Deep Learning Discrimination of Earthquakes and Quarry Blasts in Southern California

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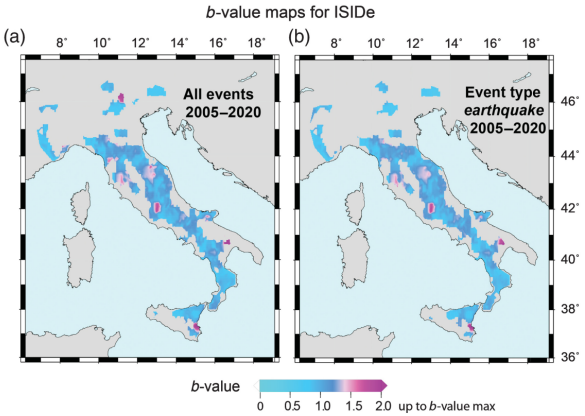
DAMS
DAta Mining for Seismology

Outline

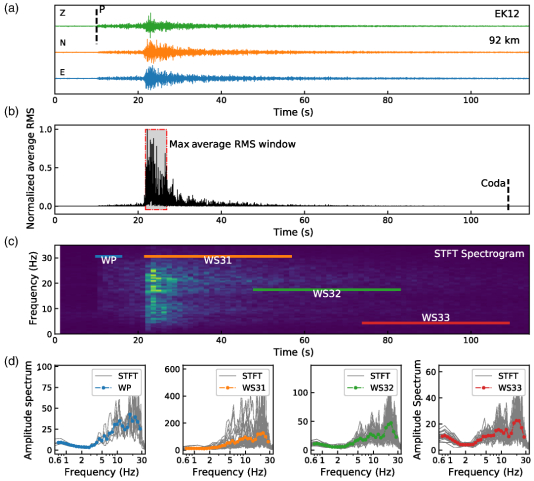
- Background
  - Manual discrimination
  - Artificial Neural Network
- Data
- Method
  - Data preprocess
  - **Data augmentation**
  - CNN architecture
- Results
- Summary

- Manual discrimination between natural earthquakes and anthropogenic activity is a laborious task.
- An automatic discriminator is essential to **seismic hazard analysis** and **fine classification catalog**.



L. Gulia *et al. SRL*, 2021

- ANN can achieve automatic discrimination with high accuracy (97%).
- CNN could be a more generalized discriminator than ANN, due to:
  - Feature extraction is done by CNN itself.

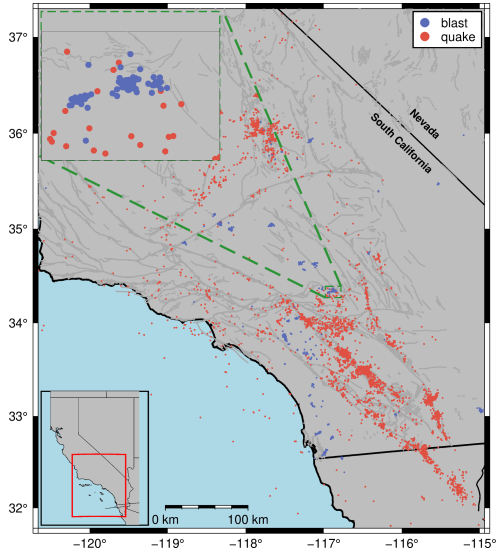


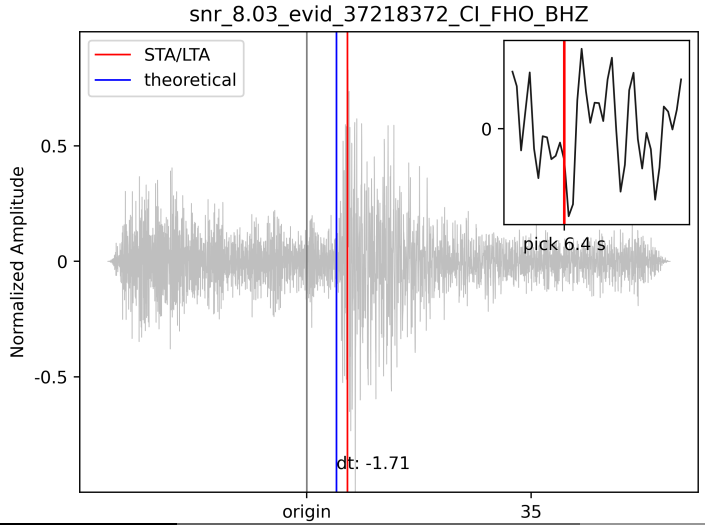
F. Miao *et al. SRL*, 2020

Data

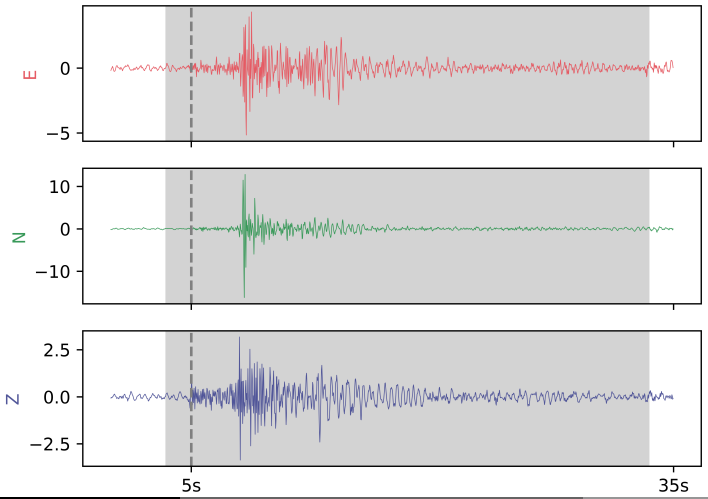
- Southern California Seismic Network

Type	#Event	#Recording
Quake	36,053	427,607
Blast	6,690	128,161
Aggregation	42,743	555,768

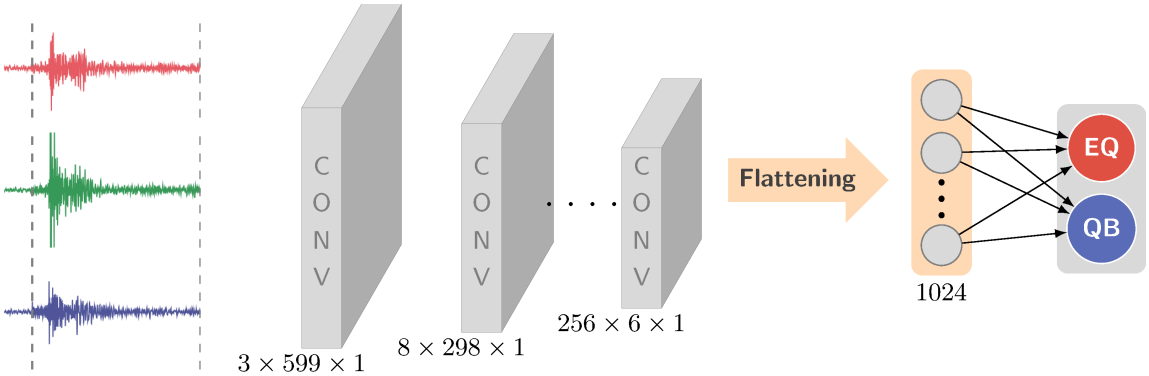



snr_8.03_evid_37218372_CI_FHO_BHZ
STA/LTA
theoretical
Normalized Amplitude
0.5
0
-0.5
0
pick 6.4 s
dt: -1.71
origin
35

Method: Data augmentation

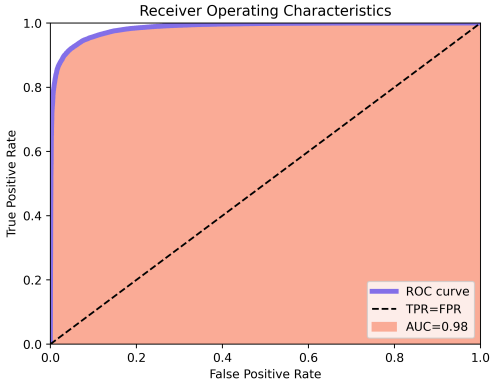


Method: CNN architecture

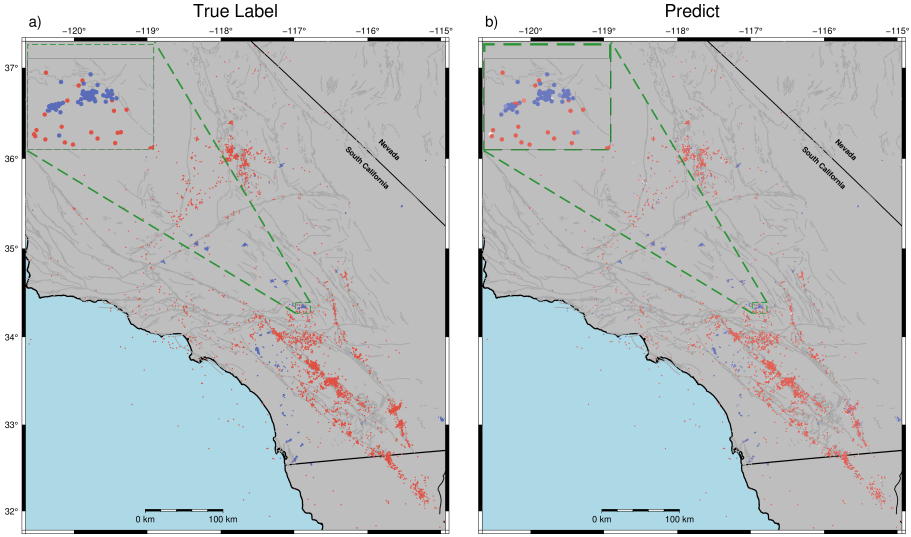


Accuracy: 93%

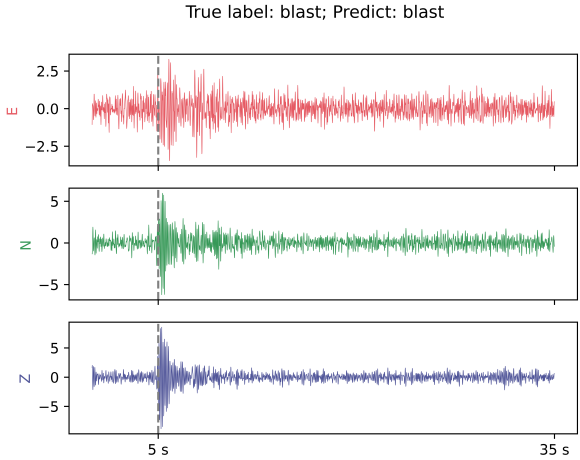
	Precision	Recall	F1-score	Support
Quake	0.98	0.92	0.95	64,014
Blast	0.78	0.95	0.86	19,186

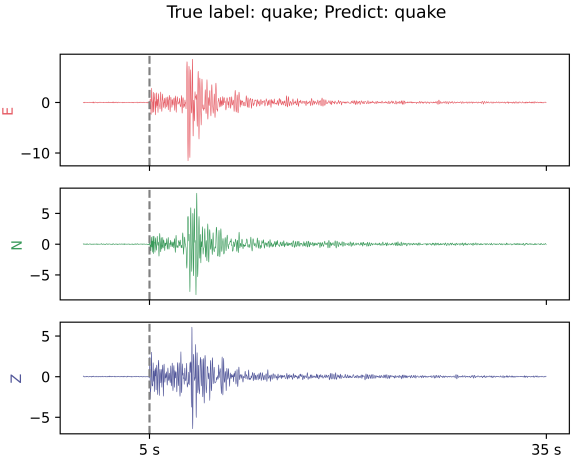


Results

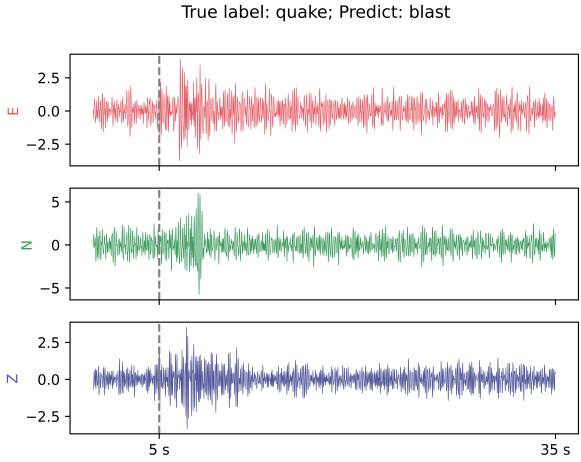

a)
True Label
b)
Predict
−120°
−119°
−118°
−117°
−116°
−115°
37°
36°
35°
34°
33°
32°
Nevada
South California
0 km
100 km

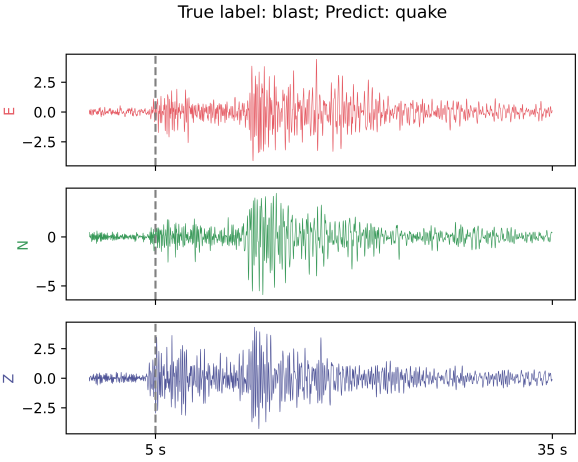
Results


True label: blast; Predict: blast
E
N
Z
2.5
0.0
−2.5
5
0
−5
5 s
35 s

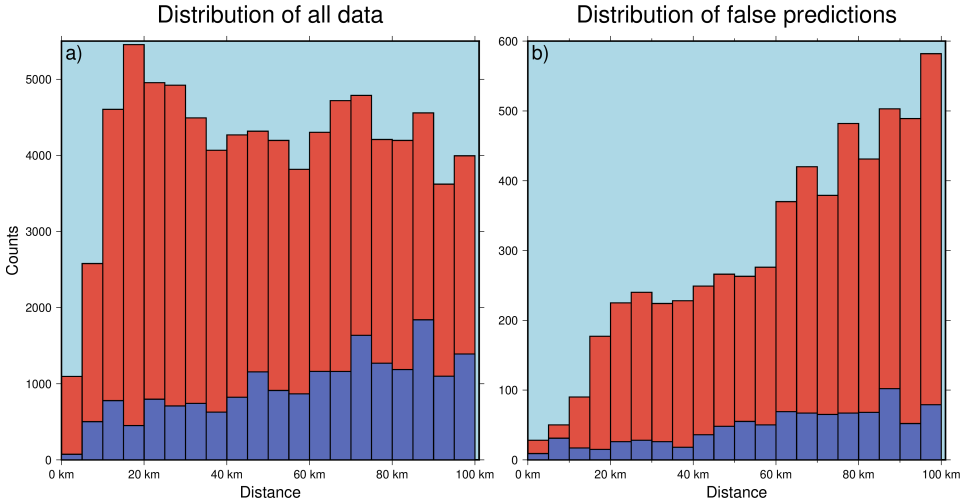

True label: quake; Predict: quake
E
N
Z
0
−10
5
0
−5
5 s
35 s

Results

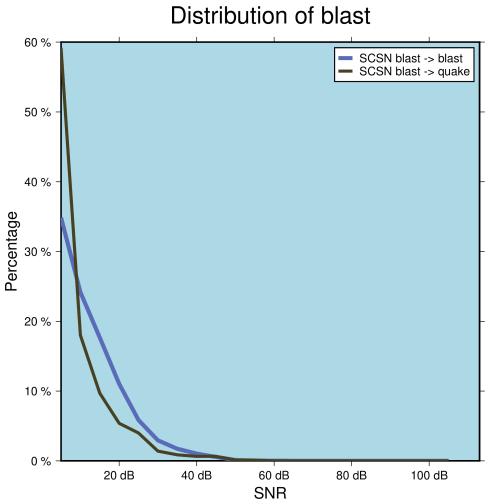

True label: quake; Predict: blast
E
N
Z
2.5
0.0
−2.5
5
0
−5
5 s
35 s

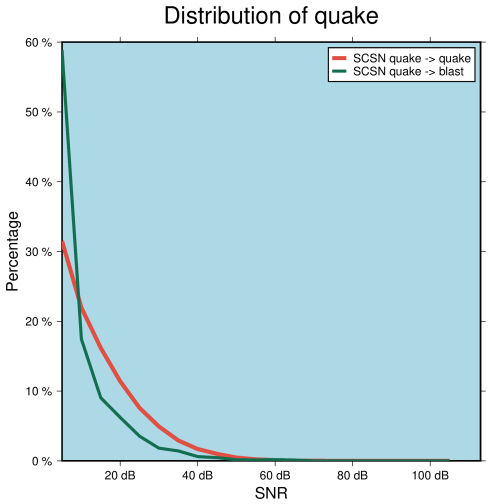

True label: blast; Predict: quake
E
N
Z
2.5
0.0
−2.5
0
−5
5 s
35 s

Results


Distribution of all data
a)
Counts
0
1000
2000
3000
4000
5000
0 km
20 km
40 km
60 km
80 km
100 km
Distance
Distribution of false predictions
b)
0
100
200
300
400
500
600
0 km
20 km
40 km
60 km
80 km
100 km
Distance

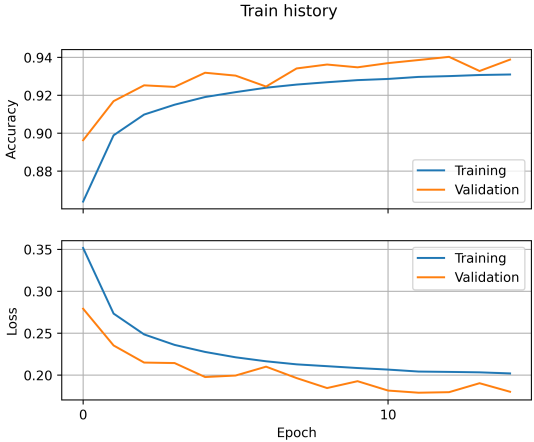
Results

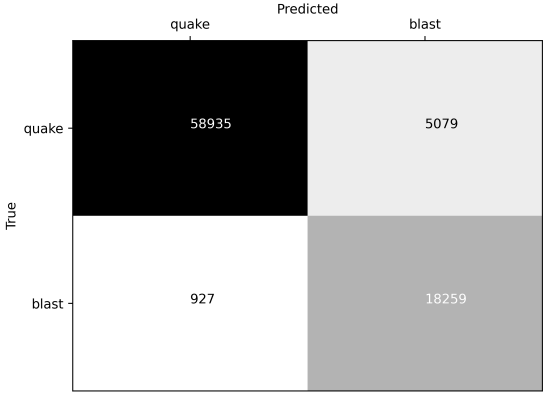

Distribution of blast
SCSN blast -> blast
SCSN blast -> quake
60 %
50 %
40 %
30 %
20 %
10 %
0 %
Percentage
20 dB
40 dB
60 dB
80 dB
100 dB
SNR

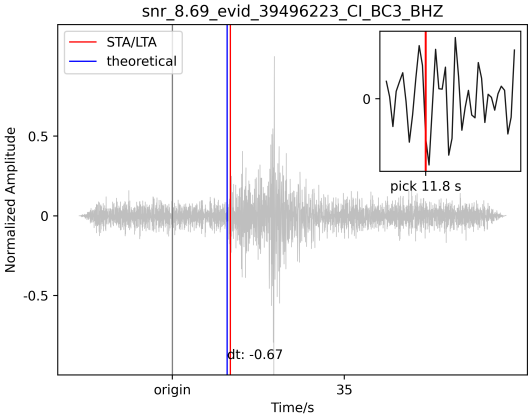

Distribution of quake
SCSN quake -> quake
SCSN quake -> blast
60 %
50 %
40 %
30 %
20 %
10 %
0 %
Percentage
20 dB
40 dB
60 dB
80 dB
100 dB
SNR

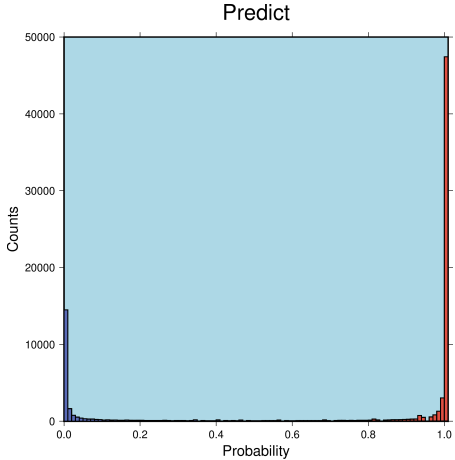
Summary

- CNN can achieve automatic discrimination without predetermined features.
- CNN can discriminate between earthquakes and quarry blasts with 93% accuracy, comparable to that of manual discrimination.
- The accuracy of CNN predicition is influenced by the the signal to noise ratio.


Train history
Accuracy
0.94
0.92
0.90
0.88
Training
Validation
Loss
0.35
0.30
0.25
0.20
Training
Validation
0
10
Epoch


Predicted
quake
blast
True
quake
blast
58935
5079
927
18259


snr_8.69_evid_39496223_CI_BC3_BHZ
STA/LTA
theoretical
0
pick 11.8 s
Normalized Amplitude
0.5
0
-0.5
dt: -0.67
origin
35
Time/s


Predict
50000
40000
30000
20000
10000
0
Counts
0.0
0.2
0.4
0.6
0.8
1.0
Probability

- Performance on Kentucky Data (Directly Applied)

	Predicted Quake	Predicted Blast
True Quake	119	42
True Blast	1,419	2,516

	Precision	Recall	F1-score	Support
Quake	0.08	0.74	0.14	161
Blast	0.98	0.64	0.77	3,935

- Performance on Kentucky Data (Retrained)

	Predicted Quake	Predicted Blast
True Quake	153	8
True Blast	110	3,825

	Precision	Recall	F1-score	Support
Quake	0.58	0.95	0.72	161
Blast	1.00	0.97	0.98	3,935

- Performance on Kentucky Data (Pretrained with 29404 Samples)

	Predicted Quake	Predicted Blast
True Quake	153	8
True Blast	51	3,884

	Precision	Recall	F1-score	Support
Quake	0.75	0.95	0.84	161
Blast	1.00	0.99	0.99	3,935

- Performance on Kentucky Data (Pretrained with 15000 Samples)

	Predicted Quake	Predicted Blast
True Quake	157	4
True Blast	86	3,849

	Precision	Recall	F1-score	Support
Quake	0.65	0.98	0.78	161
Blast	1.00	0.98	0.99	3,935