



Curtin University

# Monitoring Blasting Events in an Underground Mine with Artificial Intelligence Techniques

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2017

# Outline

1. Background
2. Methodology Framework
3. Application to Micro-seismic Monitoring in Mines
4. Summary

# 1. Background

- Vibration Source Locating



Earthquake, Ecuador, 16, April, 2016



Rock burst, northwest Russia, 25February ,2016.



Hurricane



Nuclear submarines

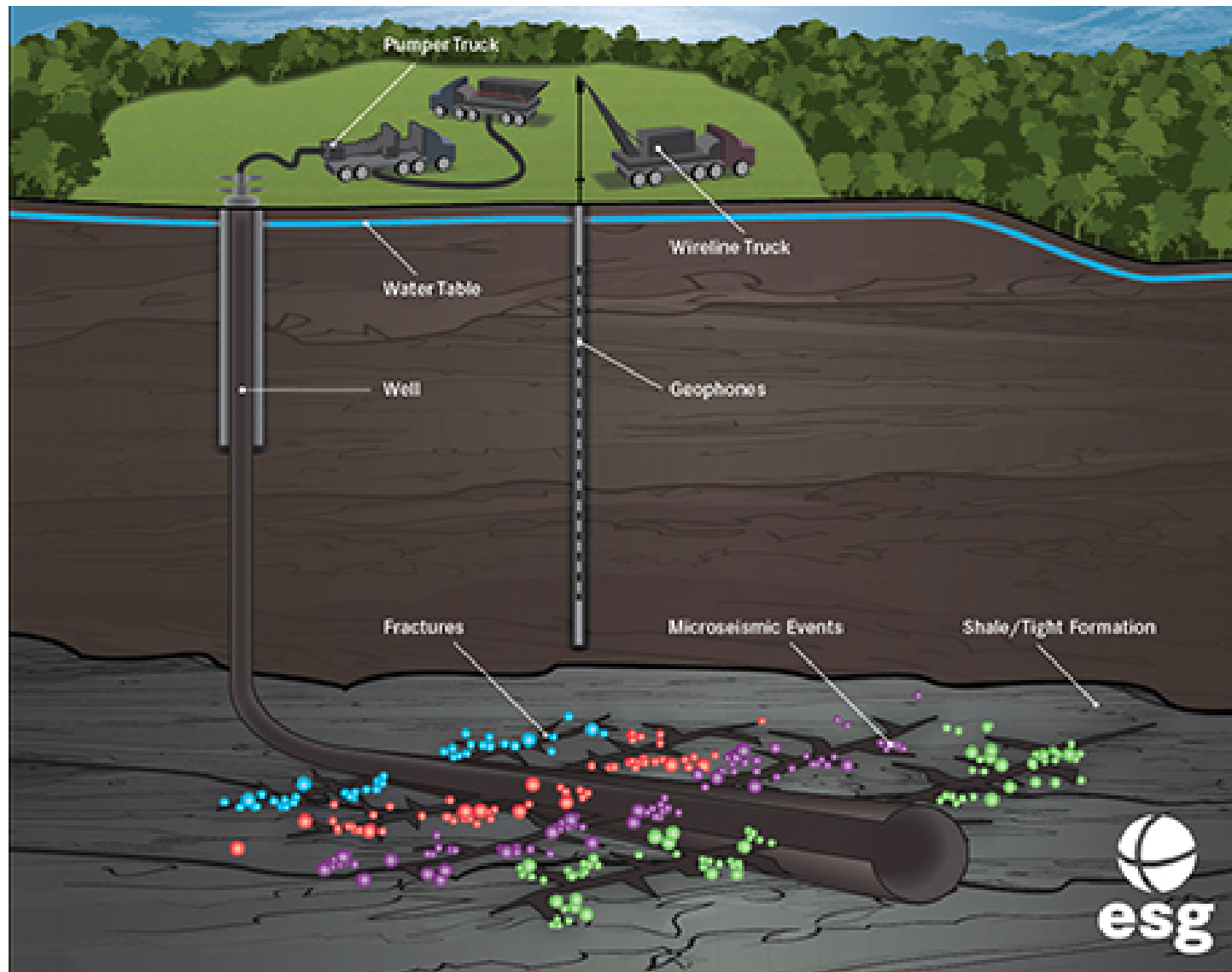
Chen, X., D. Tian, and L. Wen (2015), Microseismic sources during Hurricane Sandy, J. Geophys. Res. Solid Earth, 120, 6386–6403, doi:10.1002/2015JB012282.

<http://archive.cosmosmagazine.com/news/earthquake-tool-finds-use-hurricane-monitoring/>

<http://www.abc.net.au/news/world/>

<http://tass.ru/en/society/858987>

of Technology



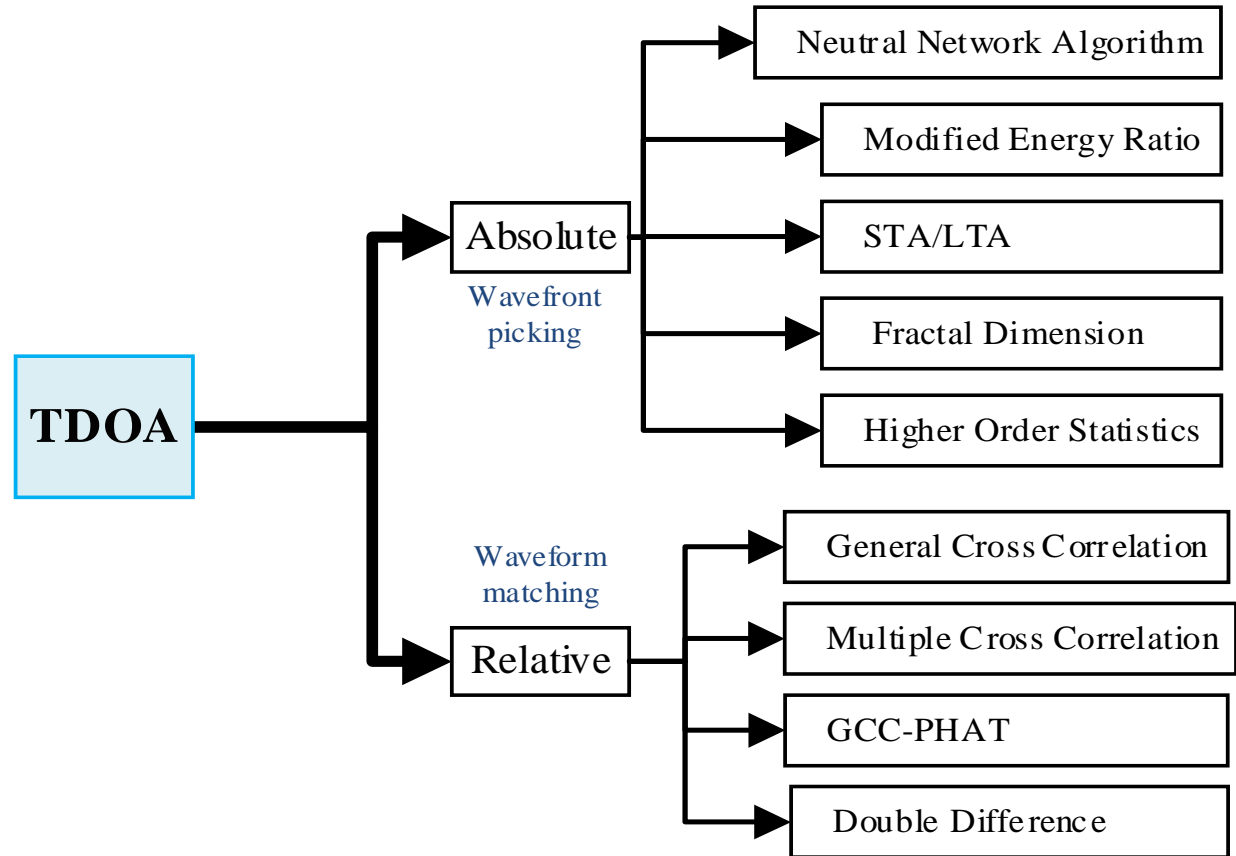
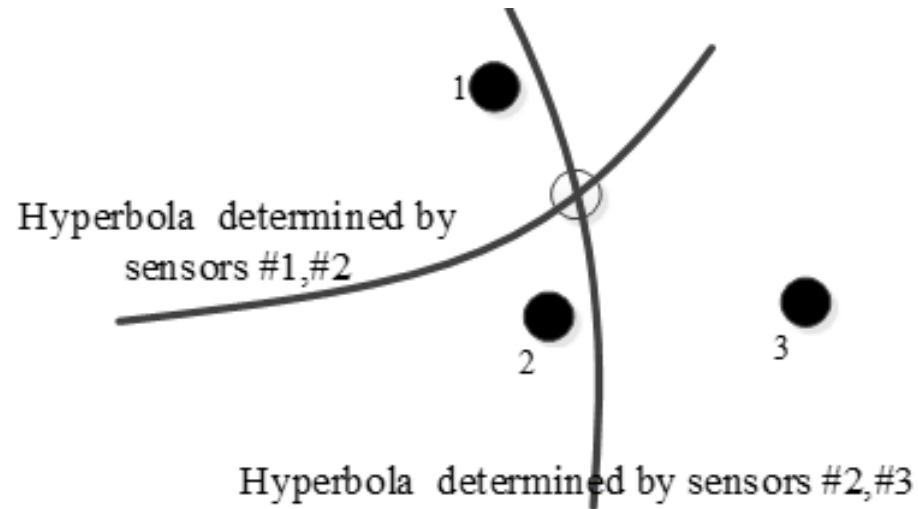
## Underground Mines

# Micro-seismic event and monitoring

- Small earthquakes, usually magnitude  $< 0$ .
- A array of geophones/seismometers deployed to record any seismic events.
- May also monitor rock burst, blast-induced vibrations, fluid movement, slope landslide etc.
- The accuracy depends on the velocity model, picking up the time instants of P-wave, the sensor arrays and the algorithms.

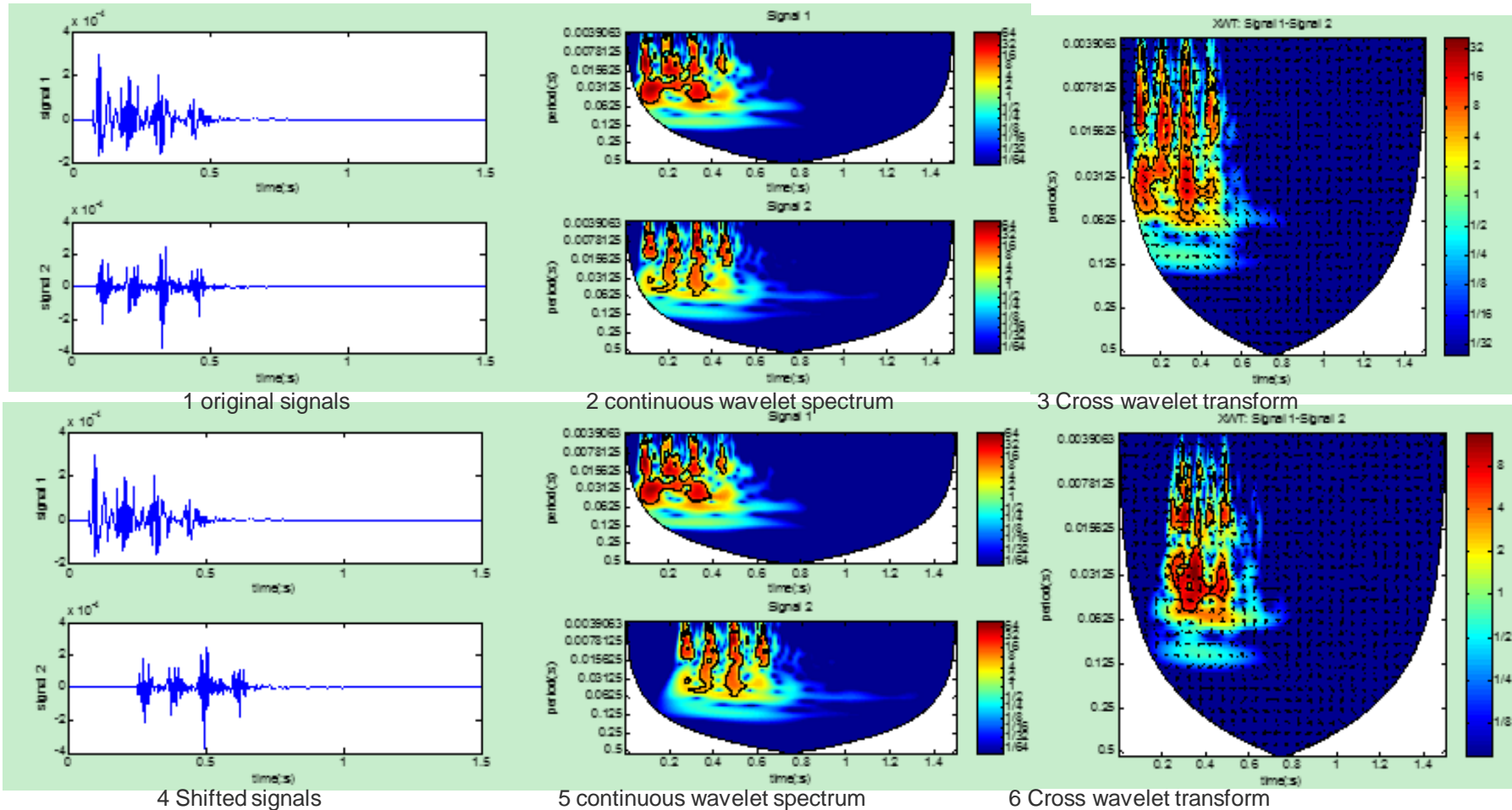
# Vibration Source locating based on TDOA

TDOA (Time Delay of Arrival)

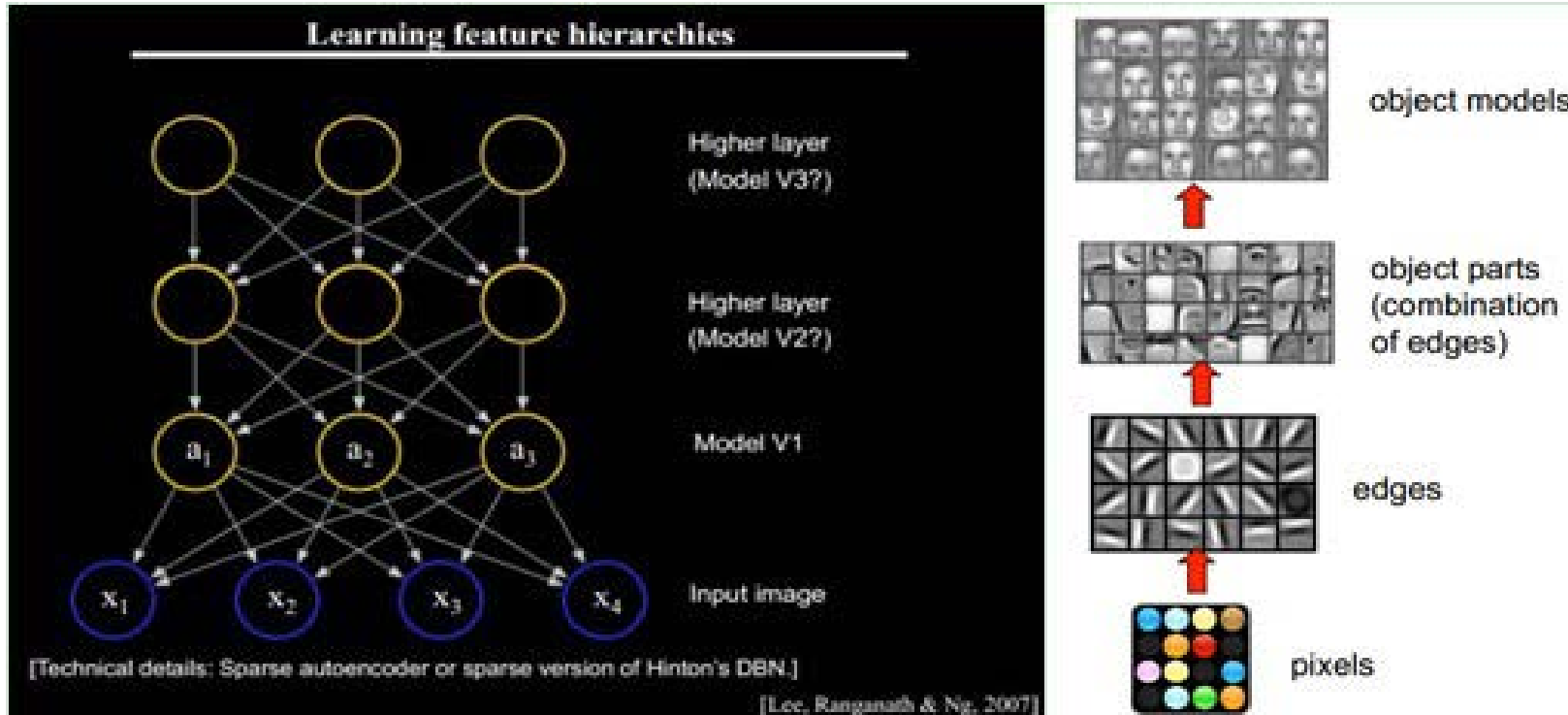




# Cross wavelet transform



# Cutting Edge of Machine Learning: Deep Learning in Neural Networks



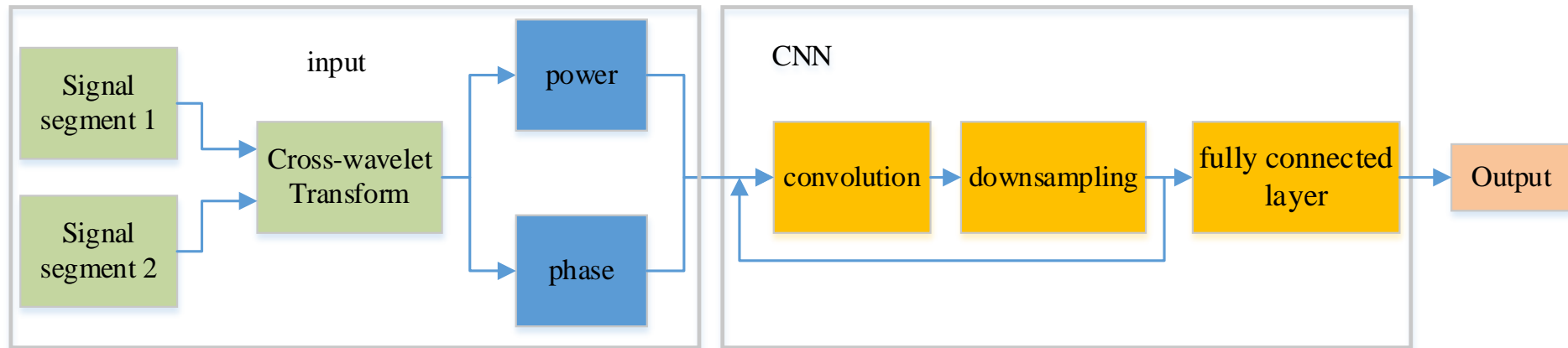
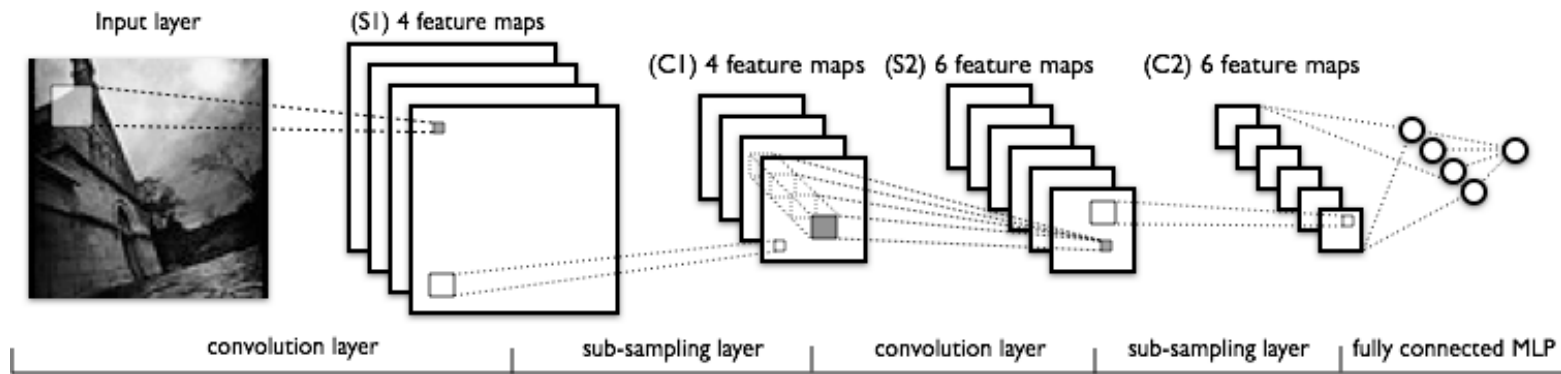
Engineering applications:

- Computer vision
- Speech recognition
- Natural Language Understanding
- Robotics

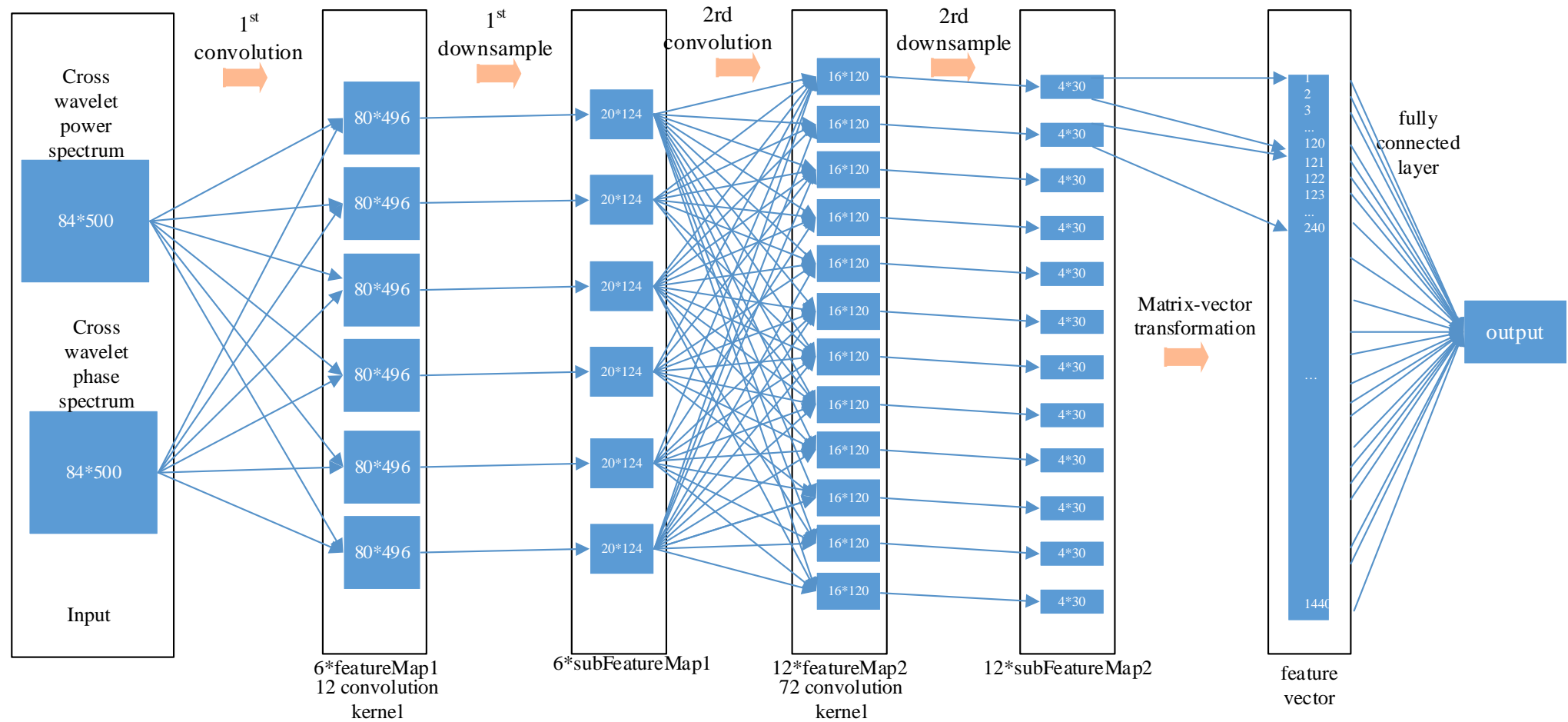


## 2. Methodology Framework

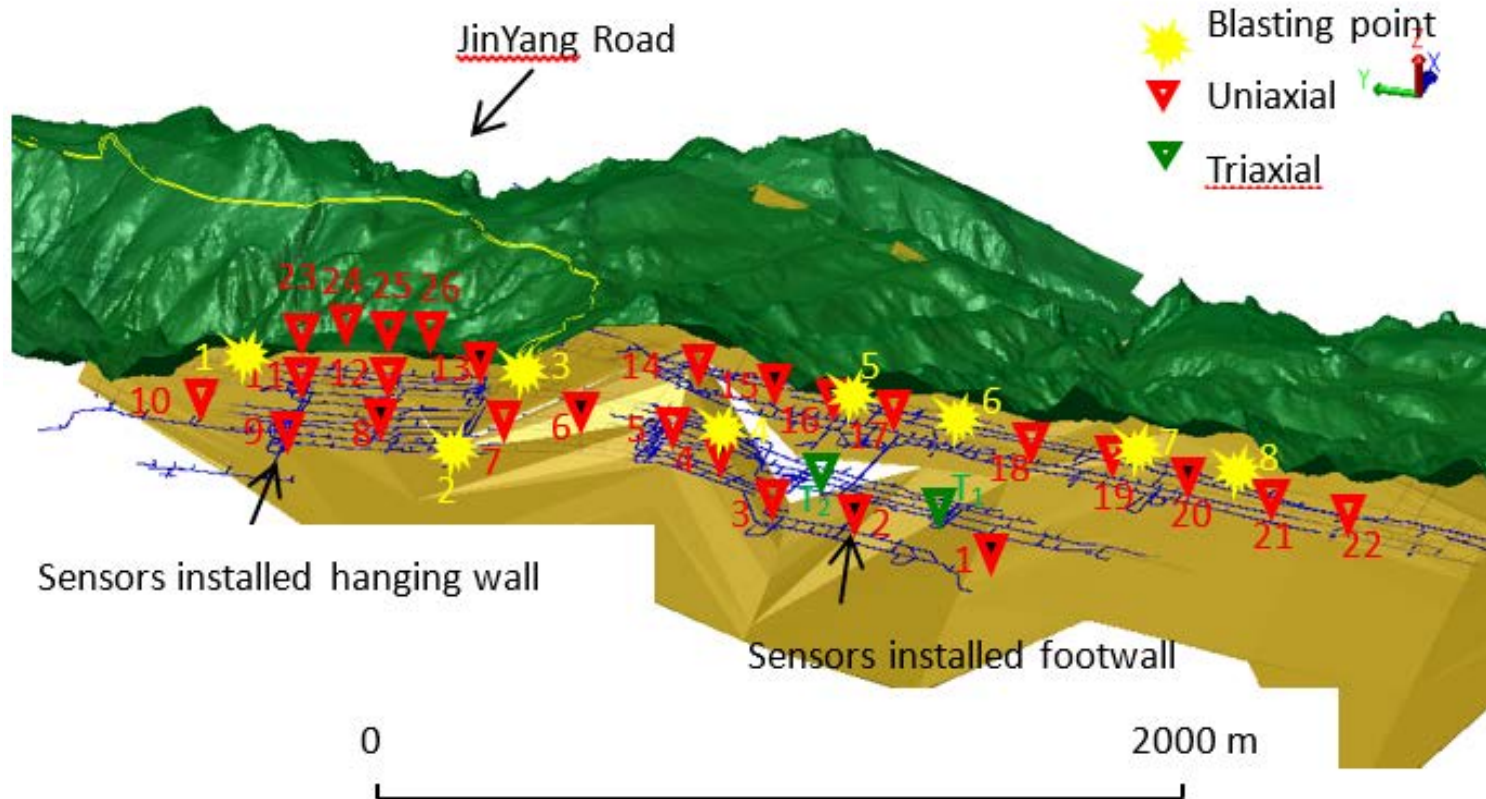
- Convolutional Neural Network and deep learning



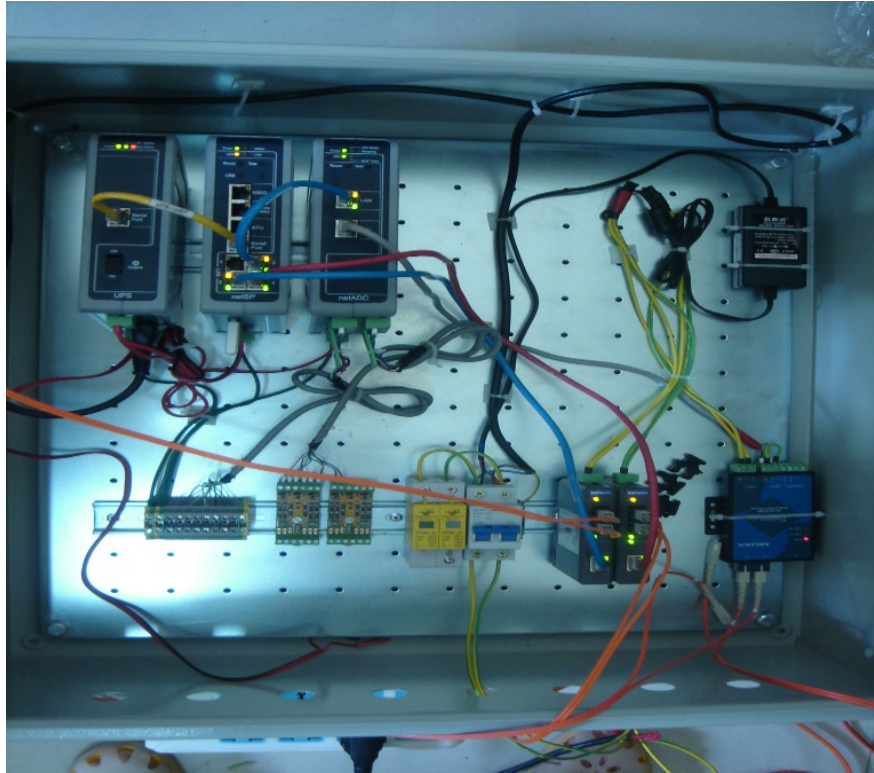
# Architecture design



# Testing with in-field blasting tests



# Sensory system

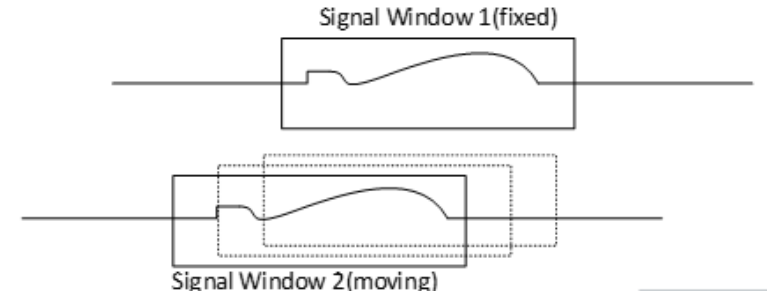


Geophone

# Training and validation

- Data generation

10 micro-seismic events, 10 sensors



(1) Input

The power spectrum and phase spectrum of cross wavelet spectrum when the time window is sliding.

For each pair waveform, there are one fixed signal window and one slide windows (slide 5 times,  $t_i$ ,  $i=1,2,3,4,5$ ).

The number of Training data:  $C(10,2)*10*5=2250$

(2) output

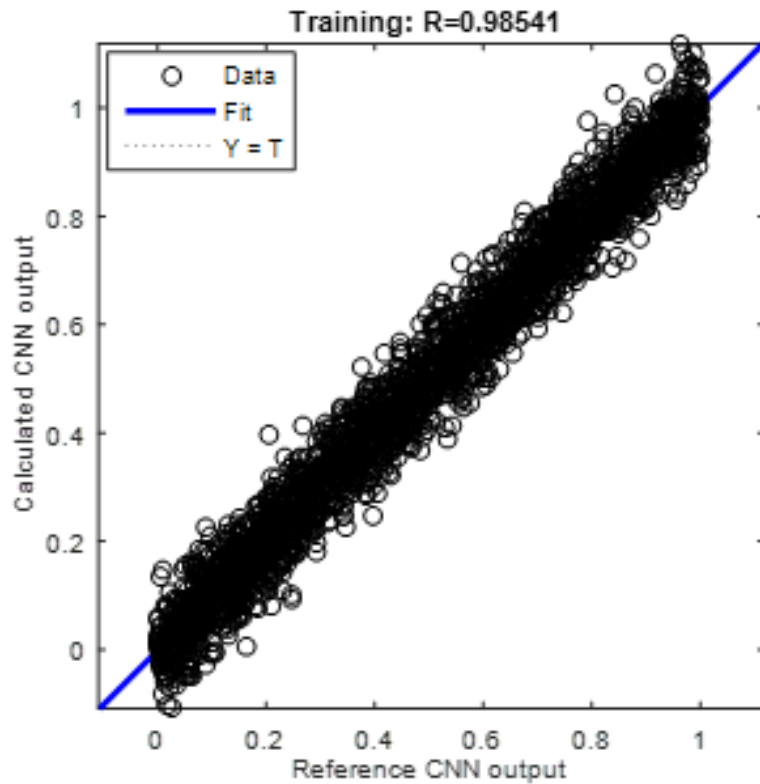
When the slide location is  $t_i$ , the expectation output of neutral network is:  $f(x)=\exp(-|t_i-TDOA|)$



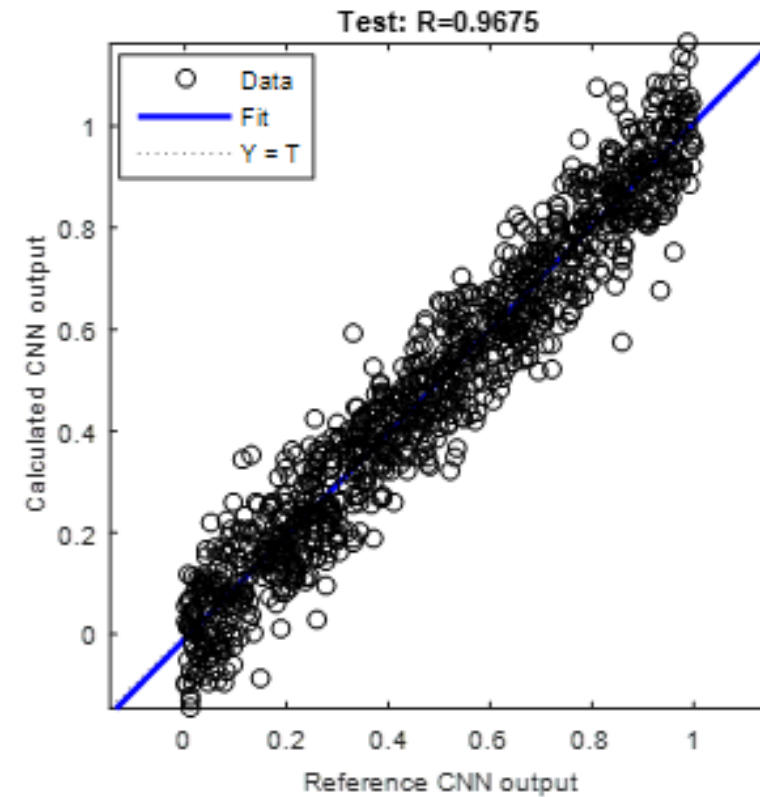
## List of functional sensors associated with each blasting test

Event No.	Functional Sensors	Number of effective sensors	Number of TDOA
1	3,4,5,6,7,8,9,10,12,13,14,15,16,17,24,25,26,27,28	19	171
2	4,8,9,10,11,12,15,16,24,25,26,28	12	66
3	1,2,3,4,5,8,15,16,17,18,19,20,21,22,27,28	16	120
4	3,4,5,6,7,8,9,10,11,12,13,15,16,17,24,25,26,27,28	19	171
5	2,3,4,5,6,7,8,9,10,15,16,17,18,24,25,26,27,28	18	153
6	1,3,4,5,6,7,8,9,10,14,15,16,17,24,25,26,27,28	18	153
7	3,4,5,6,7,8,9,10,12,13,15,16,17,24,25,26,27,28	18	153
8	7,8,9,10,15,16,23,24,25,26	10	45

# Regression in training & testing

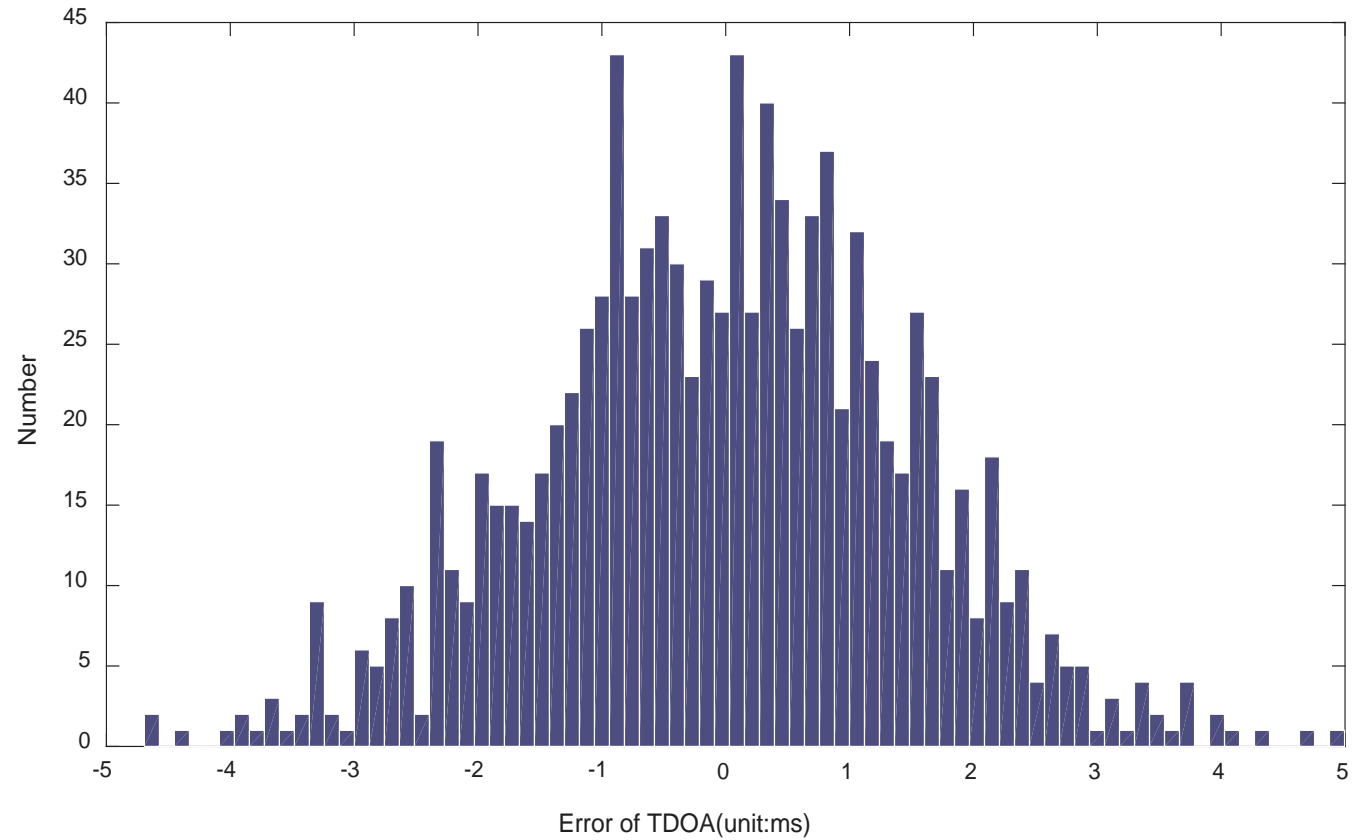


(a) Training & validation process



(b) Testing process





The statistical errors of calculated TDOA by the proposed approach

Methods	Statistical errors (ms)	
Cross-correlation	Mean	3.29
	standard deviation	5.61
Multi-correlation	Mean	2.42
	standard deviation	4.41
STA/LTA	Mean	5.96
	standard deviation	8.25
Kurtosis	Mean	3.18
	standard deviation	6.21
The proposed approach	Mean	1.16
	standard deviation	1.59

**Comparison of errors (ms) in using different methods for the identification of TDOA**

# Testing results in source locating

Absolute errors (m) in the identified source locations of conducted blasting tests

No.	Cross-correlation	Multi-correlation	STA/LTA	Kurtosis	The proposed approach
1	20.17	17.06	33.05	16.83	5.62
2	18.09	17.01	31.24	19.10	9.85
3	19.79	18.51	24.56	20.23	9.16
4	24.13	22.49	31.56	17.30	12.23
5	21.22	20.39	21.14	24.70	12.68
6	23.79	22.59	23.71	16.33	7.23
7	21.72	20.09	17.19	20.17	10.55
8	18.86	17.82	22.06	23.05	6.94

## 5. Summary

- Latest use of CNN for micro-seismic monitoring in underground mines
- Demonstrations with in-field data.



**Thank you for your attention!**

**Welcome comments and collaborations.**

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