Intelligent and real time data analytics for fiber optic sensors using deep neural networks
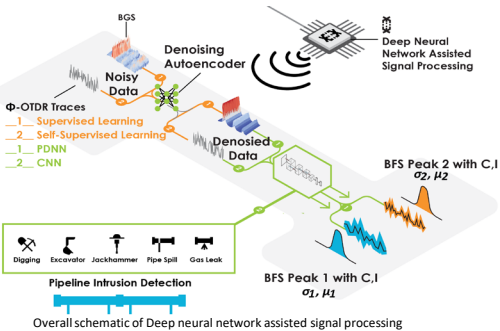
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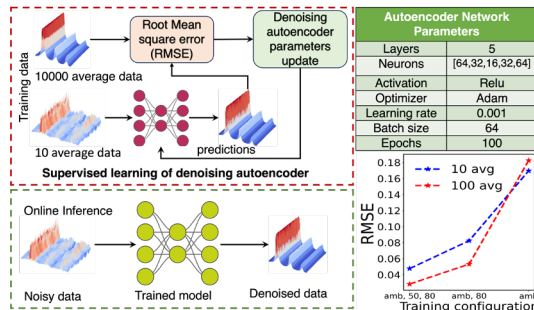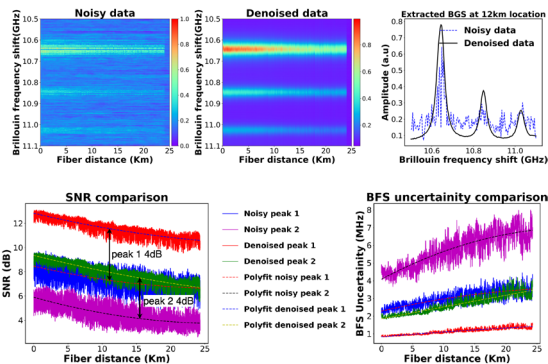
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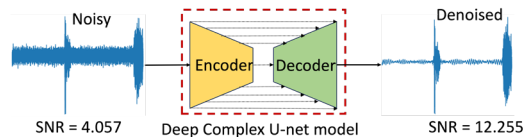
Outline:

Increase the efficiency of signal processing of fiber optic sensor data using deep neural networks. Addressed the problems of data denoising, BFS estimation with C.I and classification of third-party intrusion events using a suite of deep neural network algorithms.
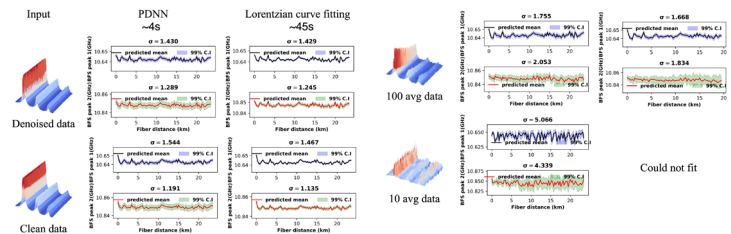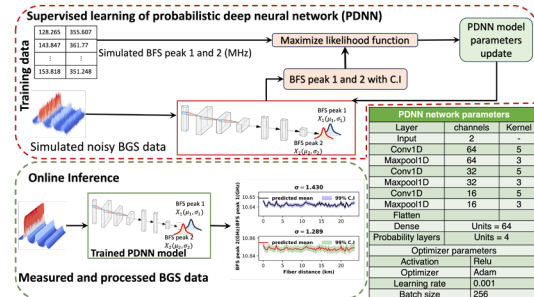

Overall schematic of Deep neural network assisted signal processing

Denoising of BOTDA data

Noisy data — Denoised data — Extracted BGS at 12km location

SNR comparison — BFS uncertainty comparison

peak 1 4dB — peak 2 4dB

Autoencoder Network Parameters

Parameter	Value
Layers	5
Neurons	[64,32,16,32,64]
Activation	Relu
Optimizer	Adam
Learning rate	0.001
Batch size	64
Epochs	100

Supervised learning of denoising autoencoder

Online Inference

Noisy data — Trained model — Denoised data

RMSE plot: 10 avg, 100 avg
Training configuration: amb, 50, 80 / amb, 80 / amb

Denoising of Φ-OTDR data

Noisy — Encoder–Decoder — Denoised

SNR = 4.057 — Deep Complex U-net model — SNR = 12.255

Brillouin Frerquency Shift (BFS) peak estimation with C.I

Supervised learning of probabilistic deep neural network (PDNN)

Training data	Simulated BFS peak 1 and 2 (MHz)
128.265	355.807
143.847	361.77
153.818	351.248

Maximize likelihood function → PDNN model parameters update

BFS peak 1 and 2 with C.I

Simulated noisy BGS data

PDNN network parameters

Layer	channels	Kernel
Input	2	-
Conv1D	64	5
Maxpool1D	64	3
Conv1D	32	5
Maxpool1D	32	3
Conv1D	16	5
Maxpool1D	16	3
Flatten		
Dense		Units = 64
Probability layers		Units = 4

Optimizer parameters

Activation	Relu
Optimizer	Adam
Learning rate	0.001
Batch size	256

Online Inference

Trained PDNN model — Measured and processed BGS data

PDNN ~4s / Lorentzian curve fitting ~45s

Input — Denoised data — Clean data

100 avg data — 10 avg data

Could not fit

Classification of third-party intrusion events

Signal from Φ-OTDR: Excavator

Mel-Spectrogram (dB)

Data pre processing:
1. Time mask
2. Frequency mask
3. Normalize

Mel-Spectrogram (dB)

Predicted class: excavator

CNN network parameters

Layer	kernel	Input size	Output size
Conv2D	5x5	1x128x977	8x64x489
Conv2D	3x3	8x64x489	16x32x245
Conv2D	3x3	16x32x245	32x16x123
Conv2D	3x3	32x16x123	64x8x62
AdaptiveAvgPool2d	-	64x8x62	64x1x1
Dense	-	64	13

Optimizer parameters

Activation	Relu
Optimizer	Adam
Learning rate	0.001
Batch size	16
Num epochs	100

Confusion Matrix
Accuracy: 0.97

Classification network: CNN