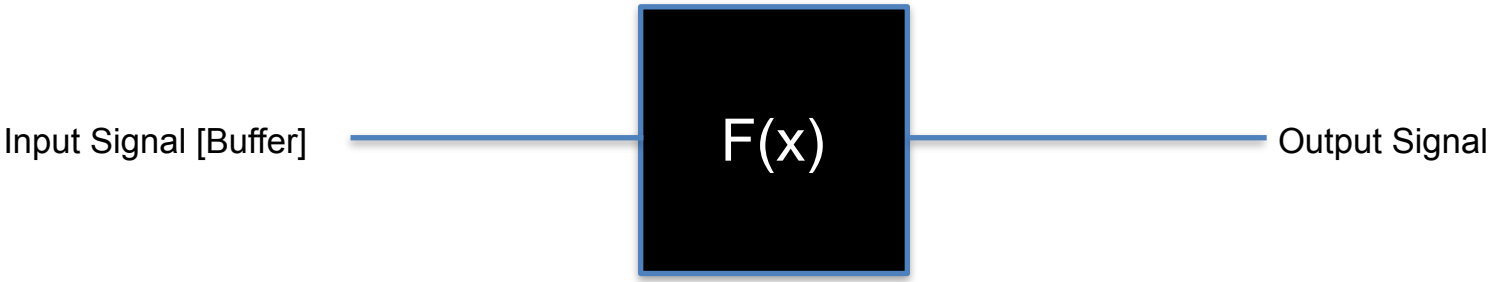
Linear Regression

Nonlinearity

What is deep learning anyway?

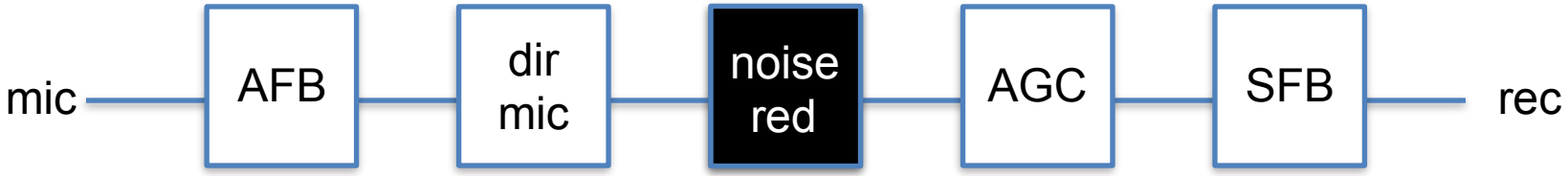


What is deep learning anyway?



- Not very smart, but very effective.
- Contents of the black box may seem unclear.
- Problem for medical devices.

Learning known Operators [MS17]



- We can exchange a single operator in the chain by a neural network.
- Restrictions to the structure of output and network help constrain the problem to be solved.

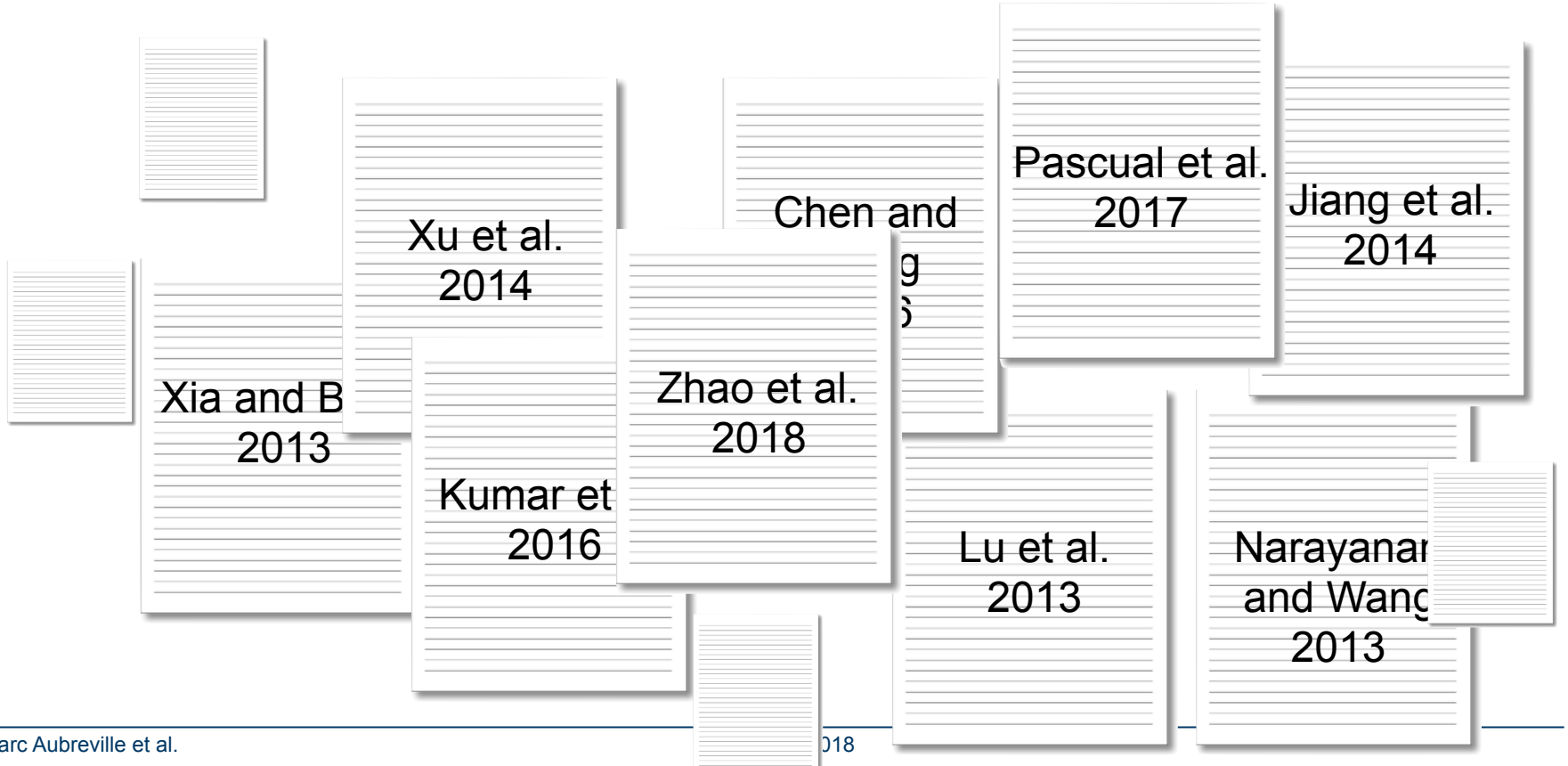
[MS17]: Maier et al., 2017: arxiv:1712.00374

Hearing Aid Side-Conditions

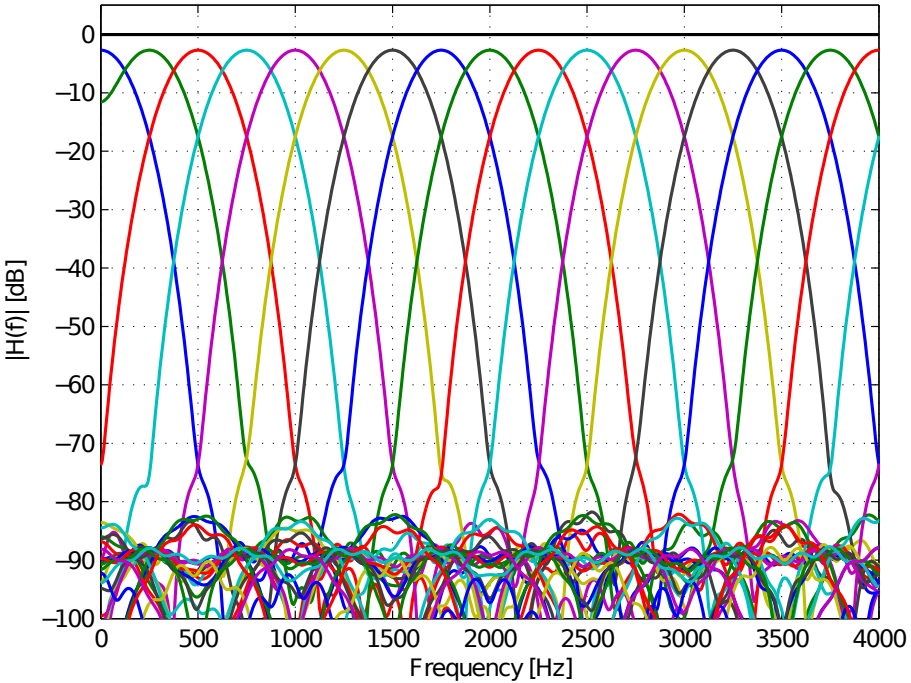
- Limited processing power
- Robustness required in any environment
- **Group delay > 10 ms objectionable to hearing aid wearers** [AT00]

[AT00]: J. Agnew and J. M. Thornton, JAAA (2000) 11:330-360

State of the (deep) art



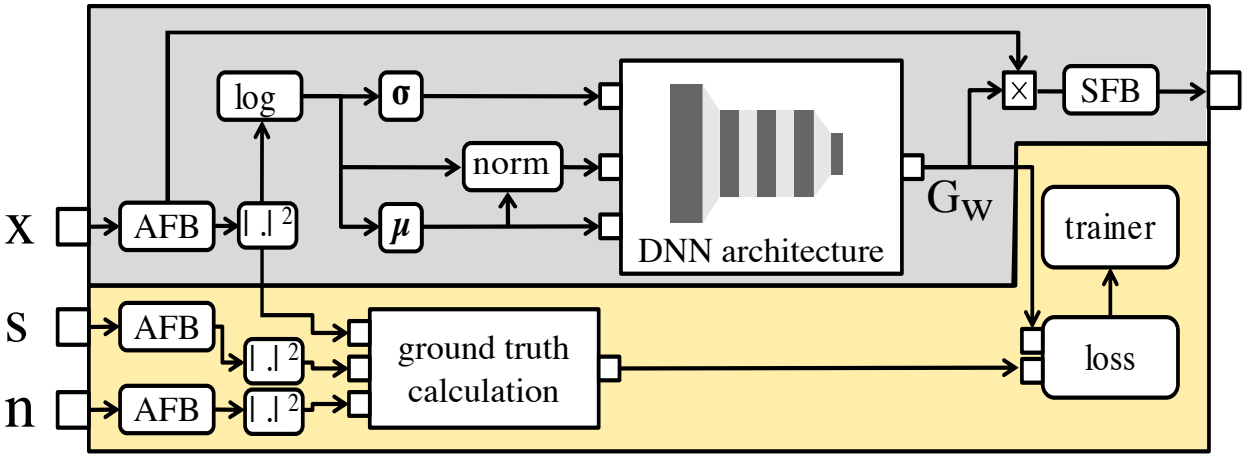
Hearing Aid Filterbank



[BS08]: R. Bäuml and W. Sörgel, EUSIPCO 2008

- State-of-the-art hearing aid filter bank
- 48 channels, uniform
- group delay: ~ 6 ms

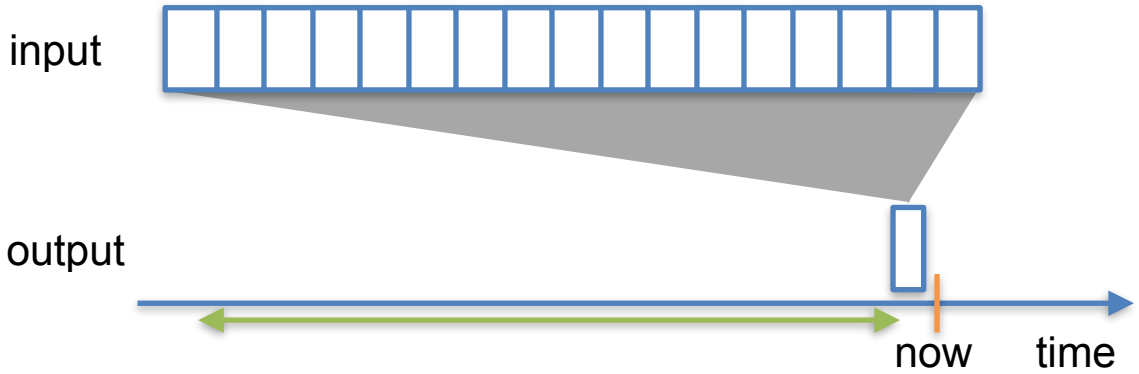
Architecture



- Input: Log-levels, normalization on window scope
- DNN with 3 hidden layers, 2048 nodes each.

Temporal context

- Temporal context should be 200-300ms, due to structure of speech (~ 4 Hz syllable rate). [HS77]
- Symmetrical context leads to high latency
- Proposal: Asymmetrical context with rich past knowledge

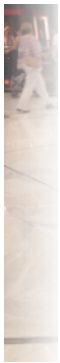


[HS77]: Houtgast and Steeneken, JASA 1985:77(3)

Our training database

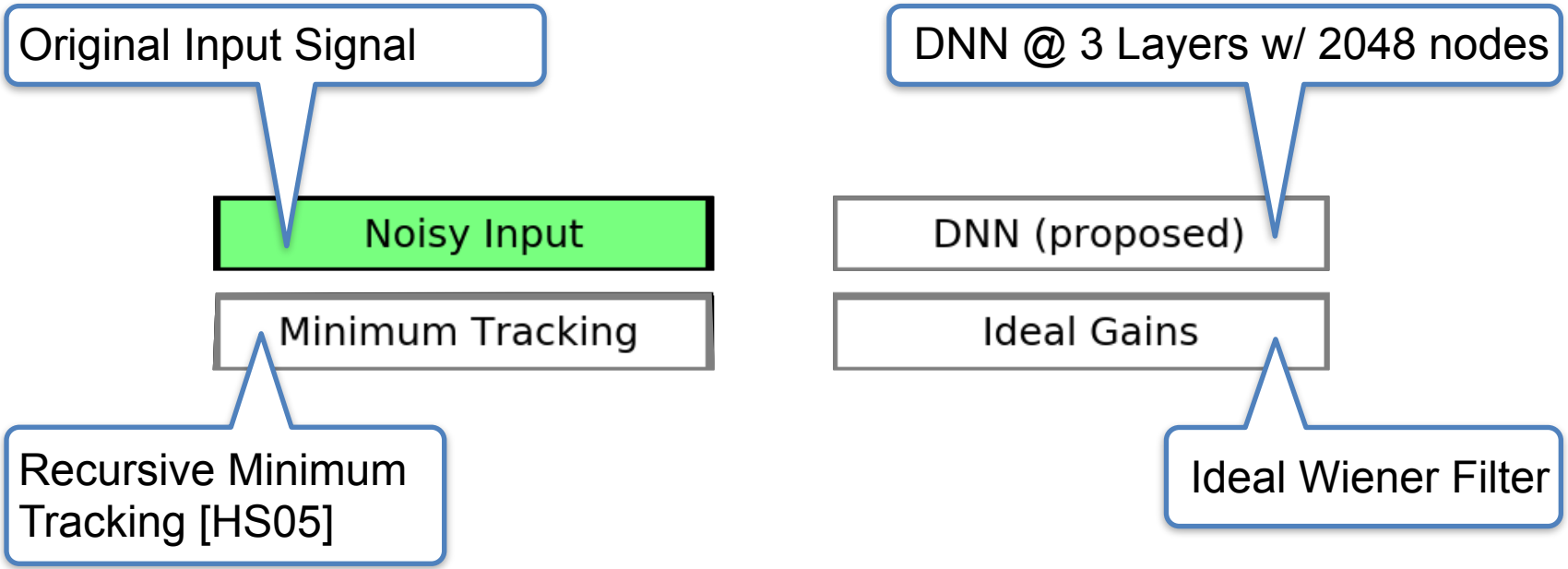
- 49 real-world noise recordings
  - recorded with hearing aid microphones
  - Mixed to achieve multi-noise conditions (Kumar et al.)



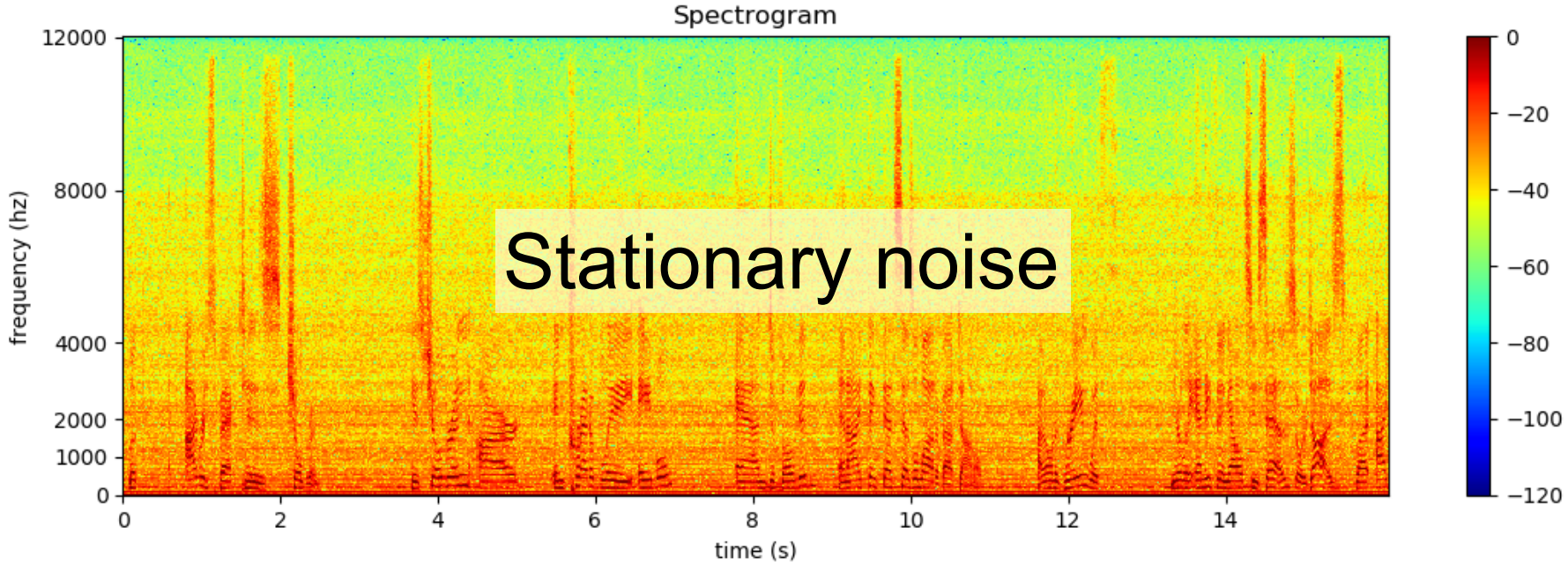


- 260 clean speech signals (EUROM, german sentences)
- Train/test split on source signal level.

Results - Conditions



[HS05]: E. Hänsler, G. Schmidt, Wiley&Sons, 2005

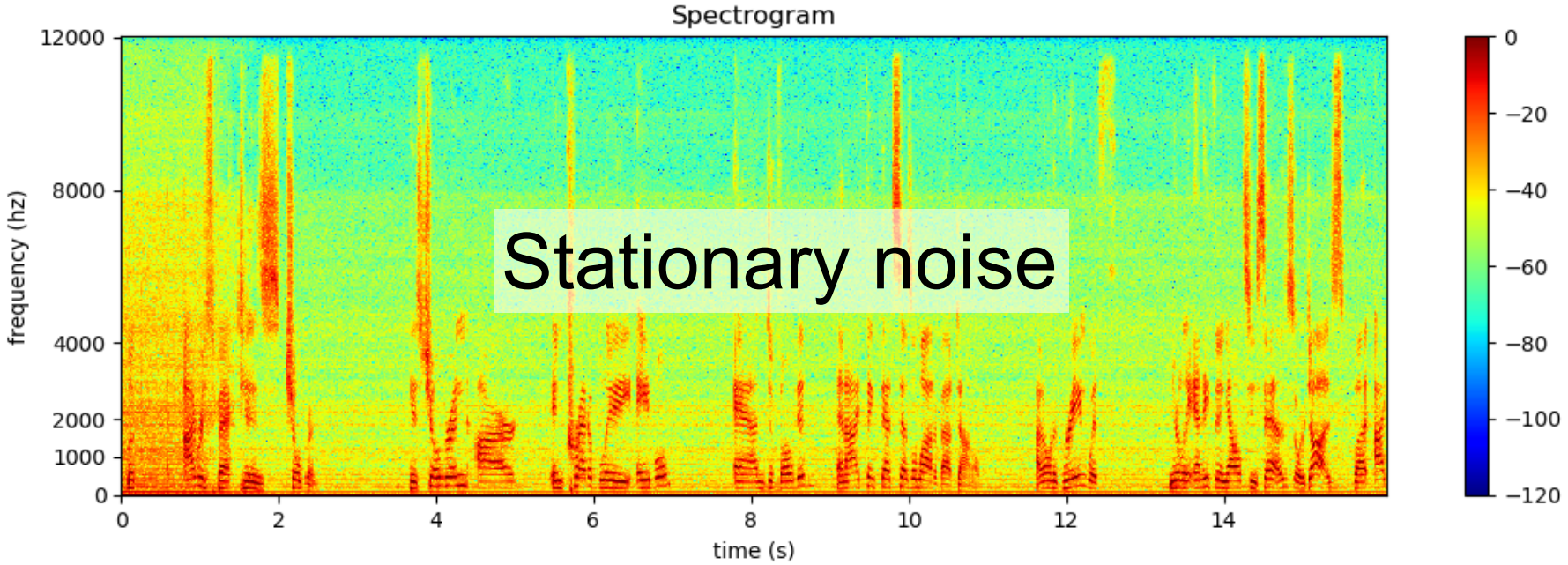


Noisy Input

DNN (proposed)

Minimum Tracking

Ideal Gains



Noisy Input

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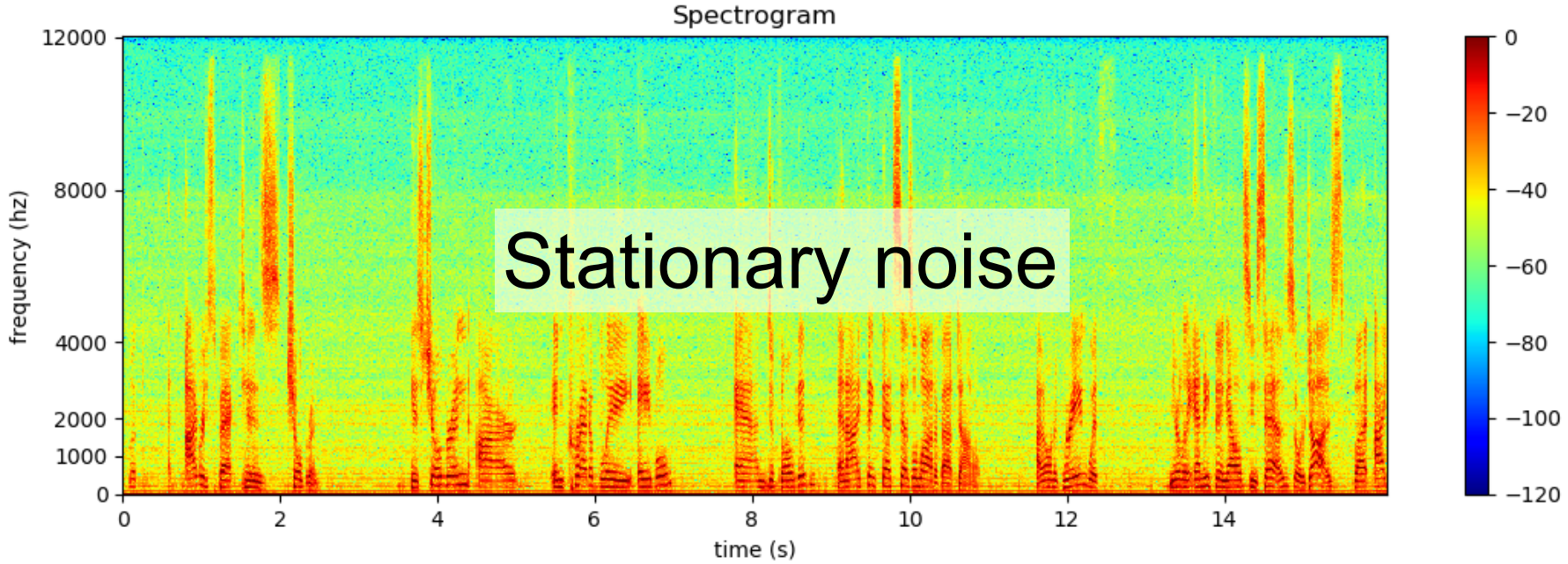

Noisy Input

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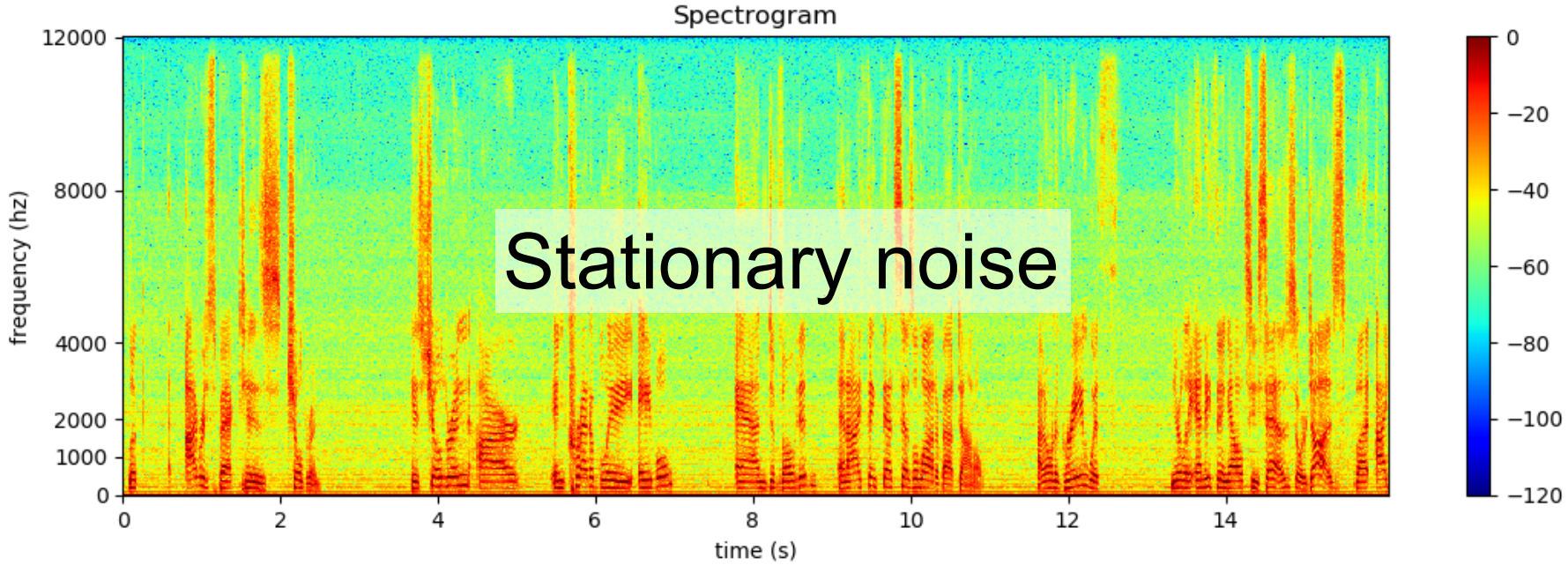

Noisy Input

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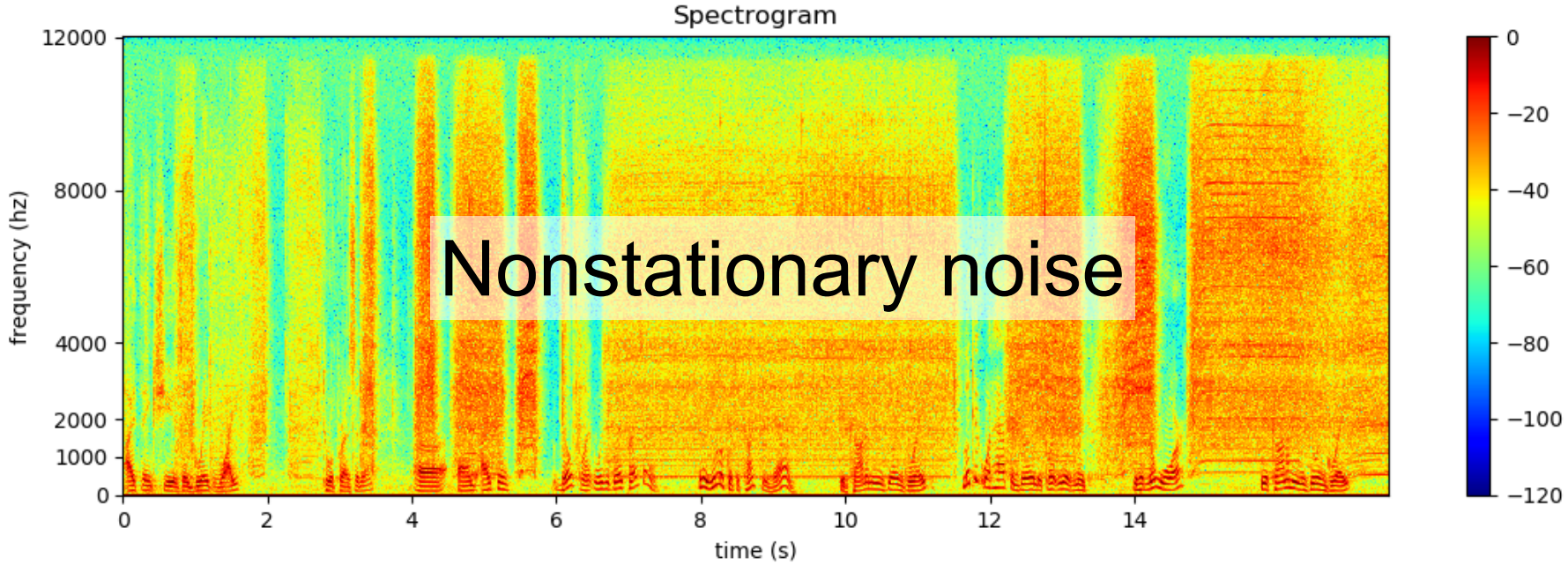

Noisy Input

DNN (proposed)

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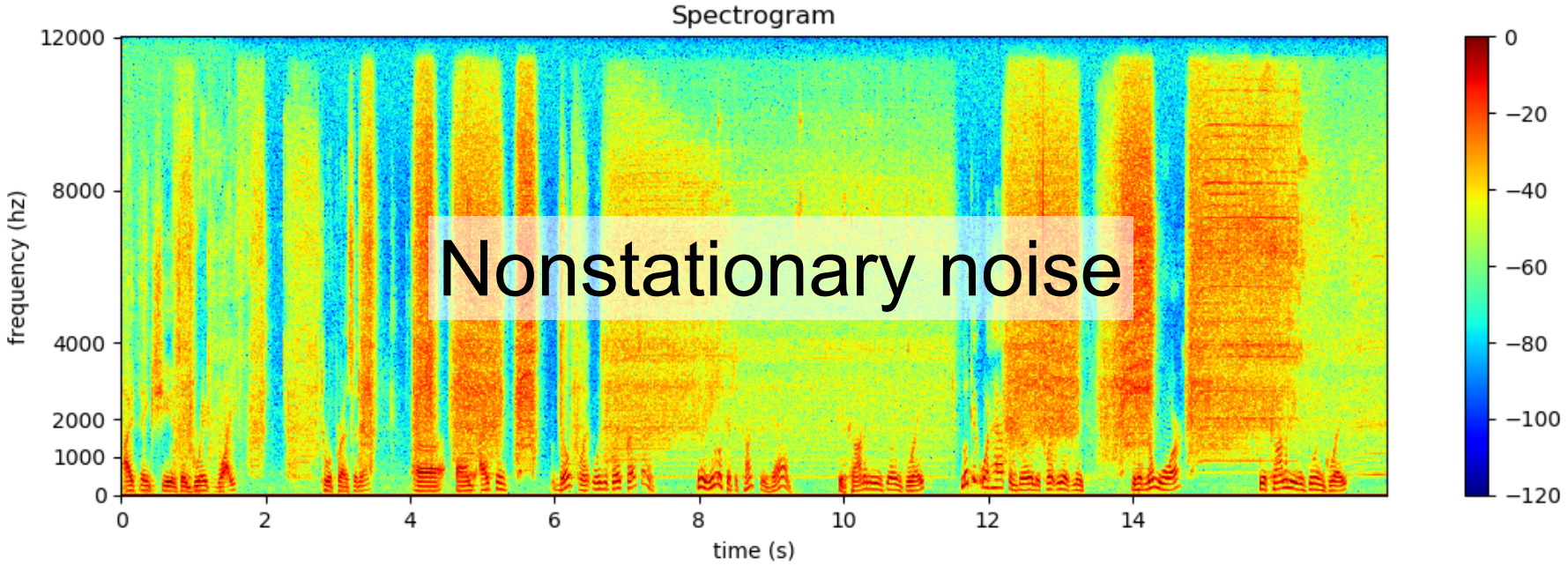
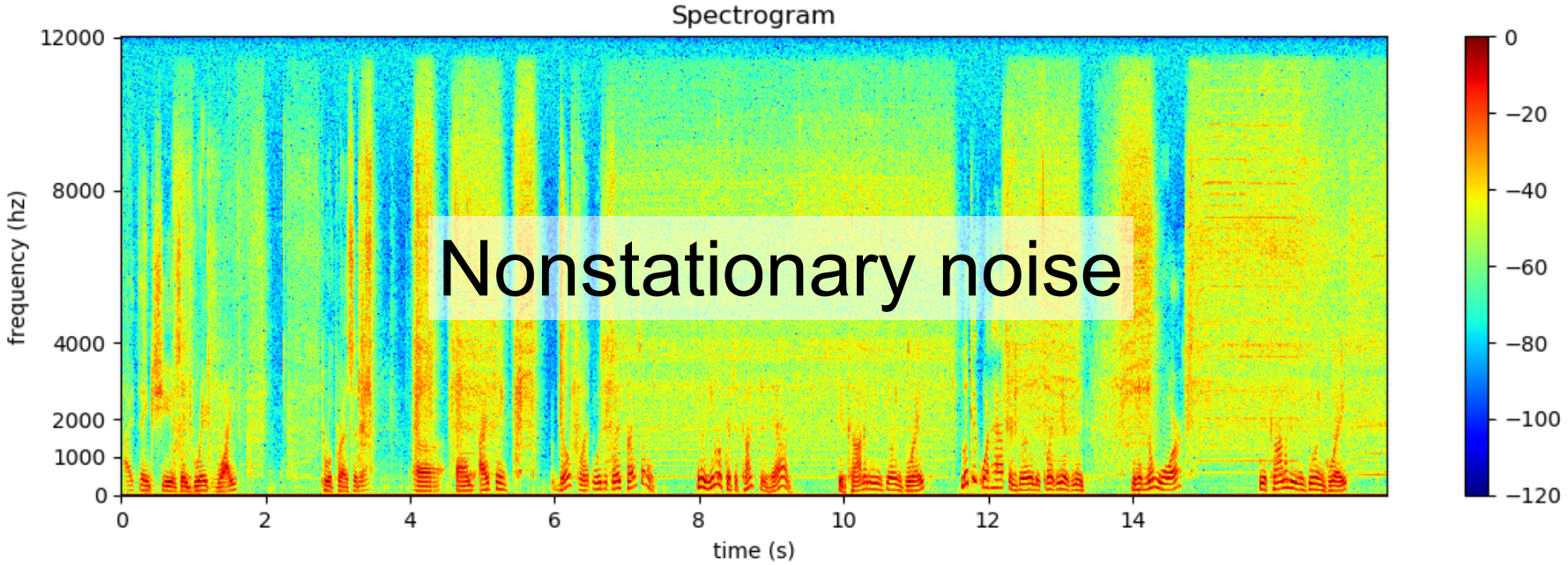


Noisy Input

DNN (proposed)

Minimum Tracking

Ideal Gains

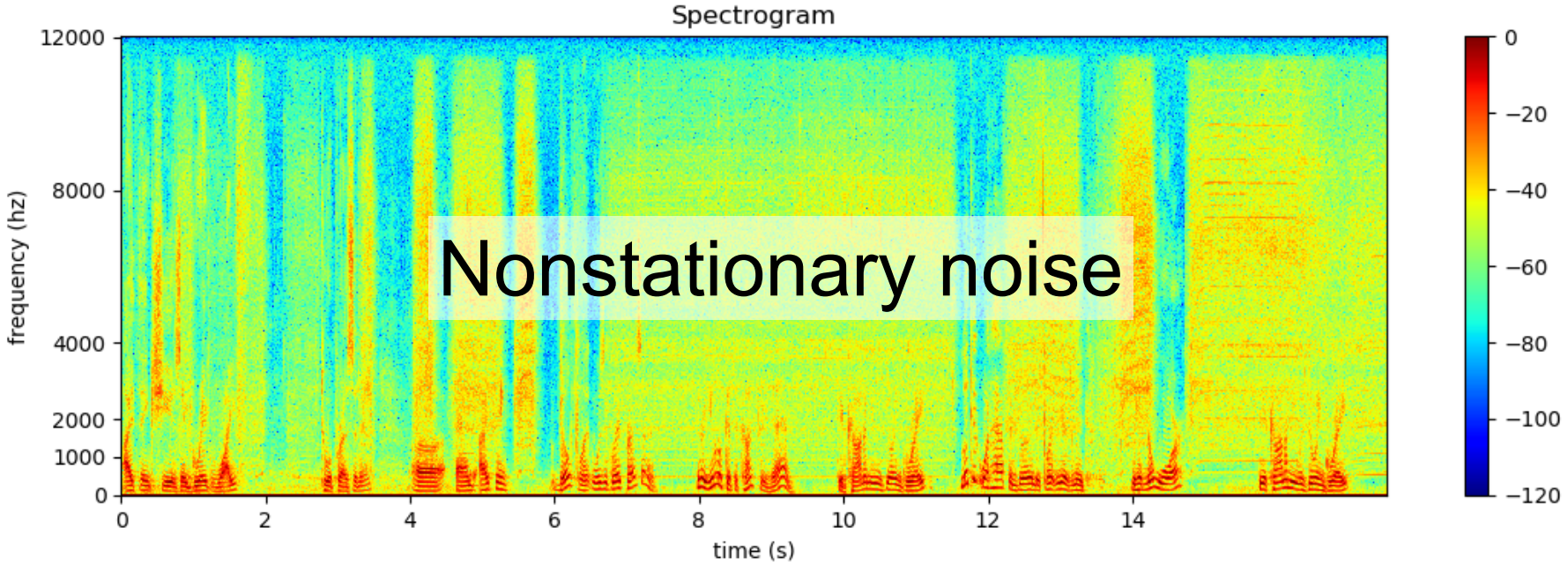


Noisy Input

DNN (proposed)

Minimum Tracking

Ideal Gains



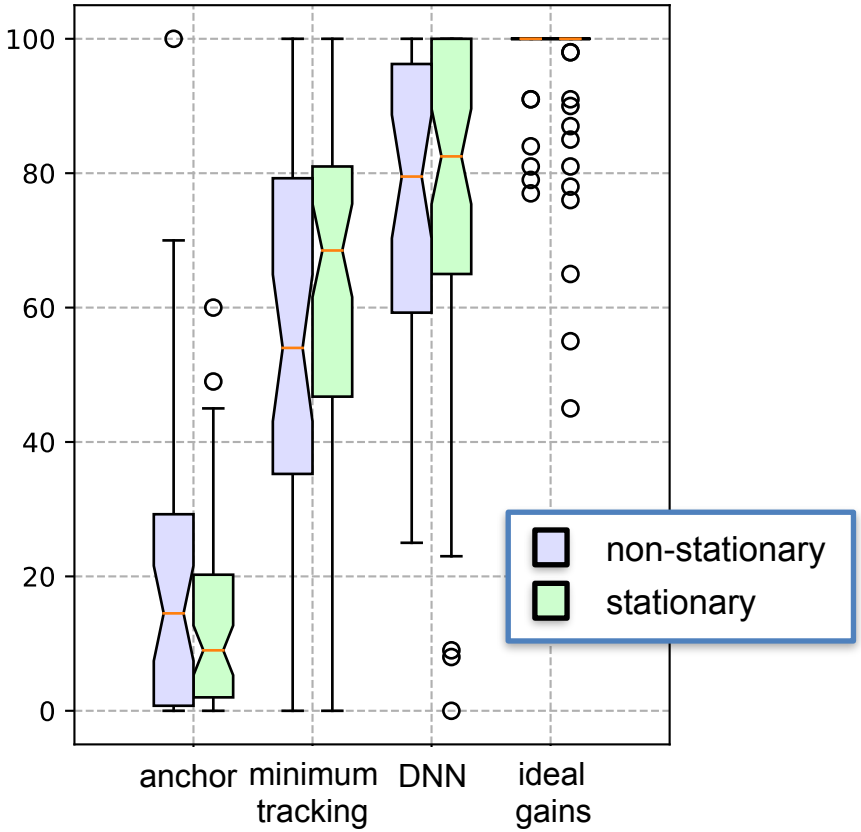
Noisy Input | DNN (proposed)

Minimum Tracking | Ideal Gains

Subjective Results

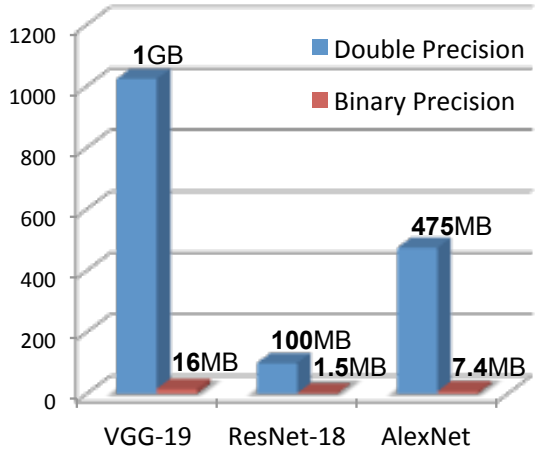
(MUSHRA, N=20)

- DNN as superior to recursive minimum tracking baseline
- Benefits especially for non-stationary signals.
- Still imperfect quality for low SNRs (phase distortion)



Deep Learning is too complex for hearing aids?

- DNNs are not dependent on floating point units.
- Even binary operations might be sufficient. (XNOR-Net [RO16])
- Potential for revival of analog computing [LY15]



[RO16]

[RO16] M. Rastegari et al., 2016, arxiv: 1603.05279
[LY15] Y. Lu et al, 2015, IEEE J. Solid State Circuits 50(1)

Summary: Hearing Aid Side-Conditions

- Limited processing power
  - ⇨ Likely not unsolvable in the future.
- Robustness required in any environment
  - ⇨ Promising, needs more evaluation.
- **Group delay > 10 ms objectionable to hearing aid wearers** [AT00]
  - ⇨ Total group delay = 8 ms.

[AT00]: J. Agnew and J. M. Thornton, JAAA (2000) 11:330-360

Thank you.

For more details:
IWAENC 2018 paper
https://arxiv.org/abs/1805.01198

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Appendix

Normalization

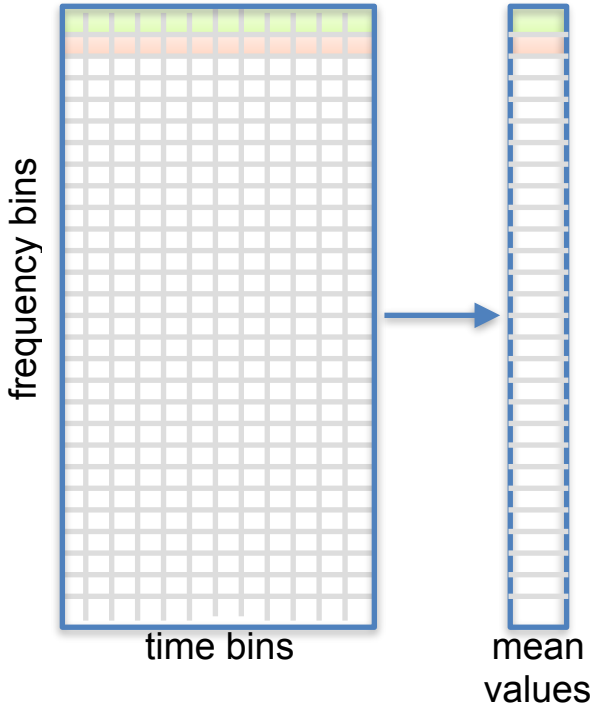
- Normalization across frequency:

$$X_{\text{norm}}(k,f) = X(k,f) - \frac{1}{\tau_1 + 1 + \tau_2} \sum_{k=-\tau_1}^{\tau_2} X(k,f)$$

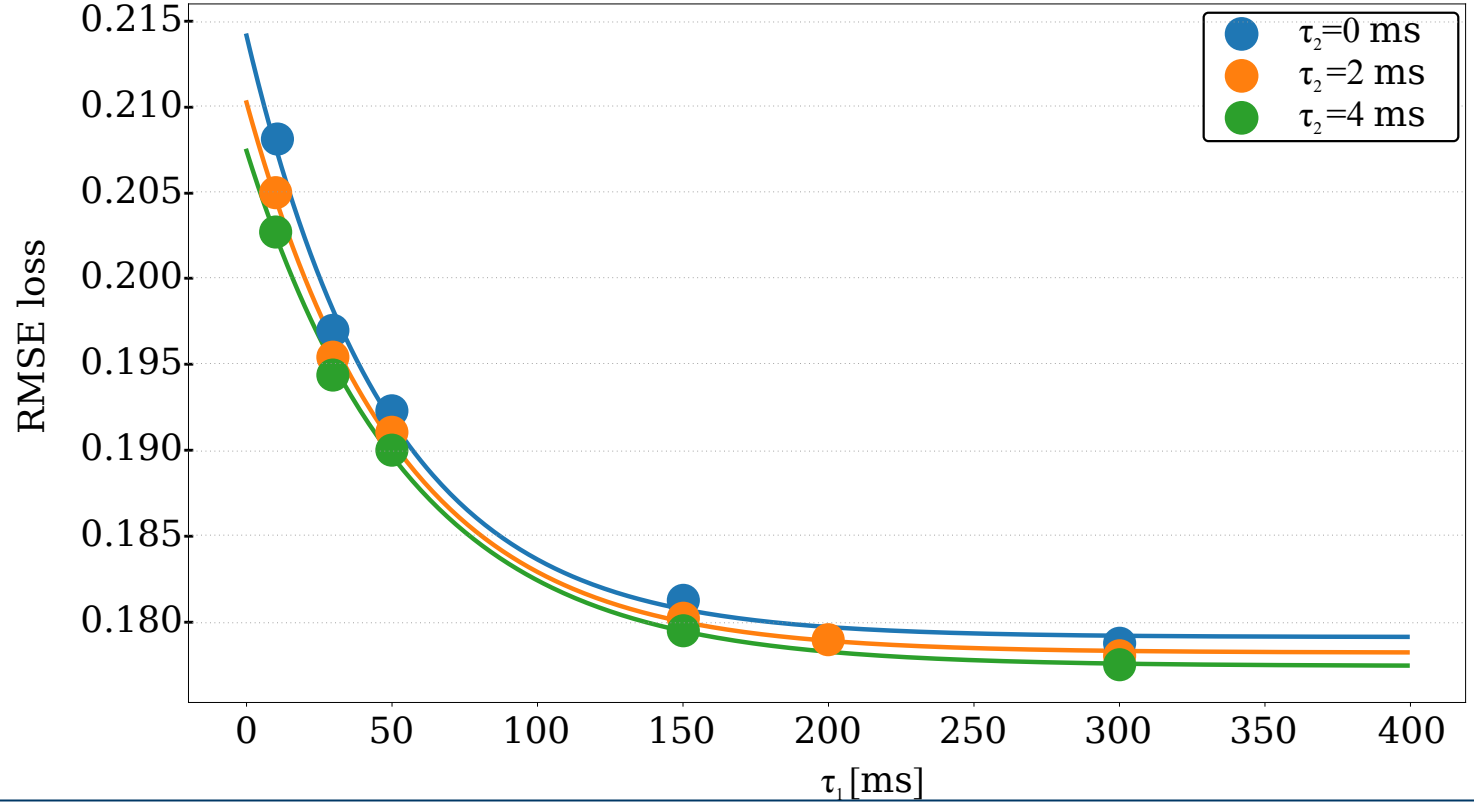
$X(k,f)$: Filterbank levels in log-scale

- Completely level independent

- Level information is fed as side-information to DNN



How much context is needed?



Context Size Influence on Gain Prediction