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Frequency of Interest-based Noise Attenuation Method to Improve Anomaly Detection Performance

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Marjo Hippi et al. "A statistical forecast model for road surface friction." InSIRWEC 15th International Road Weather Conference. 2010.

Background

Weather & Friction Coefficient

Dry : 1.00

Wet : 0.30

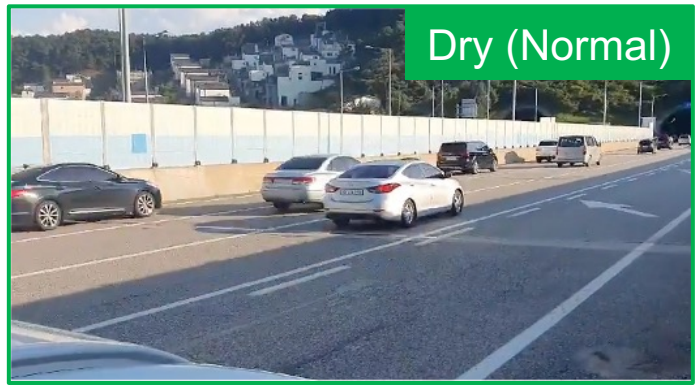
Icy : 0.14

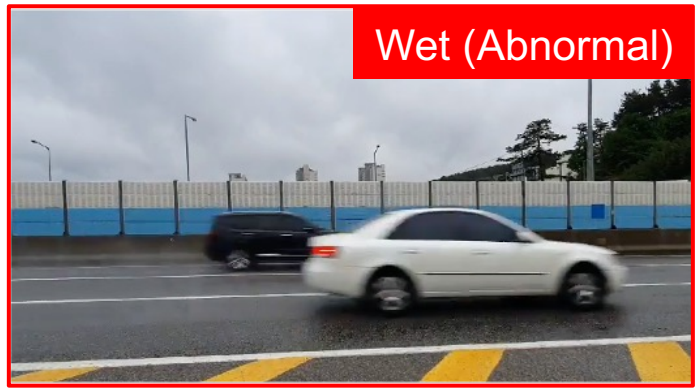
Background

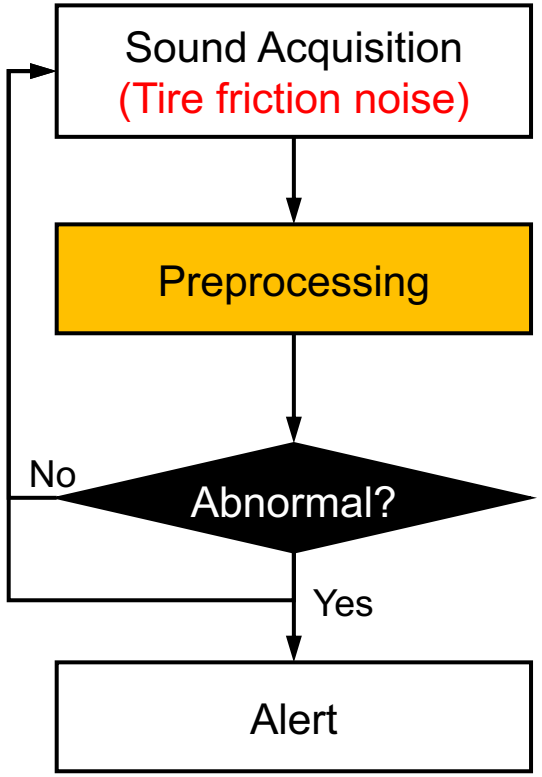
Warning Sign (passive / fixed type)

Background

Anomaly Detection (active type)







$if\ \mathcal{L}_{recon} > \theta\ then\ Abnormal$

$else\ Normal$

Summary

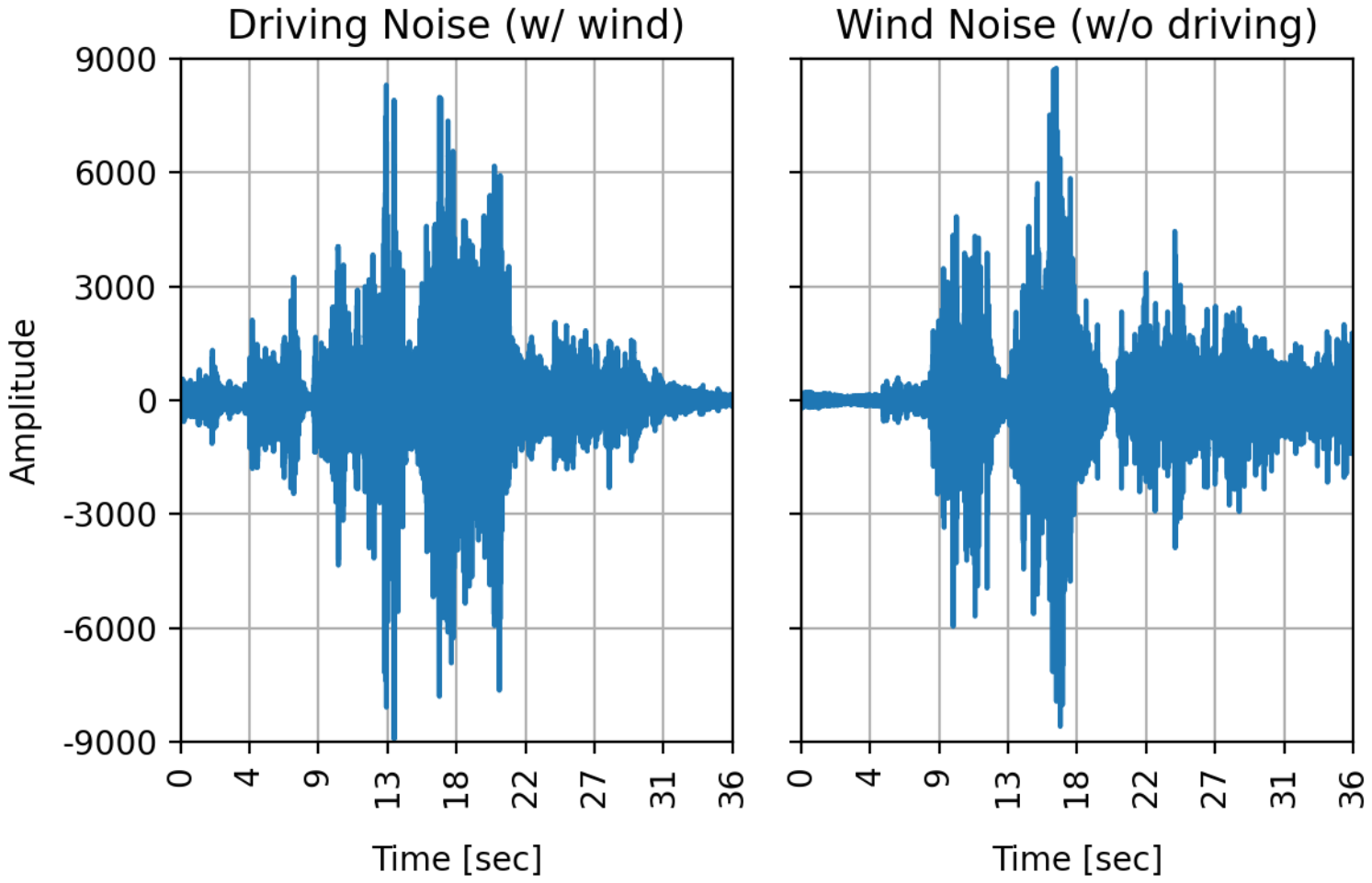
Base
- Tire friction noise is used for road anomaly detection.
- Autoencoder-based anomaly detection method is effective.

Prior limitations
- Sounds are acquired from outdoor environments.
- Wrong judgement will be occurred by other noise than tire friction.
  - e.g. mistaking wind noise as an event and determining as an abnormal.
- Labeling all driving events is not a feasible solution.
  - Types of roads, cars, and weather are infinite.

Objective
- Accurate driving event (friction noise) extraction.
- Attenuation of other noise that hinders event extraction.
- Avoid deep learning-based noise attenuation method.
  - Considering both limitations of labeling and low-power inference machine.

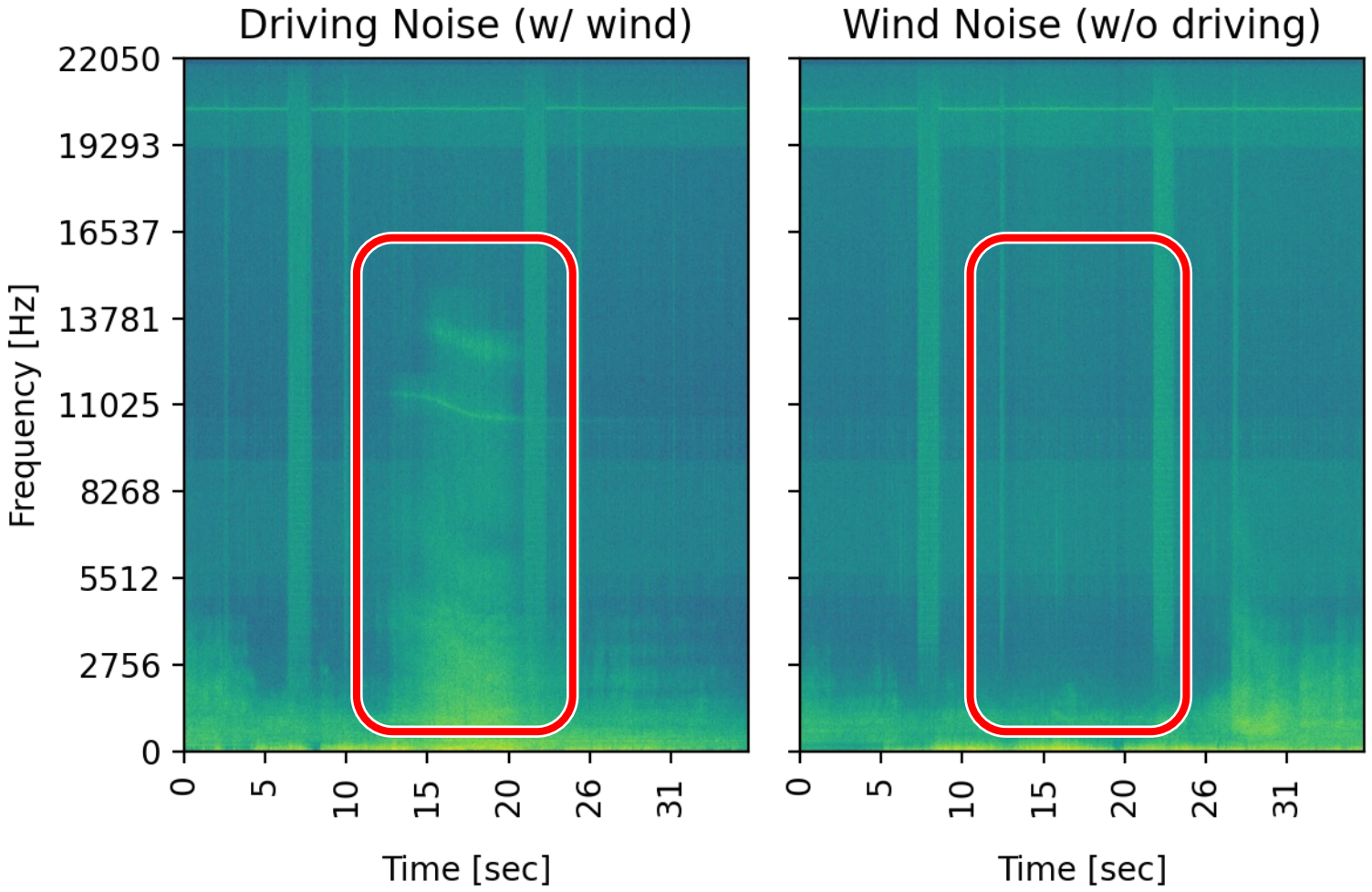
Approach

Extracted events by peak detection
Two kinds of events can be confused in amplitude domain.



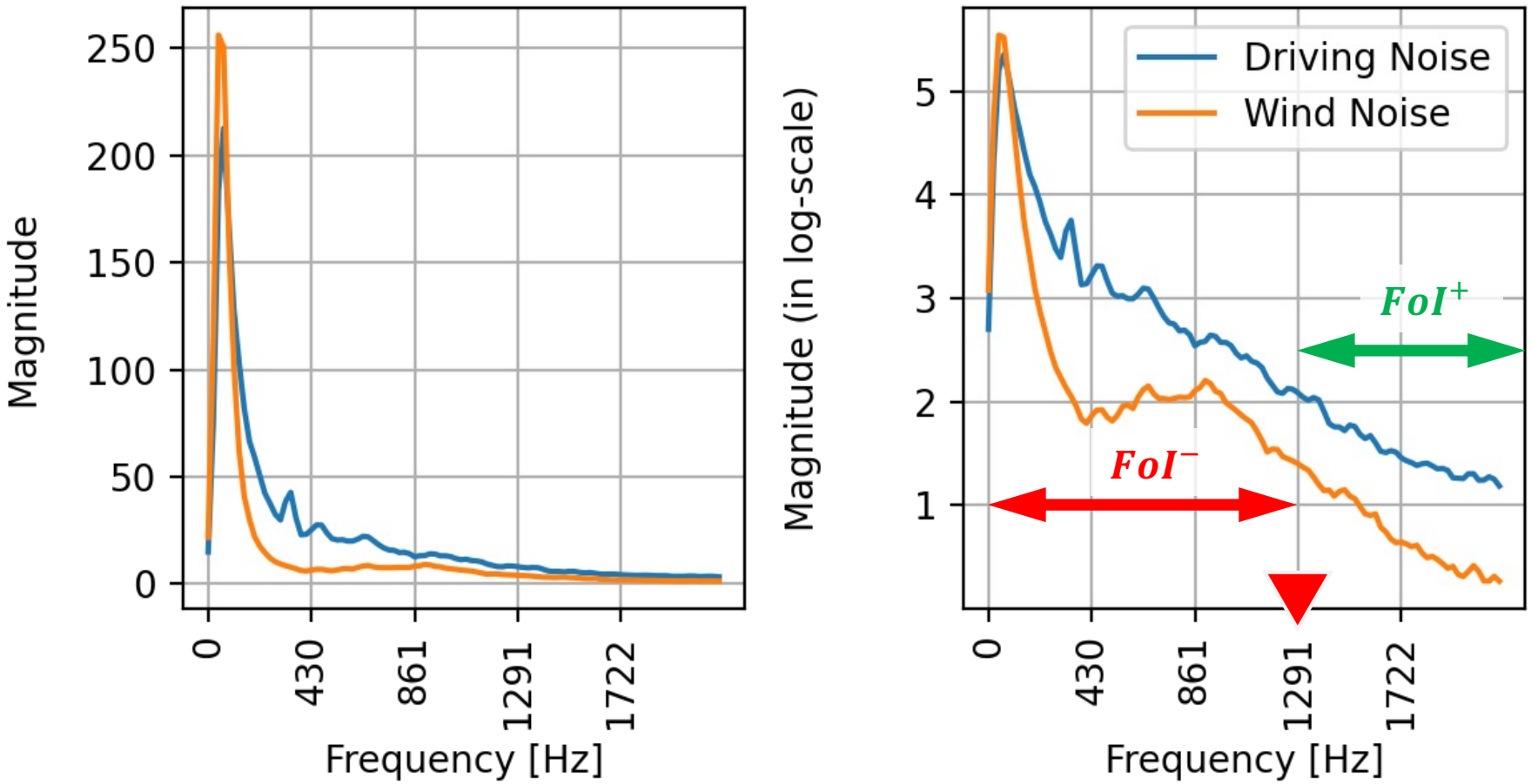
Approach

Frequency domain shows better discrimination than amplitude.
Due to the vehicle diversity, difficult to specify the frequency band of frictional noise.



Approach

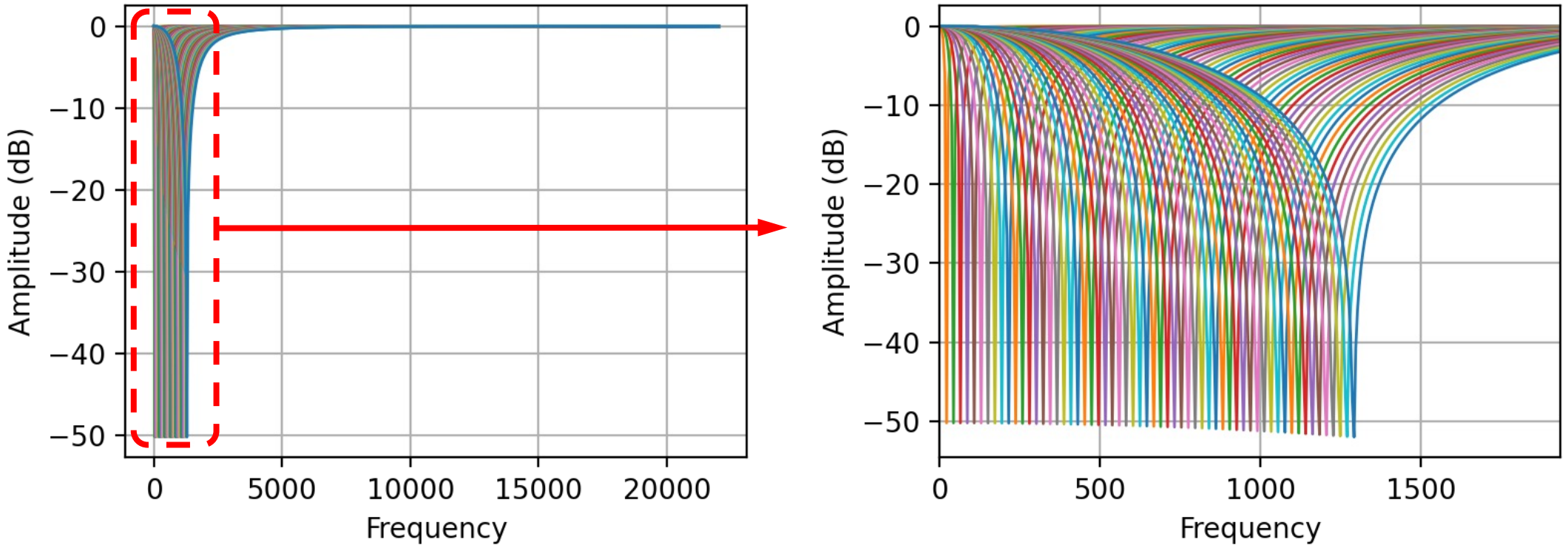
Set the frequency band of friction noise as a frequency of interest.
Attenuates common frequency to FoI and other noises.



STFT: short-time Fourier transform

Method

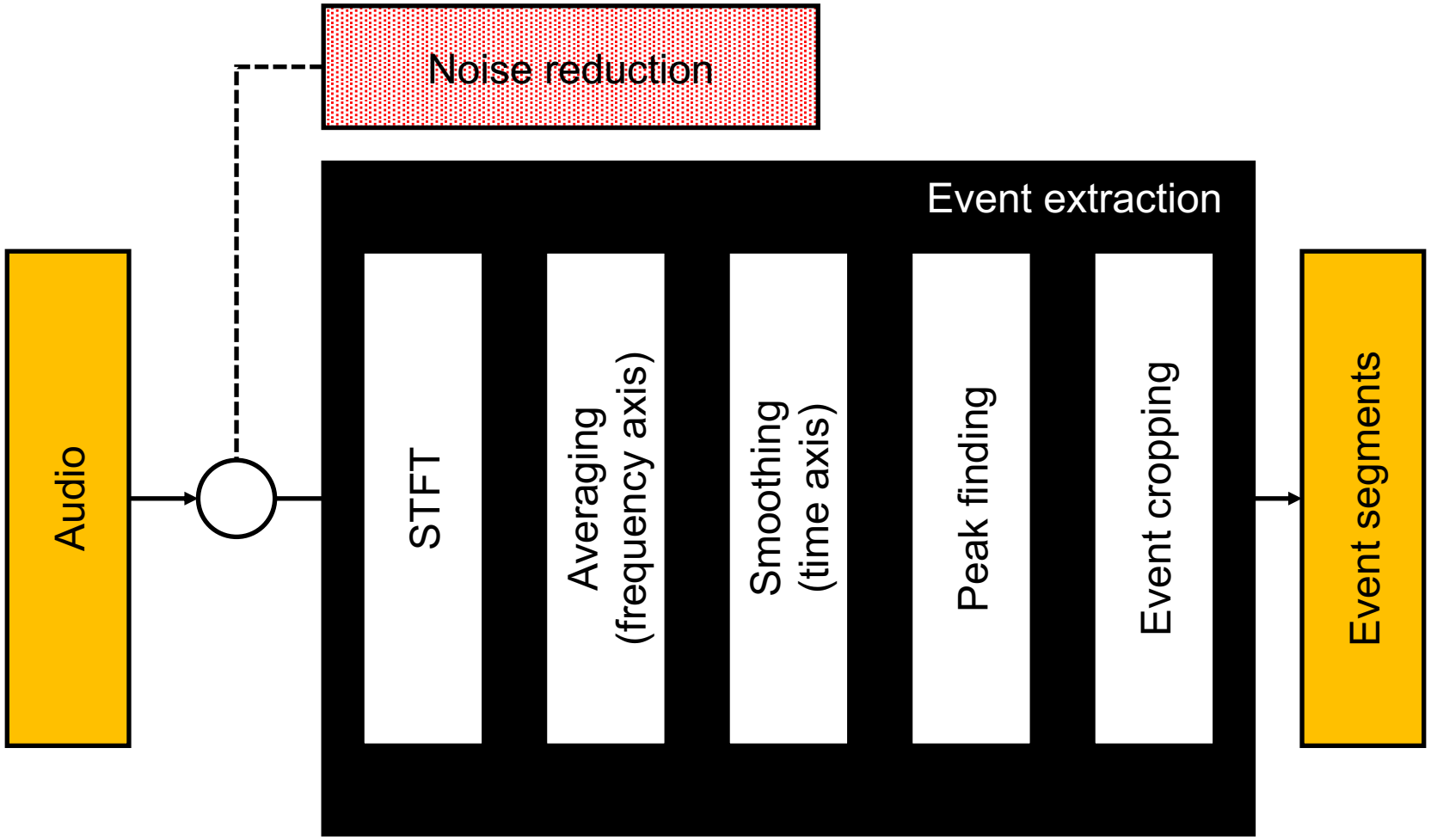
Adopting a notch filter instead of a high pass filter.
Frictional noise exists even at low frequencies.



- Attenuation target (negative FoI): 0~1290Hz
- Frequency resolution: 21.5 Hz
- Number of harmonics: 1290 Hz / 21.5 Hz = 60

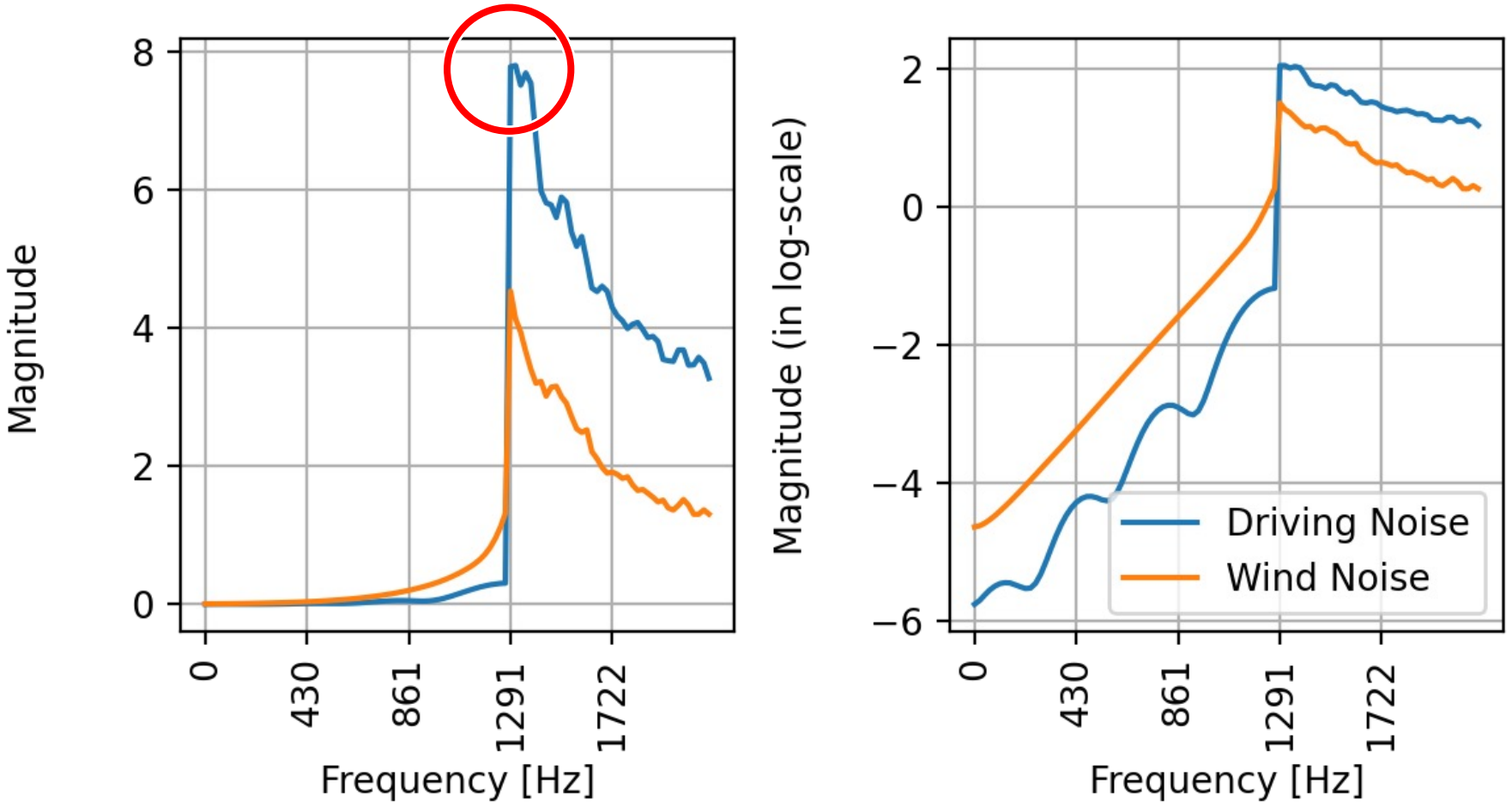
Method

Event Extraction



Result

Wind noise is attenuated effectively via a notch filter.
Now we can find events easily by peak detection.



Experimental Env.

Data Acquisition

Four road conditions for each.
(dry, wet, slush, and snow)

Post-A
(Tunnel)

Post-B
(City)

Post-C
(Outer)

Experimental Env.

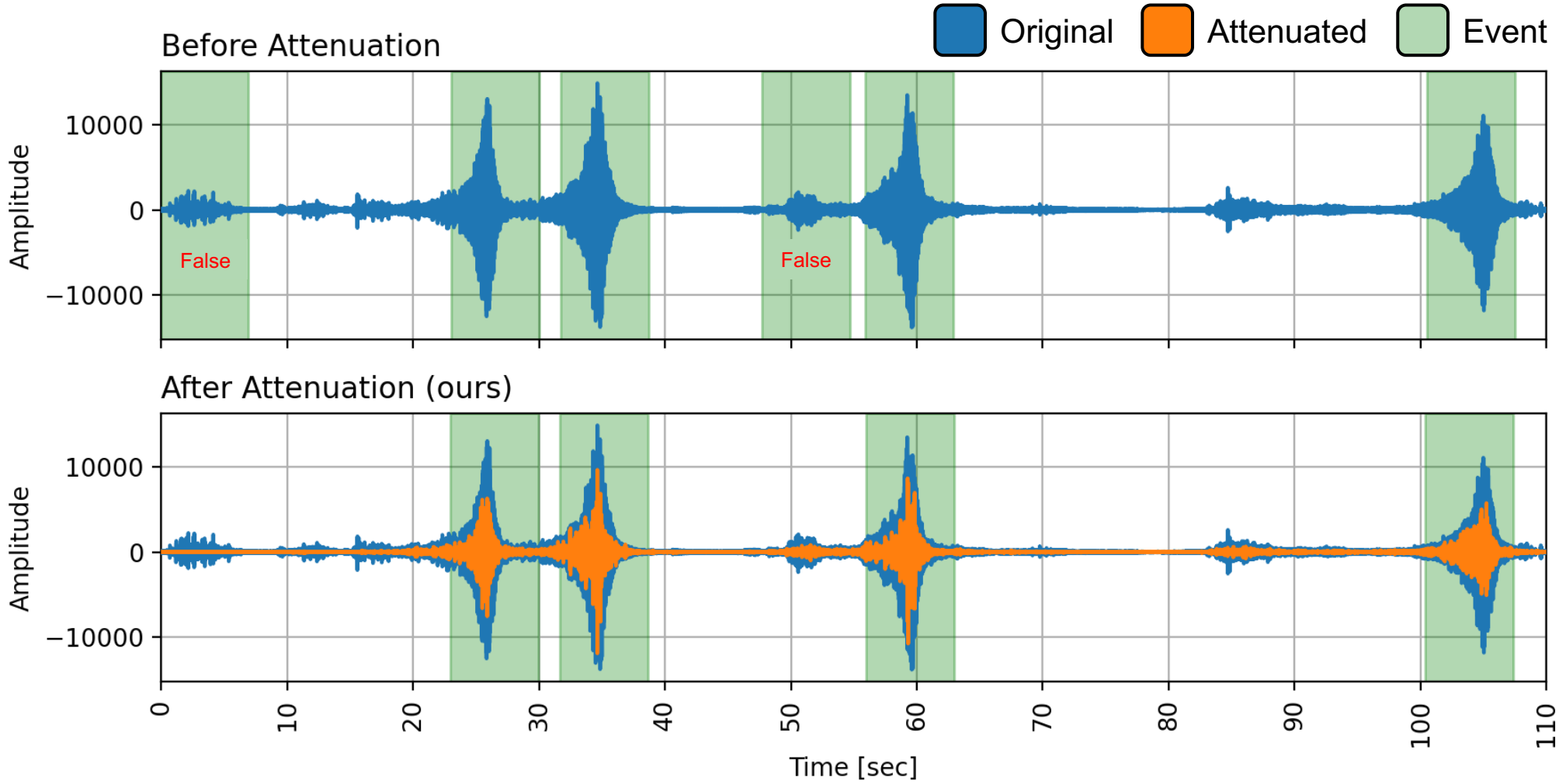
Dataset

Each sample is recorded in a 10-minute length.
(w/ 44.1kHz sampling rate)

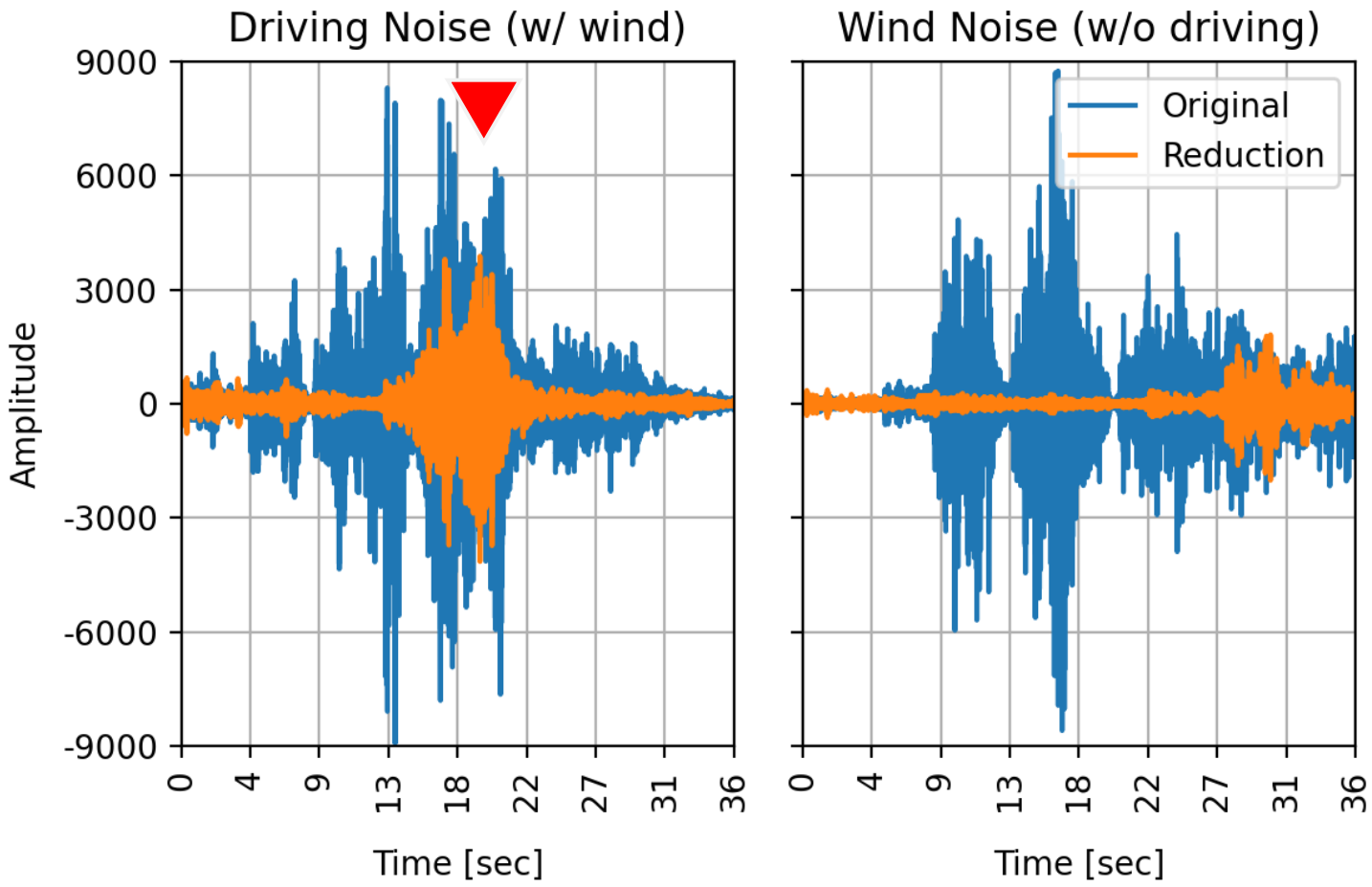
Post	Normal	Abnormal		
	Dry	Wet	Slush	Snow
A	10	10	4	-
B	10	10	2	-
C	10	9	10	3
Total	30	29	16	3

Noise Attenuation

Comparison of Event Extraction



Noise Attenuation



Event Extraction

Precision of driving event extraction is almost 1.
(Regardless of weather conditions.)

Post	Reduction	Normal	Abnormal		
		Dry	Wet	Slush	Snow
A	✗	513 / 570 (0.900)	41 / 70 (0.586)	10 / 13 (0.769)	-
	✓ (ours)	384 / 385 (**0.966**)	21 / 21 (**1.000**)	7 / 7 (**1.000**)	-
B	✗	1492 / 1545 (0.966)	568 / 568 (**1.000**)	163 / 253 (0.644)	-
	✓ (ours)	804 / 804 (**1.000**)	529 / 529 (**1.000**)	11 / 11 (**1.000**)	-
C	✗	1336 / 1337 (0.999)	1013 / 1013 (**1.000**)	149 / 246 (0.606)	15 / 55 (0.273)
	✓ (ours)	1153 / 1153 (**1.000**)	1032 / 1032 (**1.000**)	76 / 76 (**1.000**)	4 / 4 (**1.000**)

Driving Event / Extracted Event
(Precision)

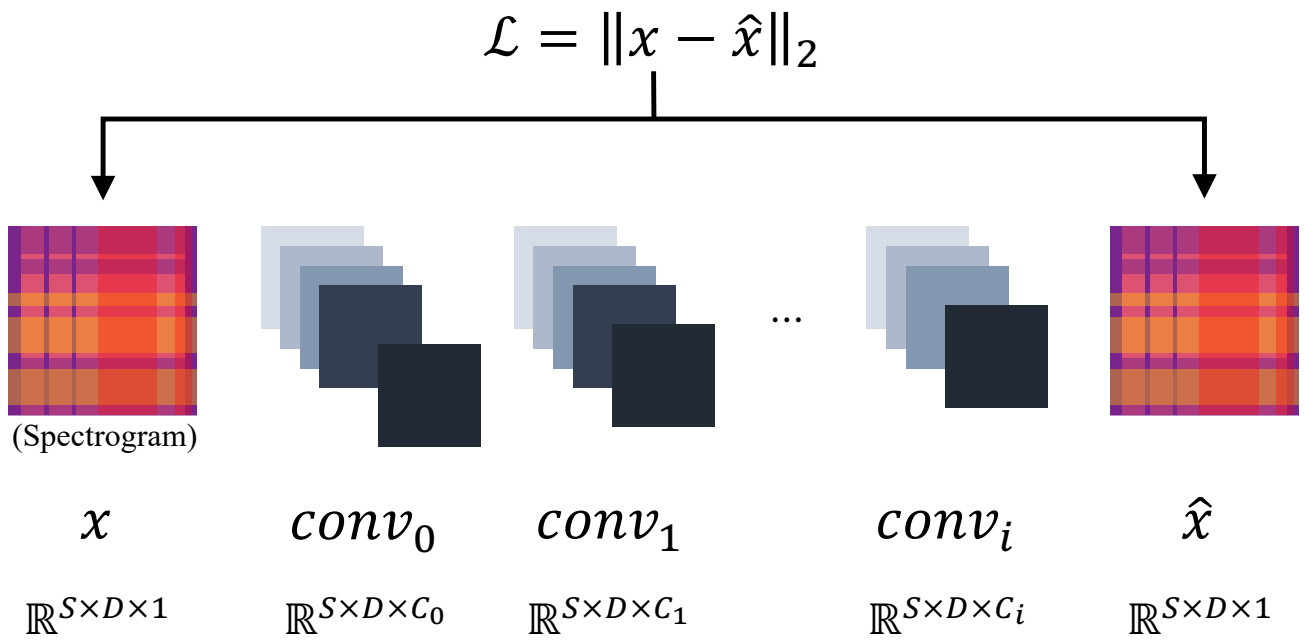
Anomaly Detection

w/ Non-Compression Auto-Encoder

Dry Wet, Slush, Snow

Post	Normal	Abnormal
A	384	28
B	804	540
C	1153	1112

- **Training** : 80% of normal
- **Test** : others



Anomaly Detection

Anomaly detection can be performed on friction noise by negative FoI attenuation.
Confusion caused by loud wind noise can be avoided.

Post	Original	Reduction	Improvement
A	0.883	**0.963**	9.060%
B	0.837	**0.871**	4.062%
C	0.890	**1.000**	12.360%
Average	0.870	**0.944**	8.506%
Post-Merge	0.654	**0.915**	39.908%

Conclusion

Rethinking tradition
- In our environment labeling is impossible
- However, the traditional approach is effective instead of deep learning.
  - e. g. notch filter used in this study

Efficiency
- Because the deep learning model is not used for our purpose (noise attenuation).
- Thus, the required computing power is also low.

Assistance
- Noise attenuation helps to achieve high precision in driving event extraction.
- Also, it improves road anomaly detection performance.

Thank you

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