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Alternative sensor based system to augment camera-based Vehicle Detection And Classification (VDAC) – Experiments and results

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Outline

- Intelligent Traffic monitoring
- Image Classification with Deep Learning
- Model Training and Selection
- Model Integration and Program Packaging
- Experimental setup
- Image Classification
- Height Profiles from sound sensor
- Data analytics
- Training Results
- Conclusion



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Intelligent Traffic monitoring

Vehicle classification

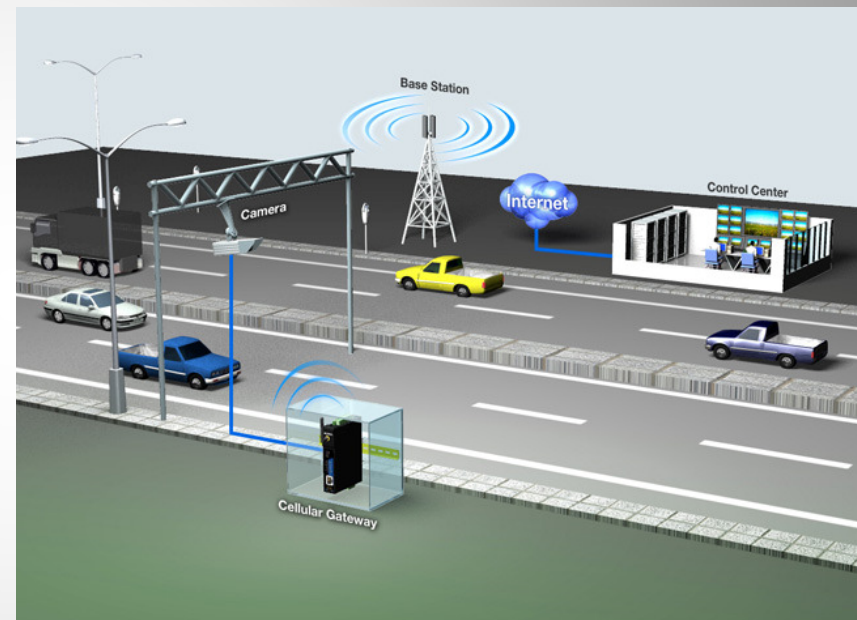
- Traffic monitoring
- Traffic violations
- Vehicle counting

Camera

- Lighting
- Occlusion
- Dust, Rain, haze

Sound sensor

- Non-visual
- Immune to lighting/occlusion
- Classify by height/length



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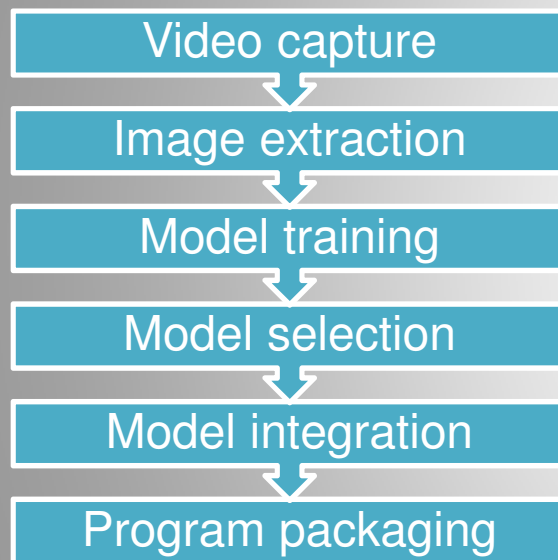
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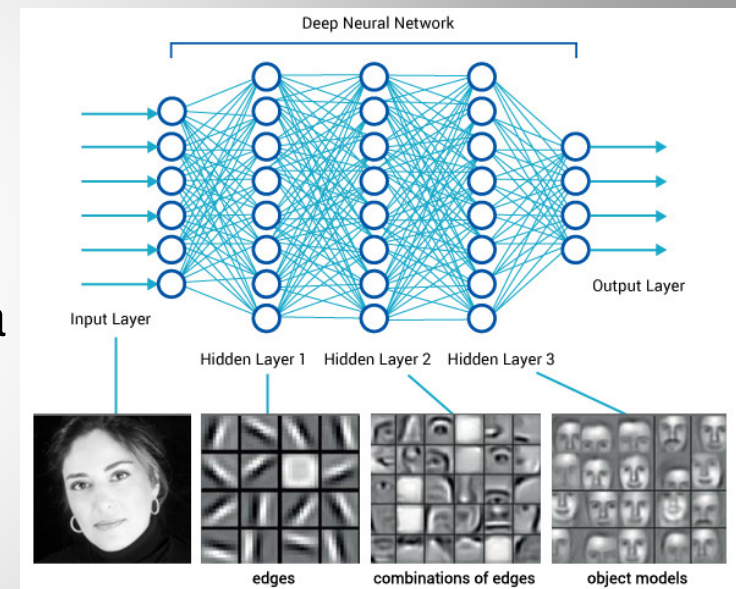


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Image Classification with Deep Learning



- Branch of machine learning
 - Recognise patterns
 - Many hidden layers
 - Large-scale input data
- Has 2 stages
 - Training
 - Inference



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Model Training and Selection



Parameter	Description
Training epochs	Total number of back-propagations
Validation interval	How often the network architecture is modified
Solver type	Back-propagation algorithm
Base learning rate	Learning rate at first epoch
Policy	Changing of learning rate
Mean subtraction	Option to subtract mean image
Network	Network architecture

The screenshot shows a web interface for configuring a model training process. It includes sections for Image Type (Color), Image size (Width x Height) (256 x 256), Resize Transformation (Squash), Training Images (folder or URL), Minimum samples per class (2), Maximum samples per class (2), % for validation (25), % for testing (0), DB backend (LMDB), Image Encoding (PNG (lossless)), and Dataset Name. There are buttons for 'See example', 'Create', and 'Use Image Folder'.

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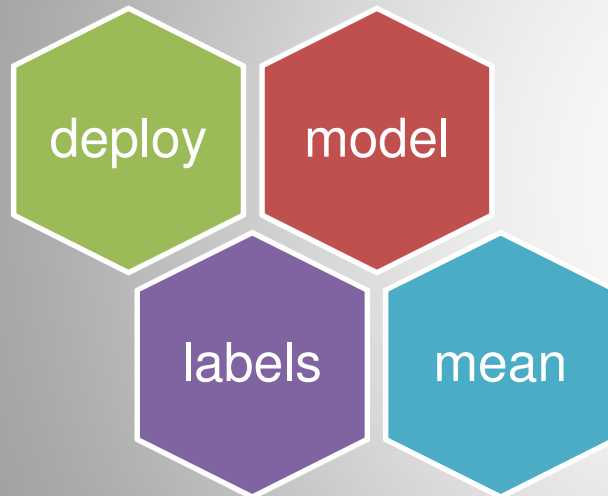
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Model Integration and Program Packaging



OpenCV

- DNN module
- Short run time
- Fails with mean-subtracted models

Caffe

- Python library
- Works with any model
- Long run time

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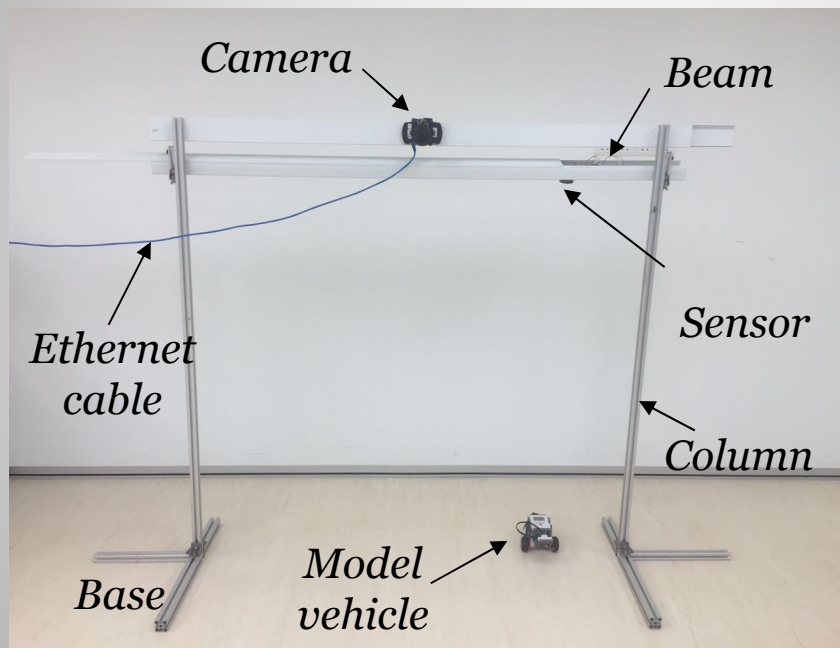


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Experimental setup



- Raspberry Pi 3: 3.3 V, 900 MHz, Wifi, microSD, Ethernet, network capable, non-volatile storage, Serial IO, GNU Linux OS



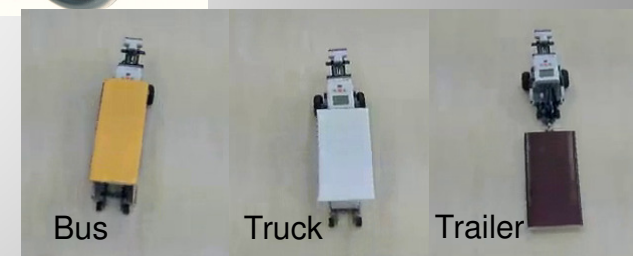
- Adjust zoom level and focus
- Capture video using OpenCV
- Extract images with vehicle



- AXIS P3384-V Fixed Dome Network Camera
 - Ethernet
 - Web interface, and Hardware reset



- URM06 UART sensor
 - Command frames
 - 49.5 kHz emission
 - Max range of 10m



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Comparison of Image Classification

Model	1	2	3	4	5	6
Solver type	SGD		NAG		AdaGrad	
Mean subtraction	No	Yes	No	Yes	No	Yes
Network	AlexNet					
Policy	Exponential decay					
Highest accuracy (%)	89.58	99.85	63.99	99.85	97.47	99.55
Lowest loss (training)	0.2637	0.0123	0.8152	0.0040	0.0399	0.0005

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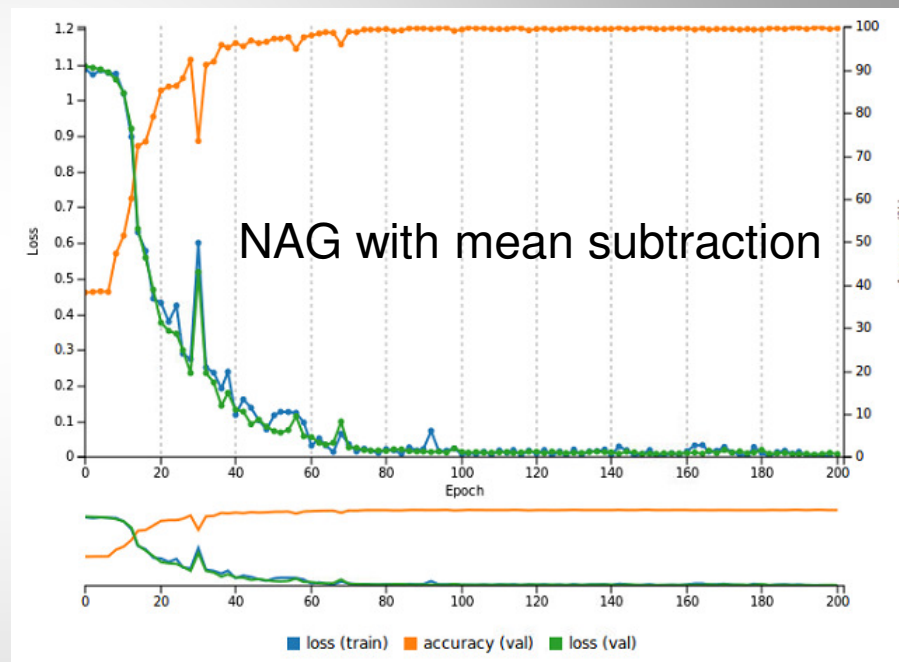
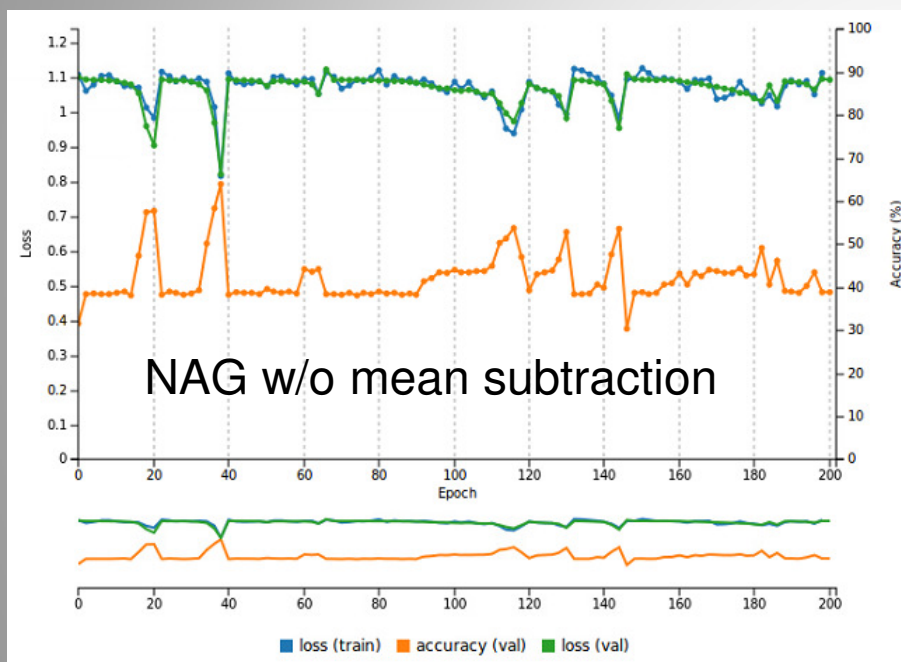
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Training Results



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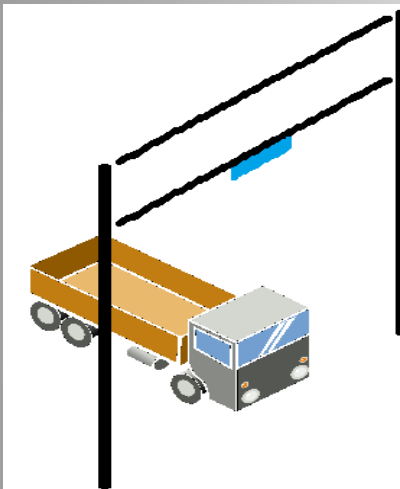
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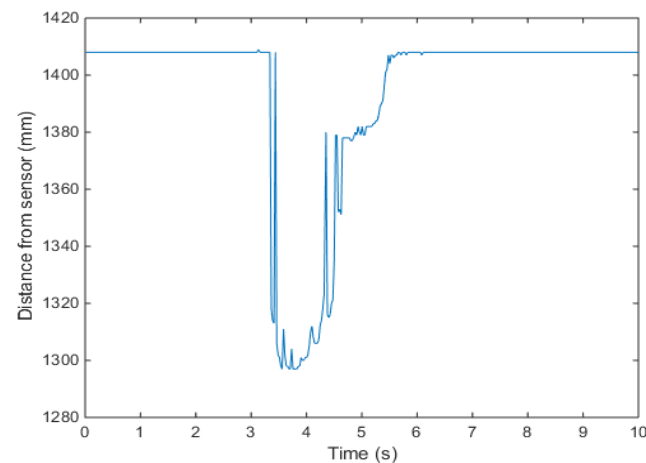


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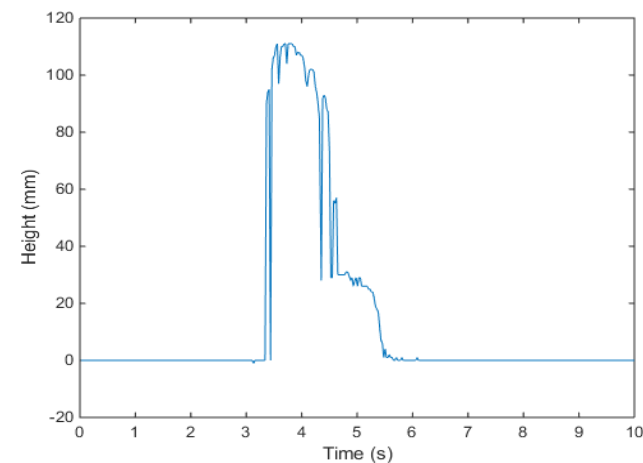
Height Profiles from sound sensor



Sensor “sees”
passing vehicle



Distance from
sensor plot



Invert to get height
plot

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Data Analysis

Extract signal



Eliminate outliers



Calculate index

- 100 data points
- Compare known signal with input

- Calculate normal range
- $(m - 1.5IQR, M + 1.5IQR)$

- Gauge correlation with NRMDS

- $$X = \frac{\sqrt{MSE(G, T)}}{mean(T)}$$

- $$MSE(G, T) = \frac{1}{n} \sum_{k=1}^n (G_k - T_k)^2$$

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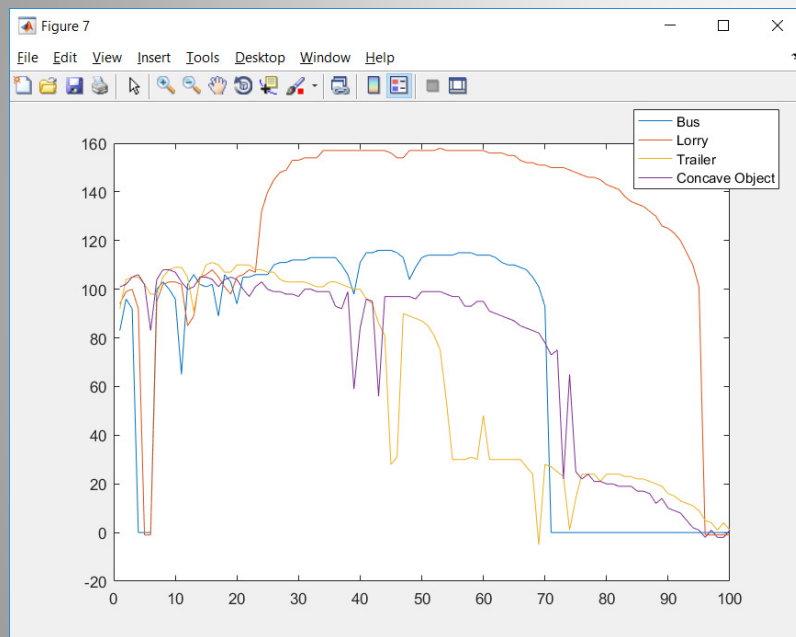
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Height signatures



Each type of vehicle got their own signal “shapes”.
Allowing the sensor to classify the vehicles based on a standard template

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Integrating data

Data

Info Video

Retrive Connect

Ultrasonic Data ConnectedEnter

1409

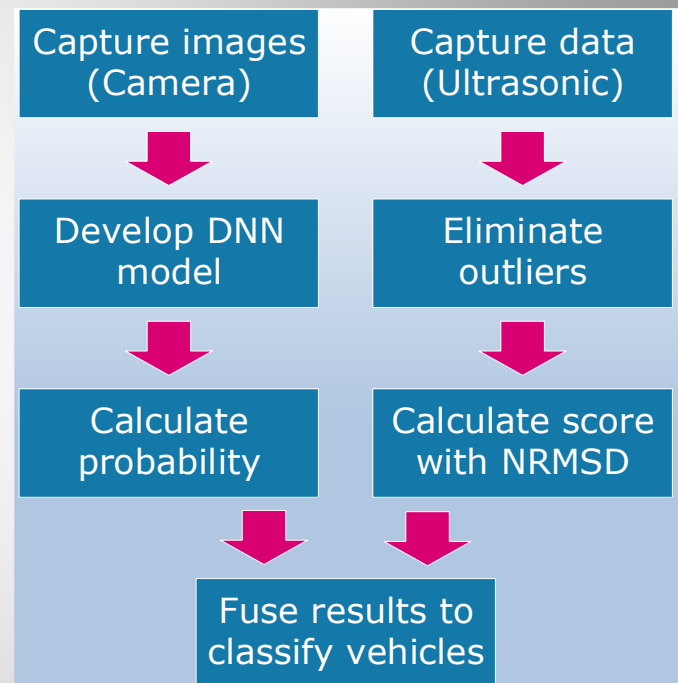
10/19/2016 12:29:35 PI

Index	Probability
Lomy	0.6941999316
Bus	0.5422503234
Trailer	0.2426707710

Ultrasonic Result Trailer

Trailer 0.999936

Index	Probability
Lomy	0.9941425924
Bus	0.0058569561
Trailer	0.5139204621



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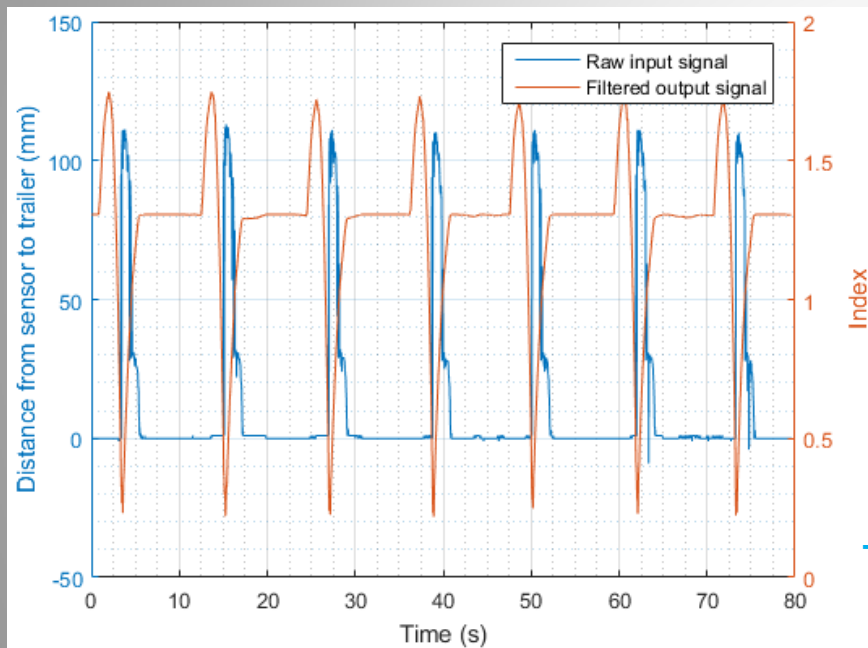
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Template Matching



- Stalactite-shaped response
- Small index when trailer detected
- Good response < 0.3

Trailer input signal & similarity index

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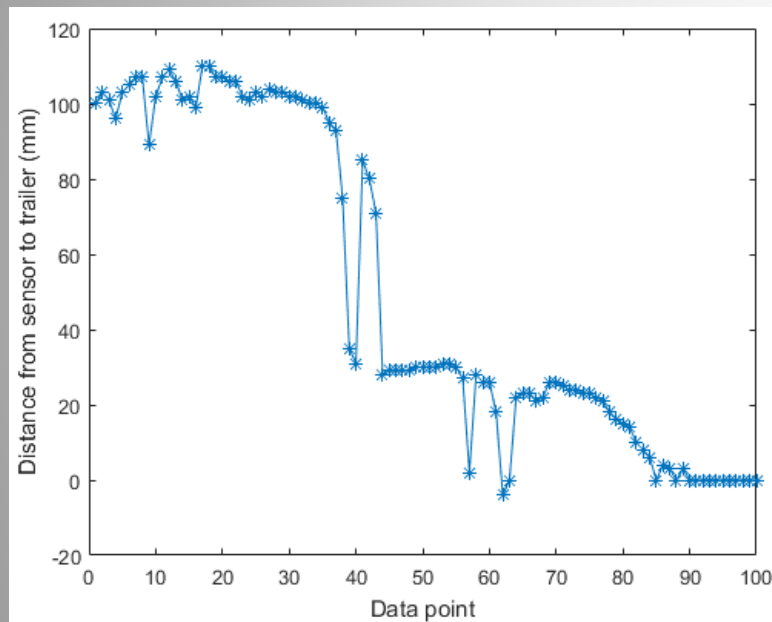
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Trailer Template Signal



- Pre-determined signal
- Signature of model vehicle
- 100 data points
 - Head
 - Tail

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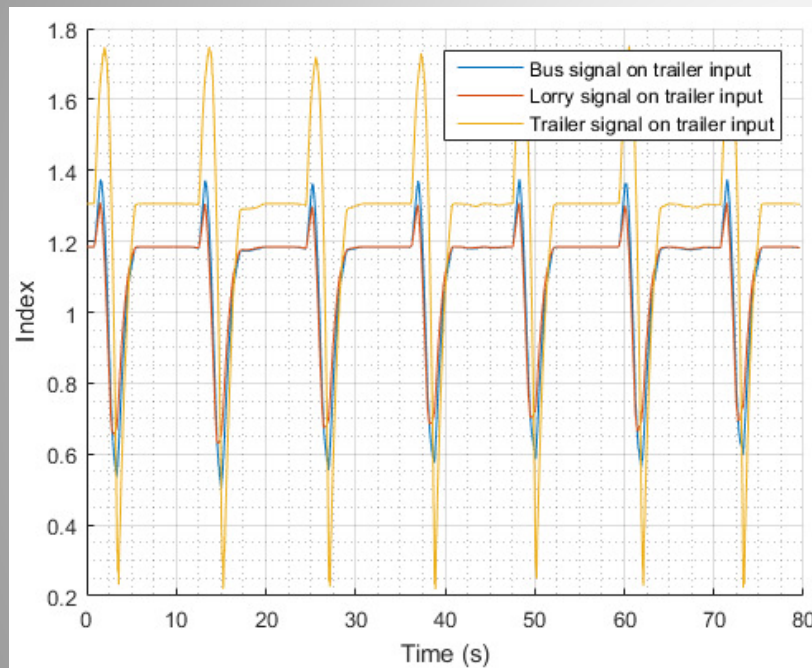
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Similarity Index Plots on Trailer Input



- Smallest index with correct match
- Upward spike before decline
 - Possible passing object
 - Biggest mismatch (error)

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Summary

- Image and sound based Vehicle Detection And Classification (VDAC) via machine learning
- Promising results
- Performance accuracy of sound sensor in VDAC is equivalent to that of camera
- Further works on sensor fusion are planned to enhance the VDAC

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