Projet Fédérateur
Mobilités et Transitions Numériques
[03/12/2018 – IFSTTAR Marne-la-Vallée]

ULTRA WIDE-BAND SHORT-RANGE RADAR FOR VULNERABLE ROAD USERS IDENTIFICATION

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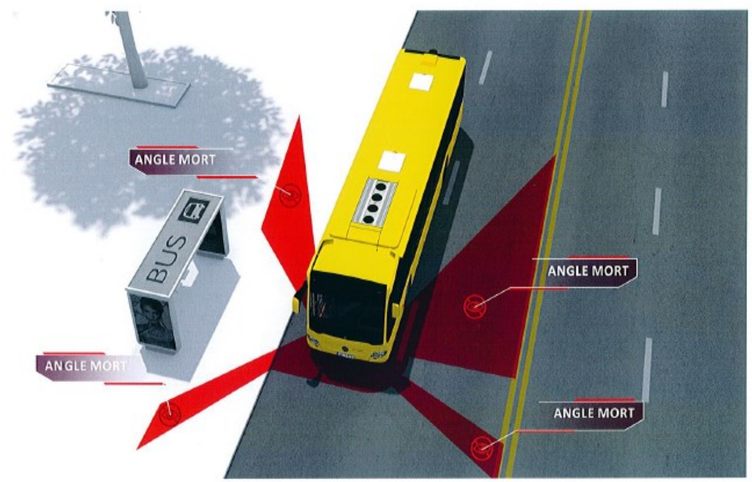
CYCLOPE

Protection électronique pour les cyclistes

Objective:

- To develop a solution that facilitates the integration of cyclists into urban traffics and protects the pedestrians by improving their safety



- To deploy the system in the blind spots areas of buses and trucks

General Problematics

- ***cyclists*** **and** ***pedestrians*** **are the most vulnerable road users**
- **around 2000 people riding bicycle are killed every year in EU countries in traffic accidents**

  [*ERSO, 'Traffic safety basic facts 2015: cyclists', Tech. Rep, European Road Safety Observatory, 2015*]

Fundamental causes:

- **lack of drivers visibilities (bus,truck:** ***blind spots*****)**
- **lack of attentions [cyclists, pedestrians, drivers]**

Proposed Solutions and Technology

- **Identification of VRUs using UWB Short Range Radar**

Target detection:

- *cyclist and pedestrians* have low Radar Cross Section (RCS)
- reflect a very limited amount of radar energy (low SNR)
- highly influenced by the capacity to distinguish the useful radar information and the noise or clutter.

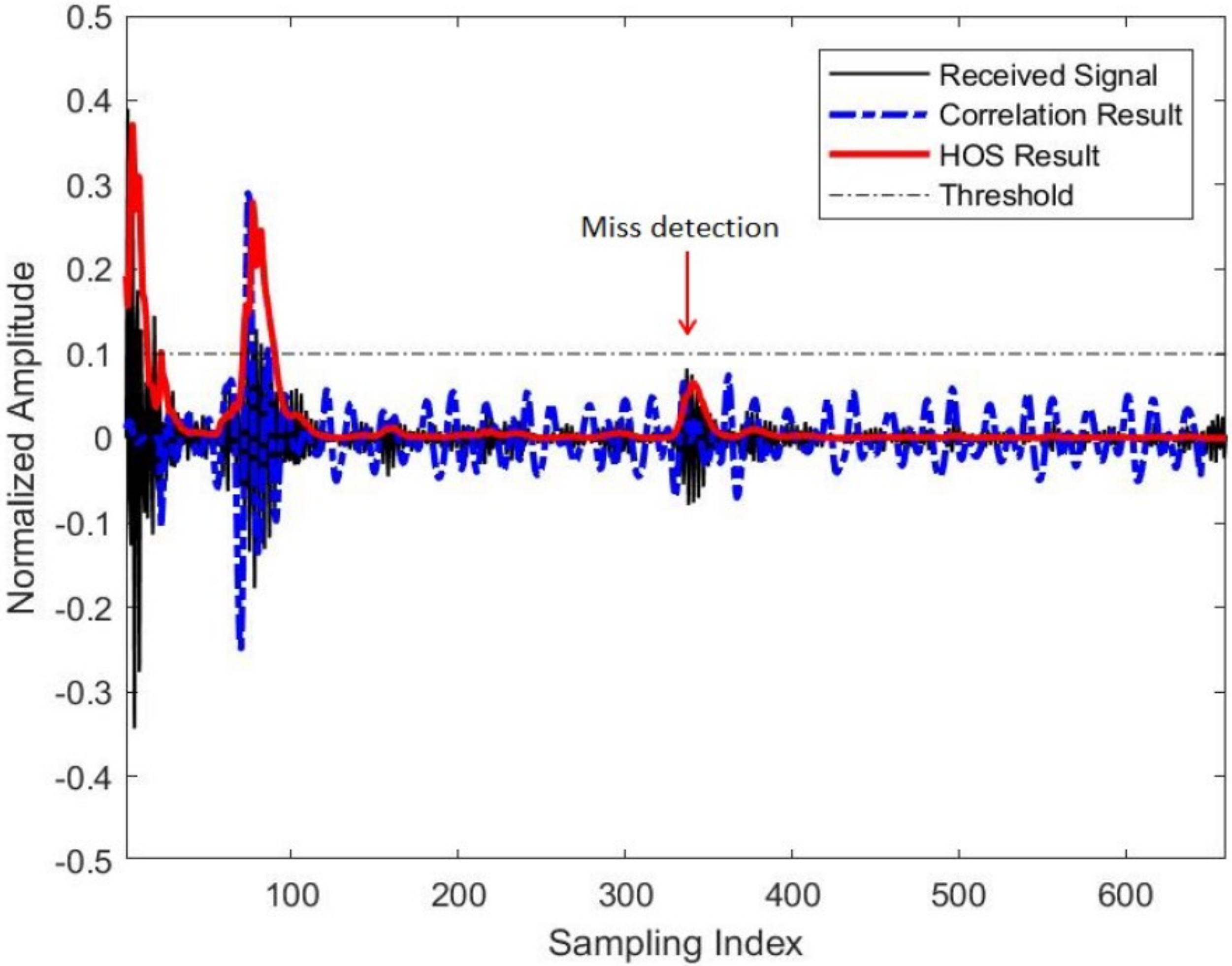
Target Recognition:

- In a real complex environment, recognizing the pedestrian and cyclist using UWB radar is required a good machine learning system

- **Detection:**
  - **HOS & CA-CFAR (1-D)**
  - **HOS & WSD (2-D)**
    - HOS : *Higher Order Statistics*
    - CA-CFAR detector: *Cell Averaging-Constant False Alarm Rate* detector
    - WSD : *Wavelet Shrinkage Denoising*

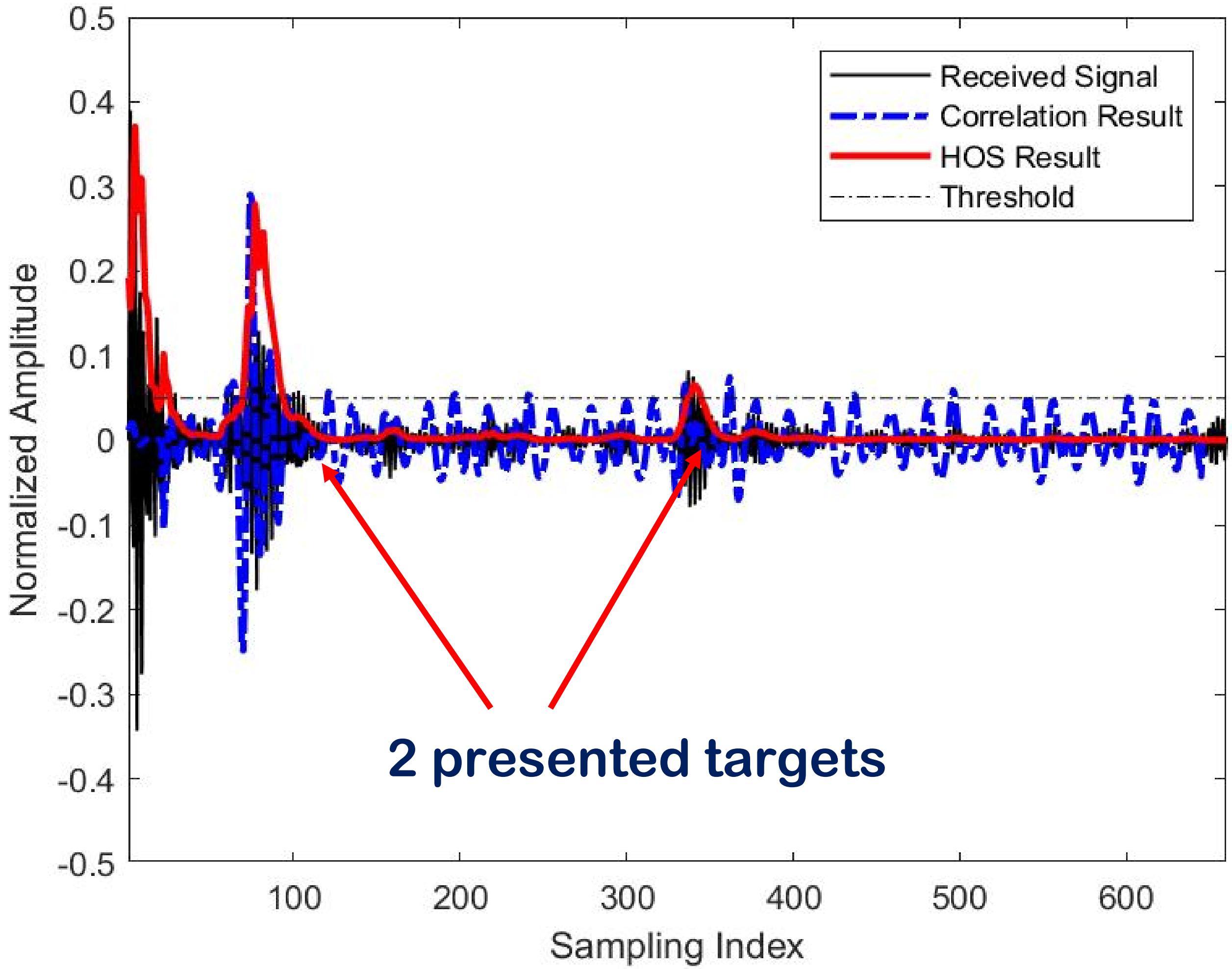
- **Identification:**
  - SVM: *Support Vectors Machines* (1-D)
  - Deep Learning Algorithm:
    - CNN (Convolution Neural Network) (2-D)

Classical Methods: ***2nd Order Statistics (Auto-Correlation) - HOS***



Threshold: 0.1

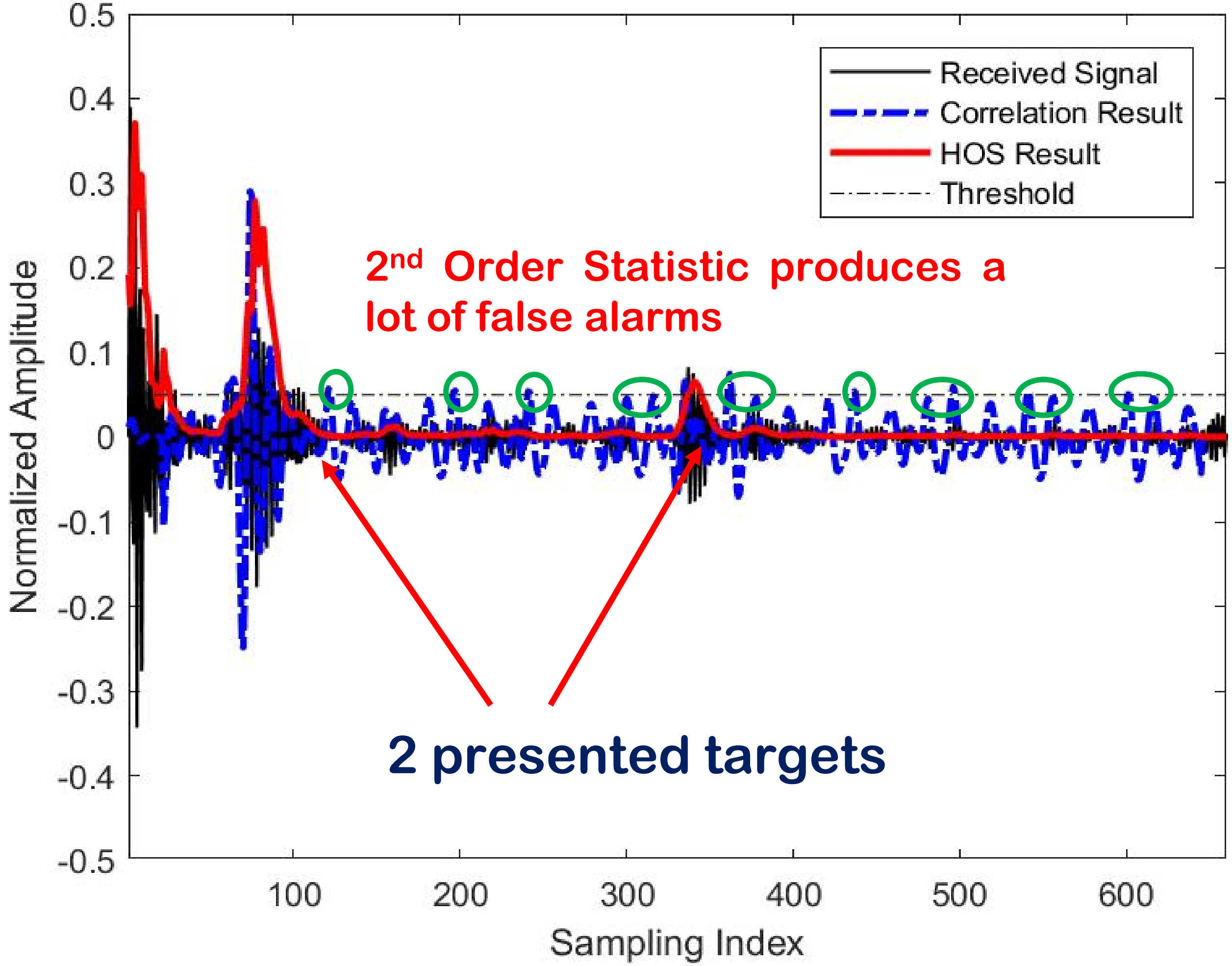
Classical Methods: *2nd Order Statistics (Auto-Correlation) - HOS*



Threshold: 0.05

Issues

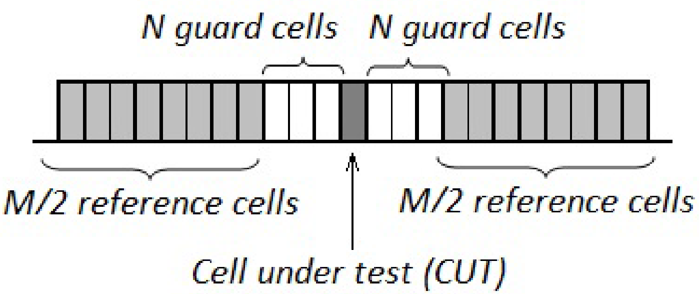
Classical Methods: *2nd Order Statistics (Auto-Correlation) - HOS*

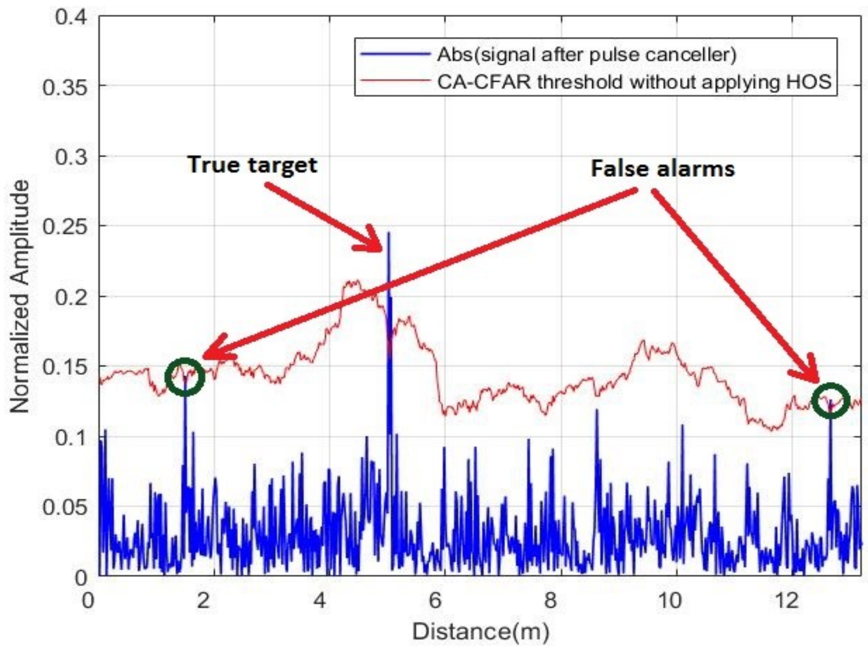


Threshold: 0.05

Well-Kown CA-CFAR Detector

Adaptively threshold based on local information on the background noise



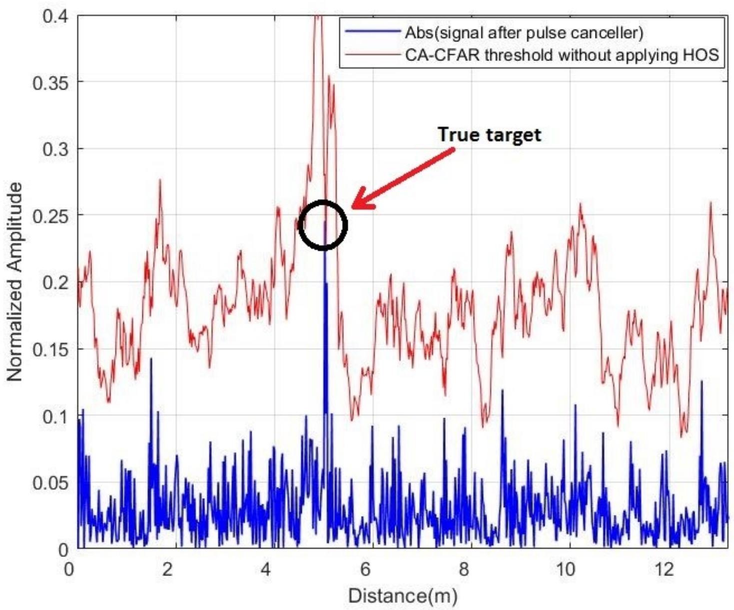


Problem: **Difficult to determine the number of reference cell (M)**

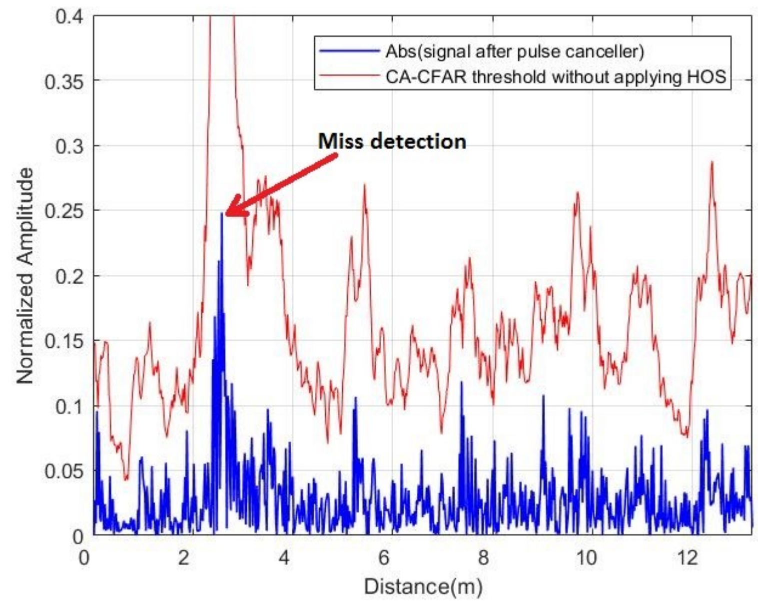
$P_{fa} = 10^{-5}$, $M = 80$, and $N = 2$.

Well-Kown CA-CFAR Detector

If we keep this setting, the next raw data will miss the target



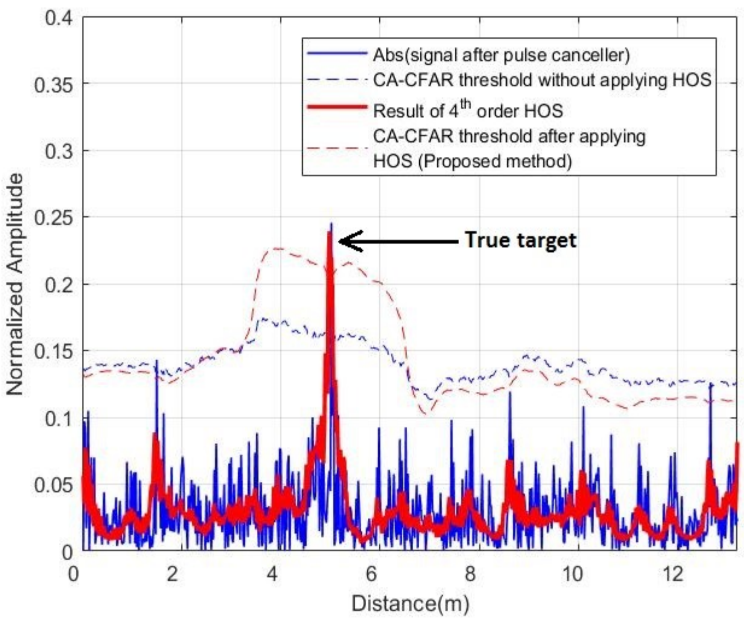
$P_{fa} = 10^{-5}$, $M = 20$, and $N = 2$.



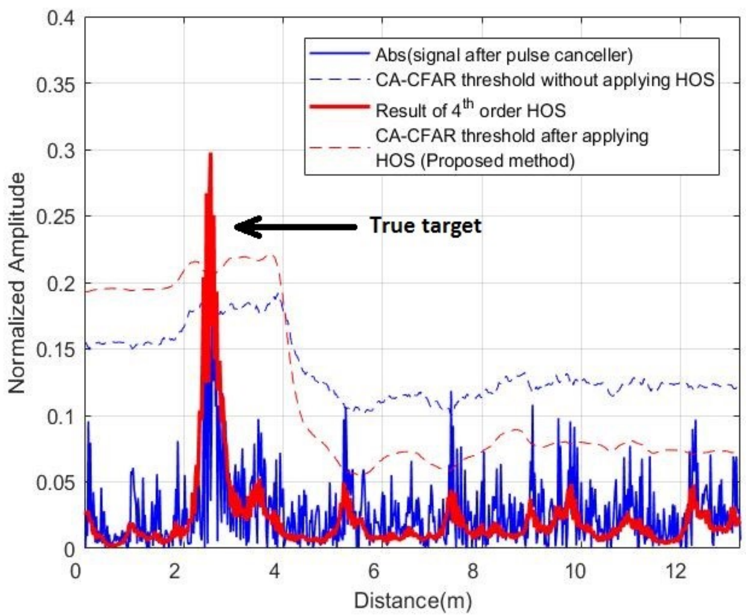
$P_{fa} = 10^{-5}$, $M = 20$, and $N = 2$.

Proposed Method

HOS + CA-CFAR



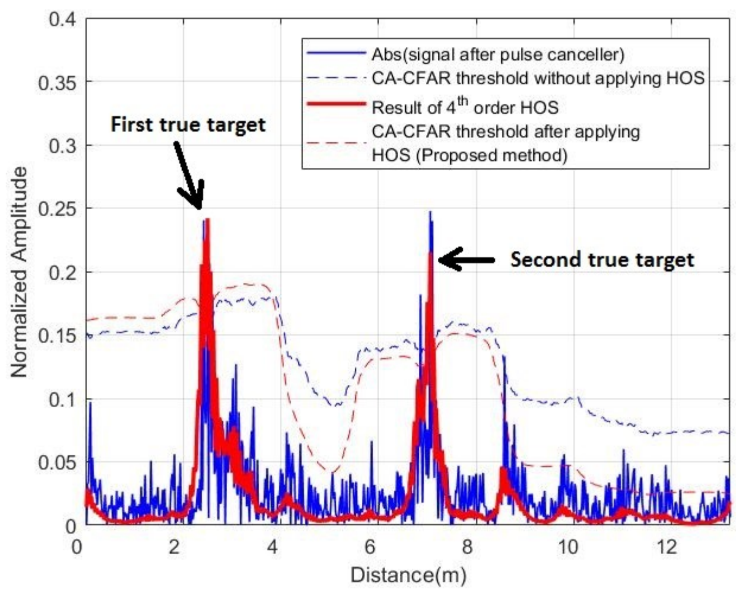
$P_{fa} = 10^{-5}$, M = 150, and N = 2. A real target presents at 5 meters away from the radar.



$P_{fa} = 10^{-5}$, M = 150, and N = 2. Two real targets present at 2.5 and 7 meters away from the radar.

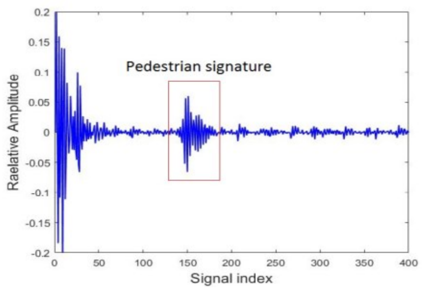
Proposed Method

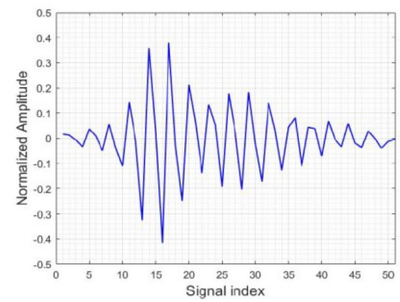
HOS + CA-CFAR



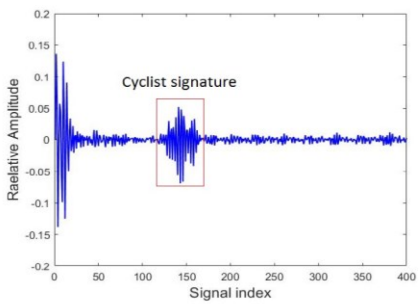
$P_{fa} = 10^{-5}$, M = 150, and N = 2. Two real targets present at 2.5 and 7 meters away from the radar.

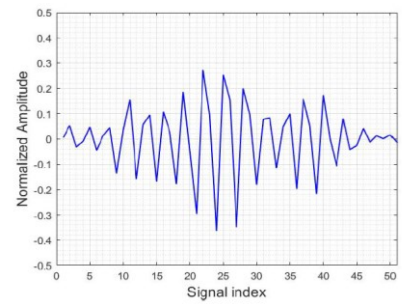
Radar Signature



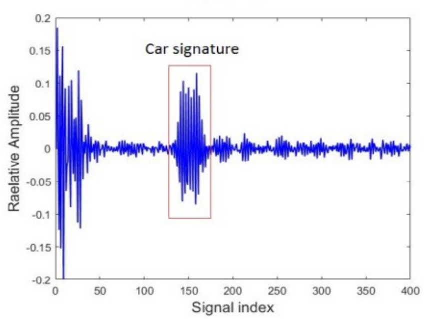


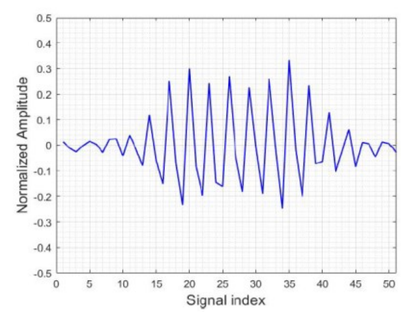
Normalized Pedestrian signature





Normalized Cyclist signature





Normalized Car signature

Result of Performance of SVM using 1-D Radar Signature

[Confusion Matrix]

	Cyclist	Pedestrian	Car
Cyclist	96.23%	2.46%	1.31%
Pedestrian	3.62%	95.25%	1.13%
Car	1.60%	1.17%	97.23%

Total Accuracy =96.24%

Total *Training* dataset= 3000, 1000 each class

Total *Testing* dataset= 1200, 400 each class

Proposed Method:

Higher Order Statistics **(HOS) +** ***Wavelet Shrinkage Decomposition*** **(WSD)**

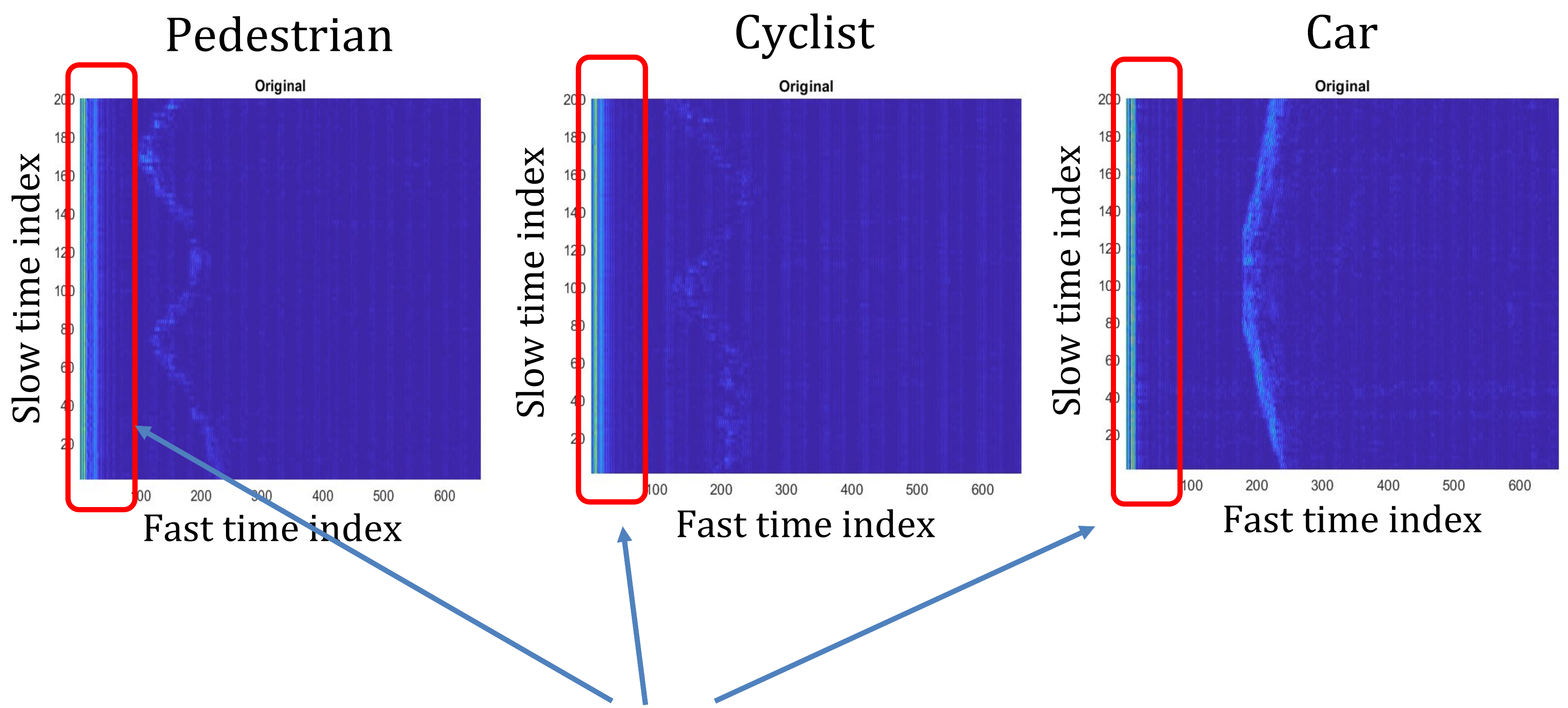
WSD

Advantage: preserve the signal characteristics, and regardless of its frequency contents

HOS

Advantage: Good in suppresing the non-gaussian noise

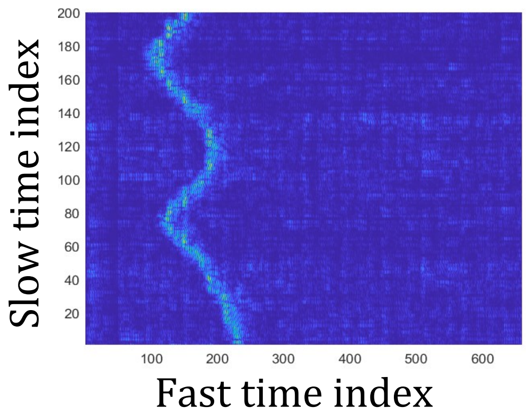
[Original B-scan (2D) data]



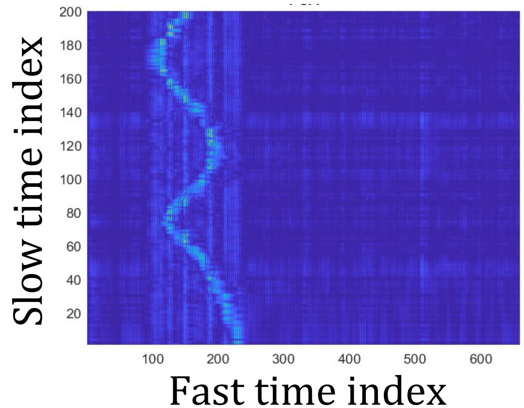
#1: Apply Pulse Canceller to remove direct coupling between two antennas

Performance of the HOS+WSD [Pedestrian]

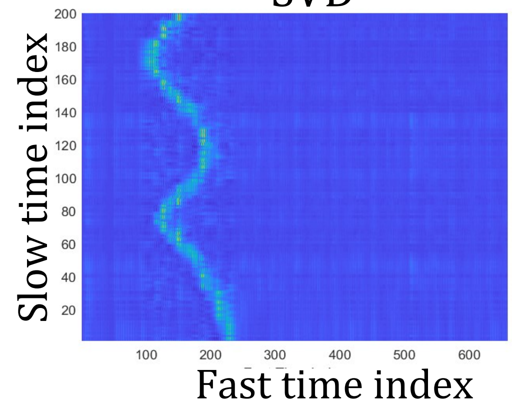
Pulse Canceller



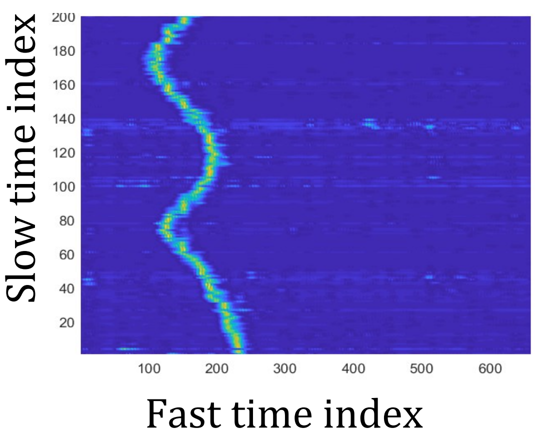
PCA



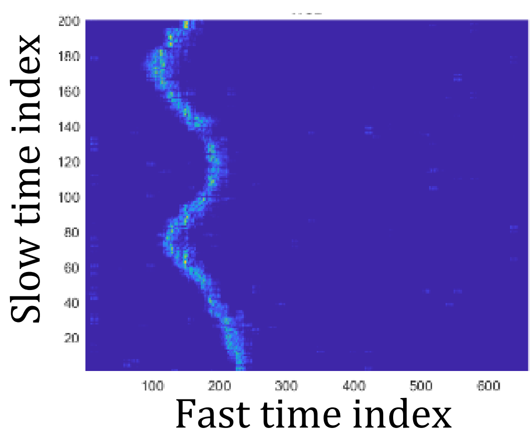
SVD



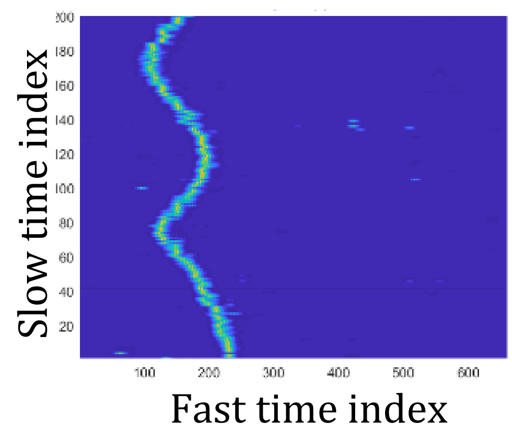
HOS



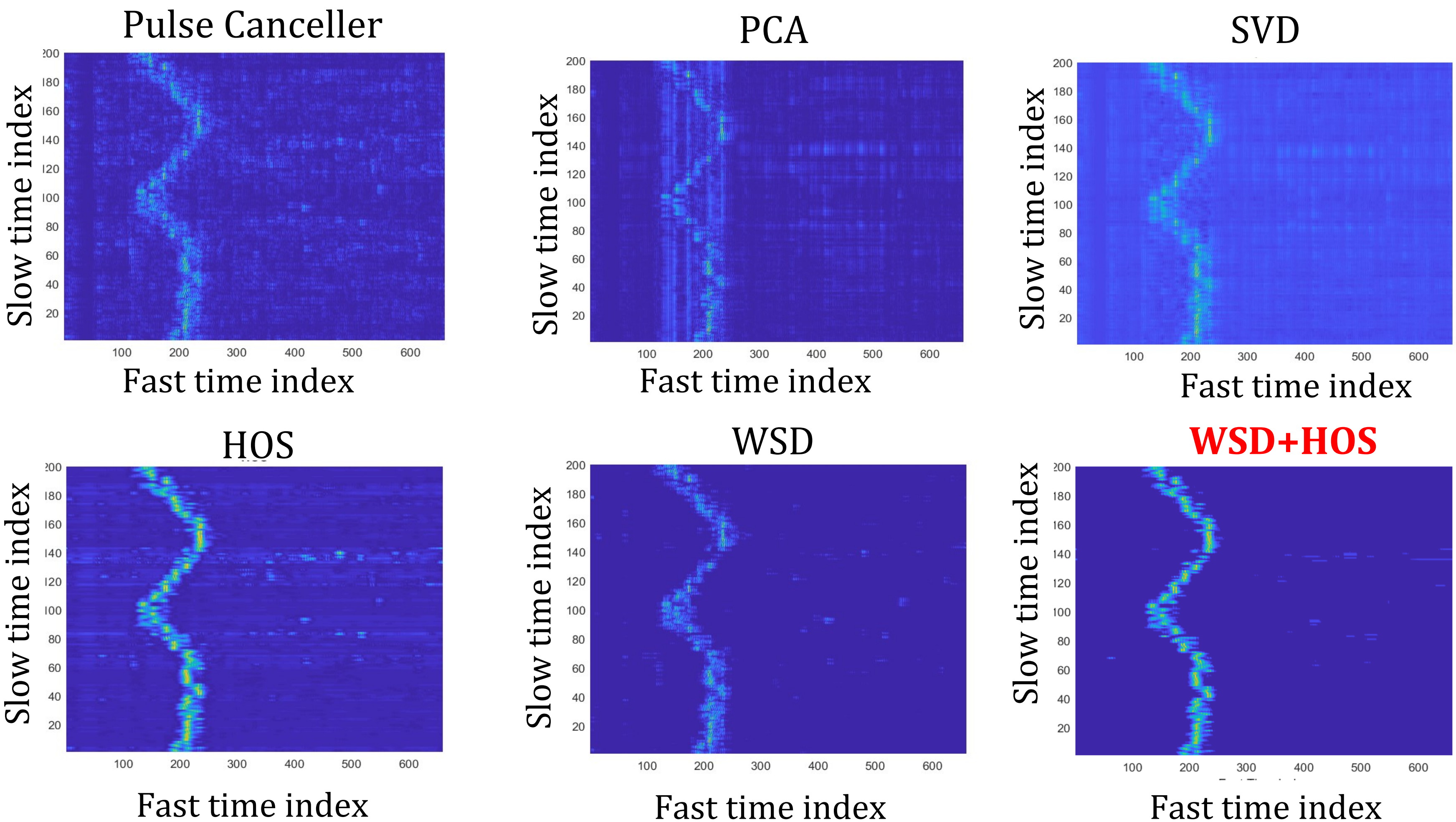
WSD



WSD+HOS



Performance of the HOS+WSD [Cyclist]



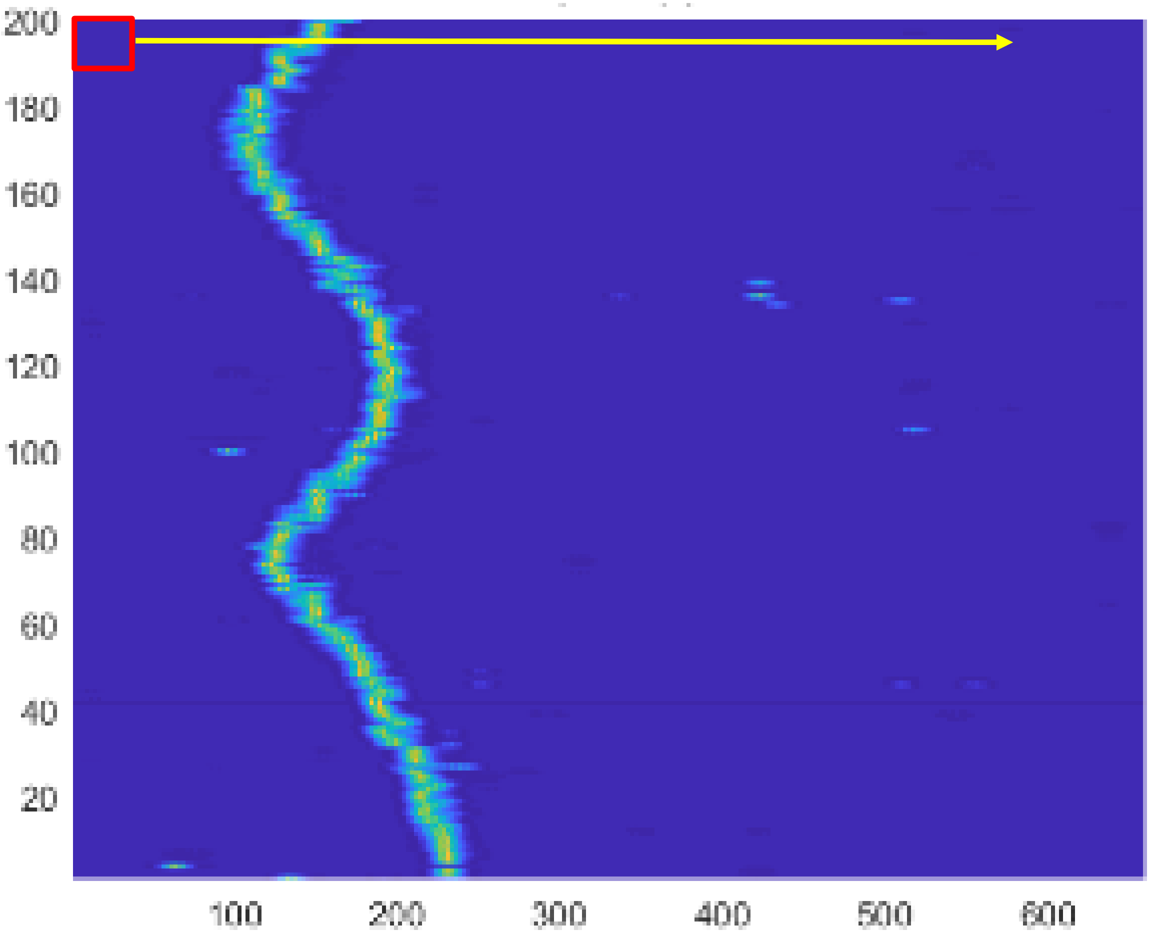
Performance of the HOS+WSD

PERFORMANCE COMPARISON SNR(dB) FOR DIFFERENT NOISE REMOVAL METHODS.

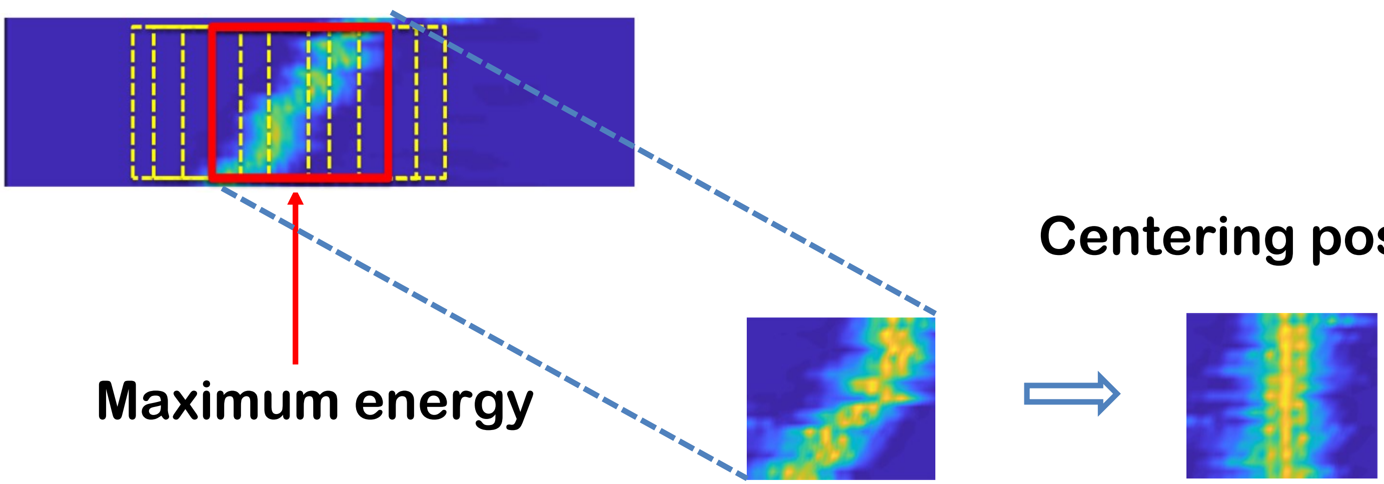
Target Types	Noise Removal Methods					
	Pulse Canceller	PCA	SVD	WSD	HOS	WSD+HOS (*Our Method*)
Pedestrian	16.34	19.12	20.53	25.18	25.18	**32.47**
Cyclist	15.68	18.26	19.48	23.22	26.02	**29.13**
Car	20.82	21.44	21.91	29.30	33.99	**38.61**

Target Detection

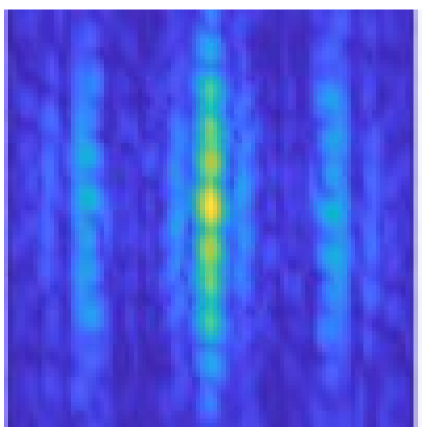
Sliding Windows Approach



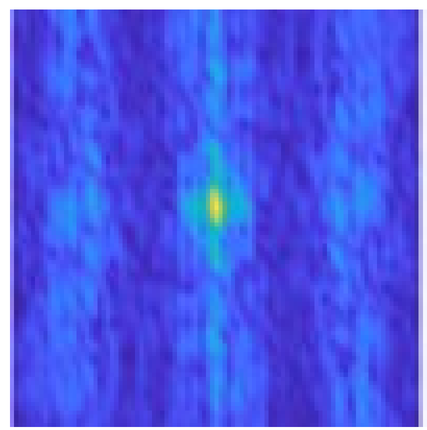
Applying Non-Maximum Suppression on the overlap windows



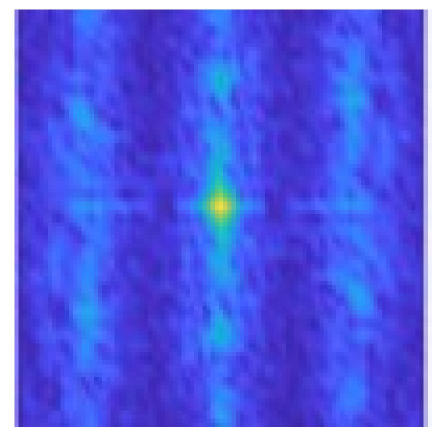
Transform detected region into power spectral density



Car

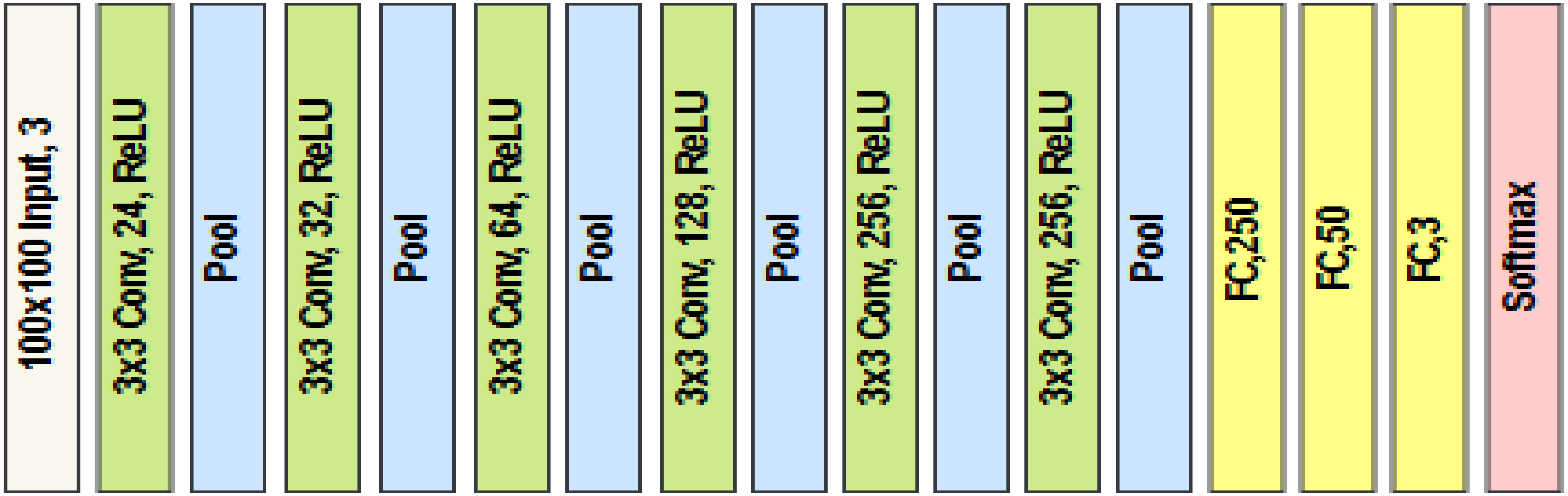


Cyclist



Pedestrian

Proposed Architecture



Input Layer, 3 RGB Channels

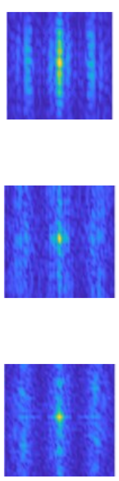
6 Convolution Layers + Max Pooling
(Filter 3x3, Channels: 24, 32, 64, 128, 256, 256)

3 Fully Connected Layers, Channels: 250, 50 and 3

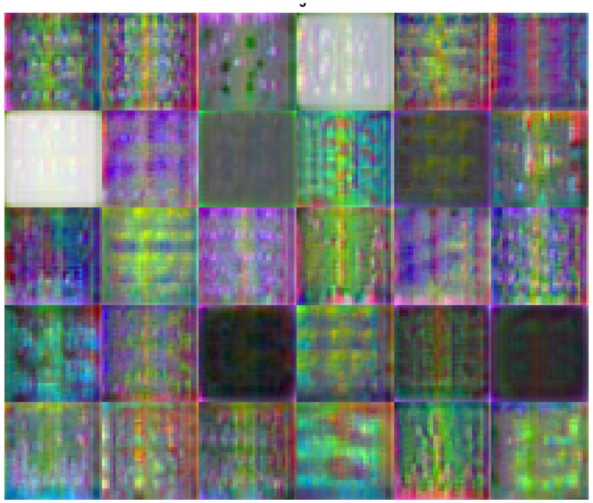
Softmax Output Layer: 3 Classes

Feature Maps Visualisation

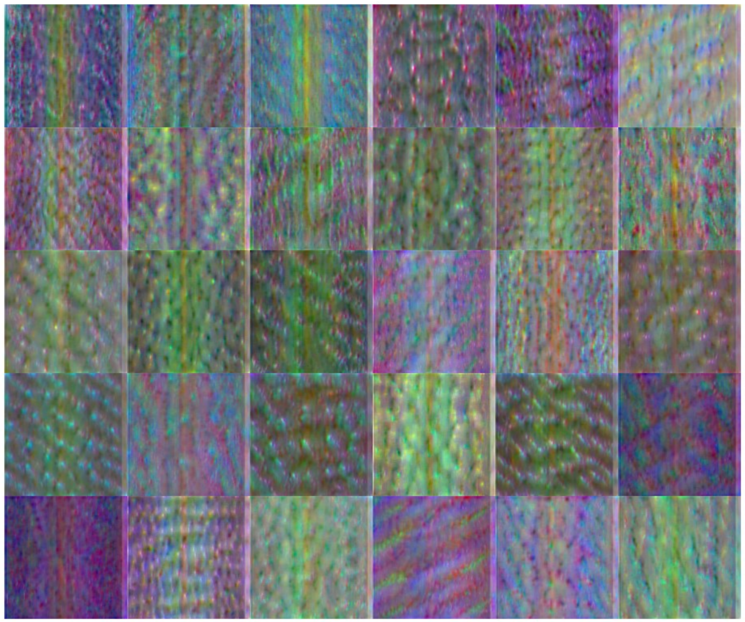
Input Images



Layer Conv_3 Features



Layer Conv_5 Features

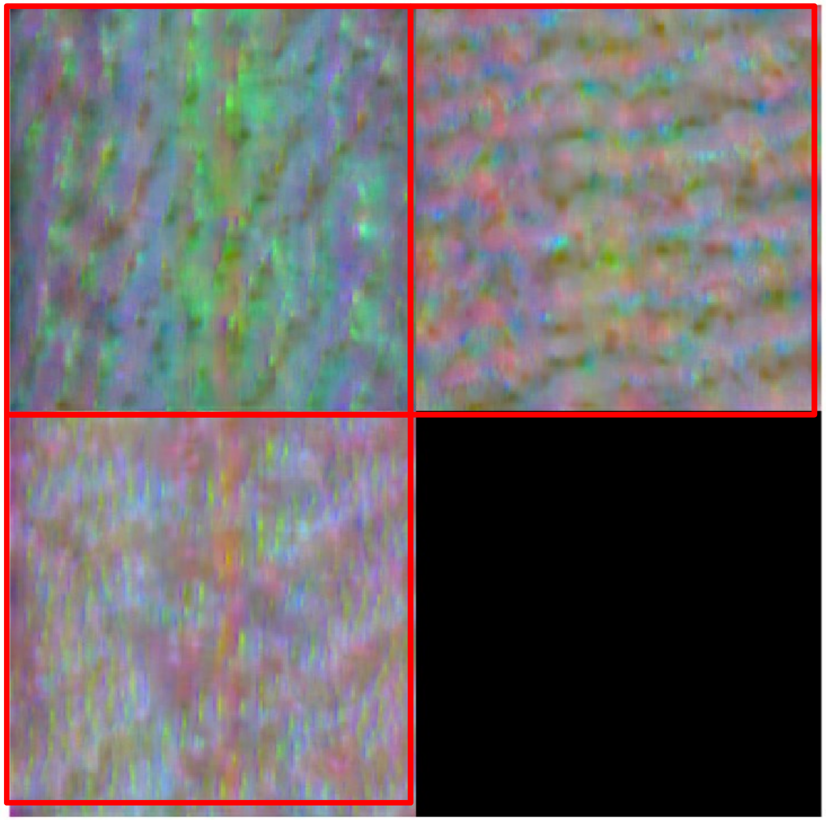


Feature Maps Visualisation

Layer fc_3 Features

Car

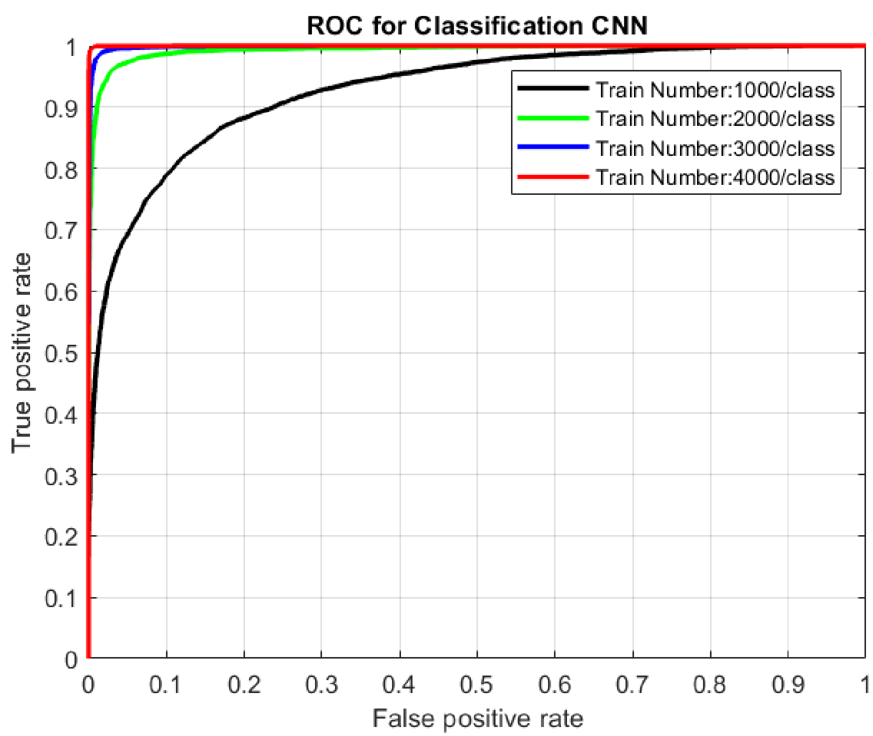
Pedestrian



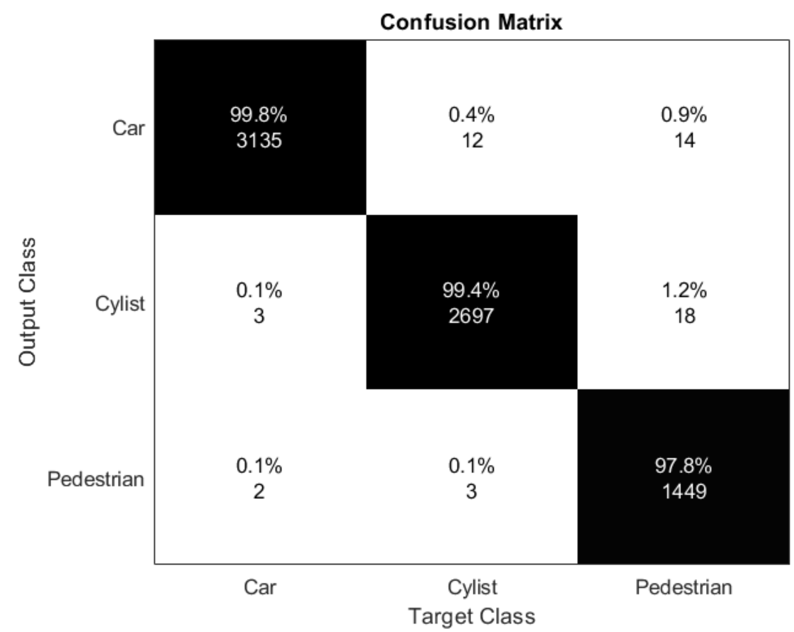
Cyclist

Performance Evaluation

Receiver Operating Characteristic (ROC)



Confusion Matrix



- The task of detecting the cyclist and pedestrian using UWB radar requires a good separation of two subspaces data (Signal and Noise)

- Combination of Higher Order Statistics (HOS) and Wavelet Srinkage Denoising (WSD) promises a better result for noise removal and provides good SNR.

- Convolution Neural Network (CNN) is very promising technology in identification of Vulnerable Road Users (cylist and pedestrian) using UWB radar

- This research's method will be applied to develop a system protection of VRUs by combining a tracking system like Extended Kalman Filter and Particle Filter

THANK YOU FOR YOUR ATTENTION