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TexITE Dallas Section Meeting

Leveraging Connected Autonomous Vehicles for Traffic Management: Challenges and New Directions

Dr. Song Fu and Dr. Qing Yang

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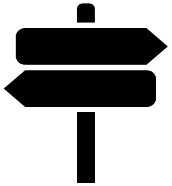
Outline

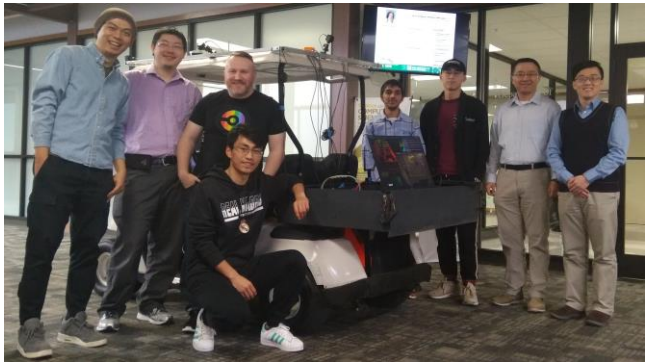


- Connected Autonomous Vehicles (CAV) group at UNT
- CAVs for traffic management
- CAV projects
  - Edge Computing for CAVs
  - Finding Blurry Vehicles
  - Cooperative Perception
  - Occluded Road Sign Detection
- Future Work

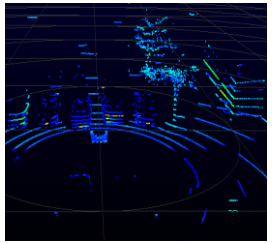
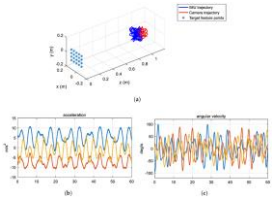
CAV Group @ UNT

TIER 1 research university

- Drs Fu and Yang, and collaborators in EE & ME
- 7 PhD, 2 MS, and 3 undergraduate students
- Equipment
  - Two golf carts with sensors
  - Processing unit: NVIDIA PX2
  - A Polaris GEM4 (incoming)
  - Self-driving truck for testing
- Collaborations
  - Toyota, Fujistu, Peterbilt, Frisco Public Works, NCTCOG, …

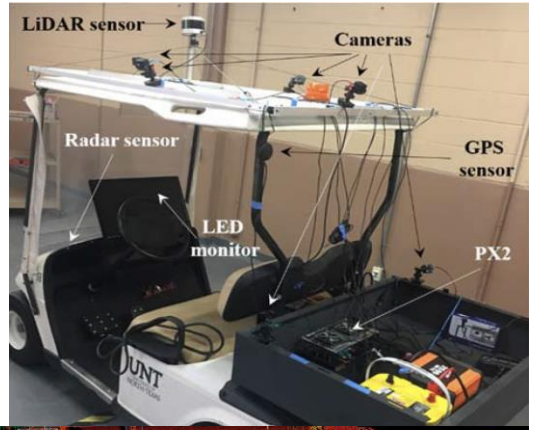


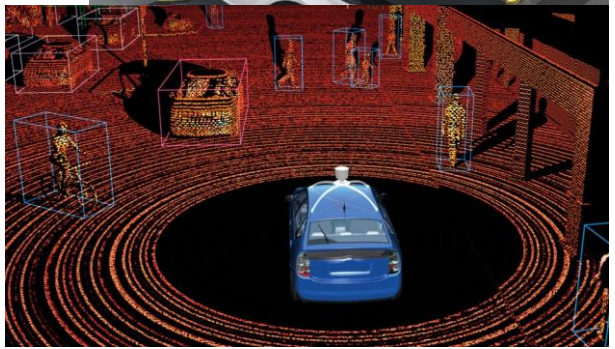
Sensors

LiDAR	Image-Based Camera	GPS	IMU
			
			

Projects @ CAV Group

- Accurate pedestrian and cyclist detection using 2D and 3D data fusion
- Finding blurry vehicles using Generative Adversarial Network
- Designing efficient deep learning models for autonomous vehicles
- Cooperative perception for connected and autonomous vehicle
- Edge computing for traffic monitoring

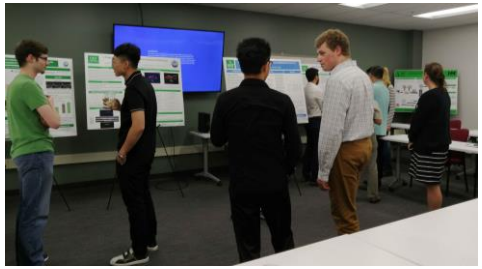




CAV Workshop

- Connected Autonomous Vehicles Workshop 2019 @ UNT
  http://www.cse.unt.edu/~song/CAVWorkshop/

Technical presentations, CAV test platform demonstration, poster session, open discussion, …



You are warmly welcome to join CAV Workshop 2020!

CAVs for Traffic Management

Opportunities

- **Connected vehicles** technologies for congestion control, accident awareness, self-driving, and more
- Vehicle-to-**infrastructure** communication to improve road safety, transportation forecast, and traffic management
- **Edge computing** with information-sharing portal for traffic management partners and private sector collaborators sharing real-time data

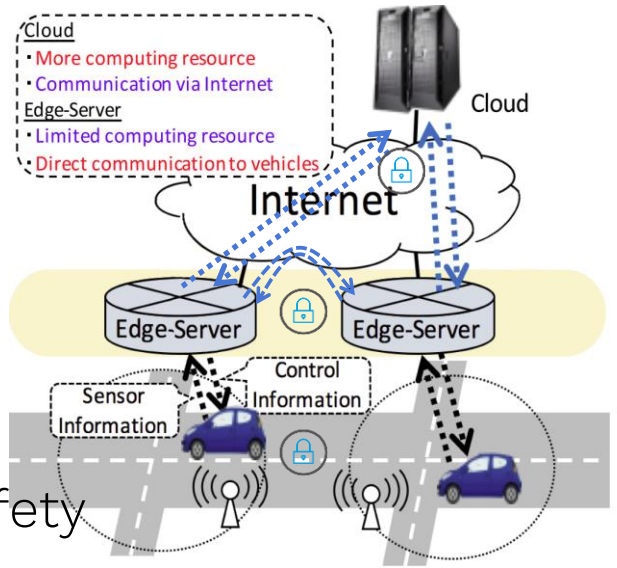
Edge Computing for CAVs

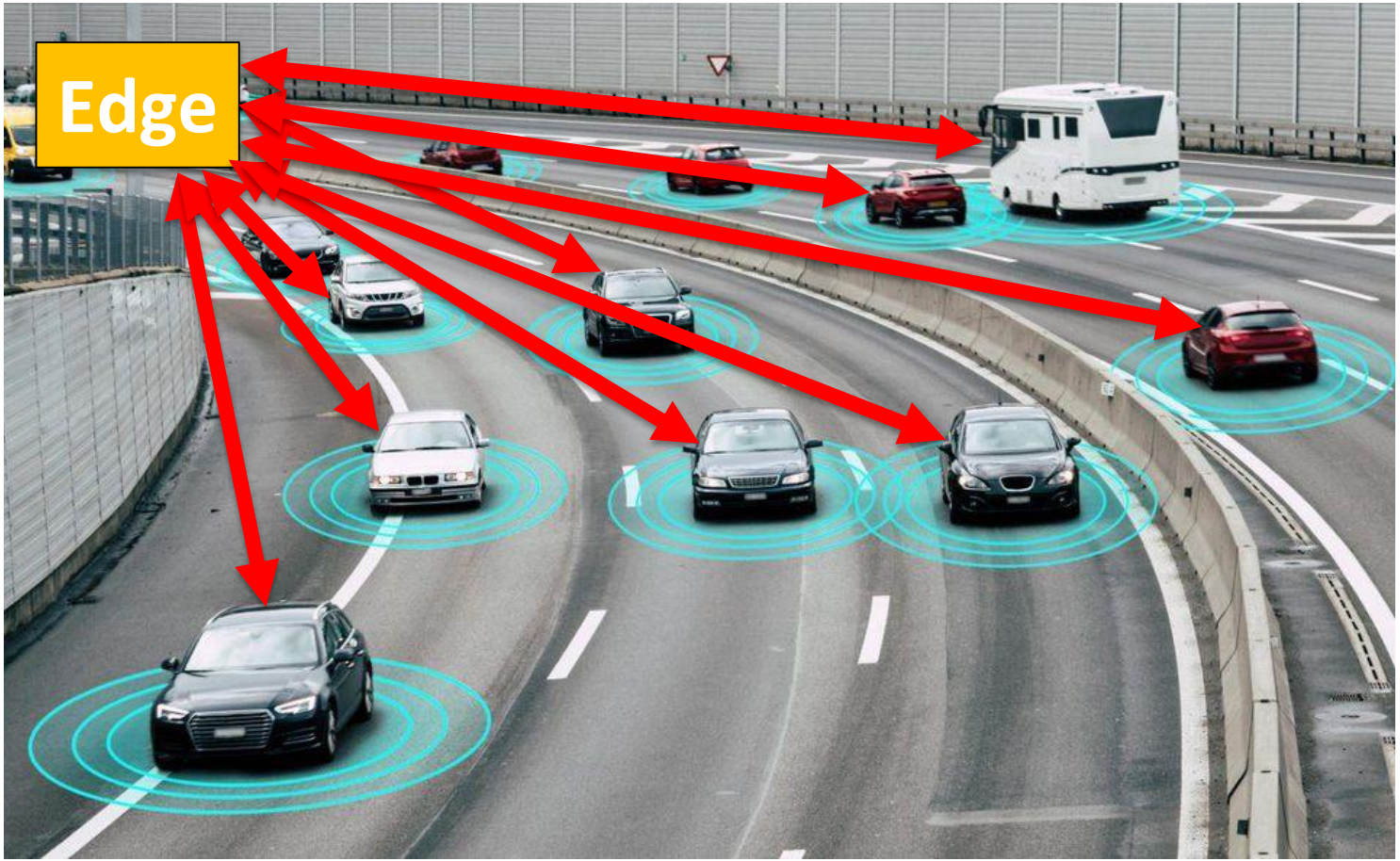
Low-latency and quick-response decision making for autonomous vehicles

Edge Computing

Edge servers vs. cloud datacenter

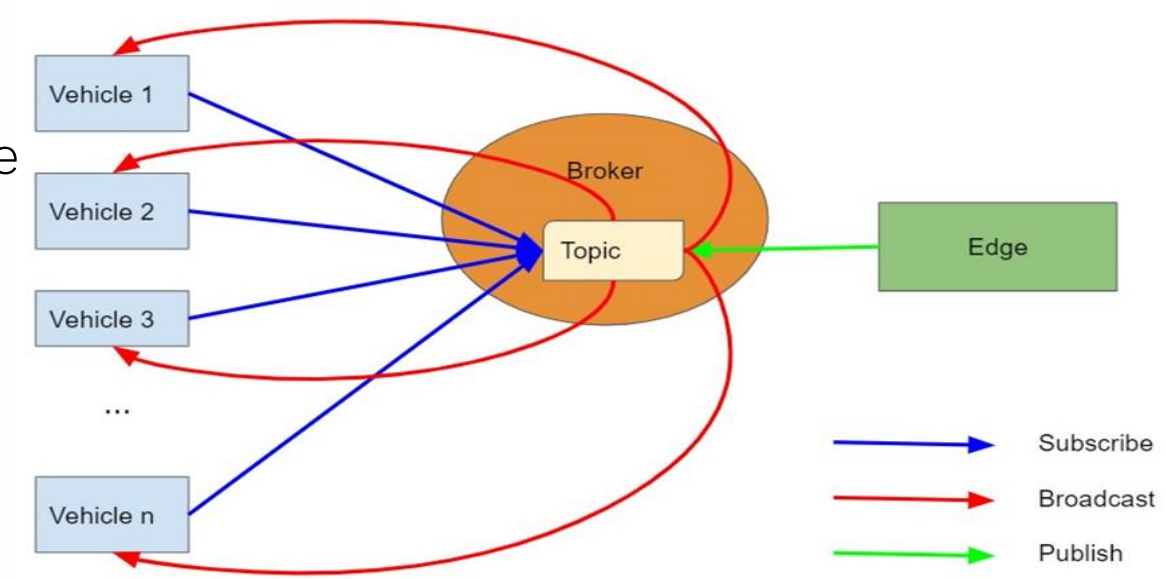
- Edge servers are much closer to cars
- Low latency for data movement, high responsiveness
- More computing capability than cars
- Local traffic management
  - Traffic monitoring & update, accident analysis, intersection safety




Edge

Vehicle-Edge Communication

- Publish-Subscribe paradigm
- Message queuing telemetry transport (MQTT)



Case 1

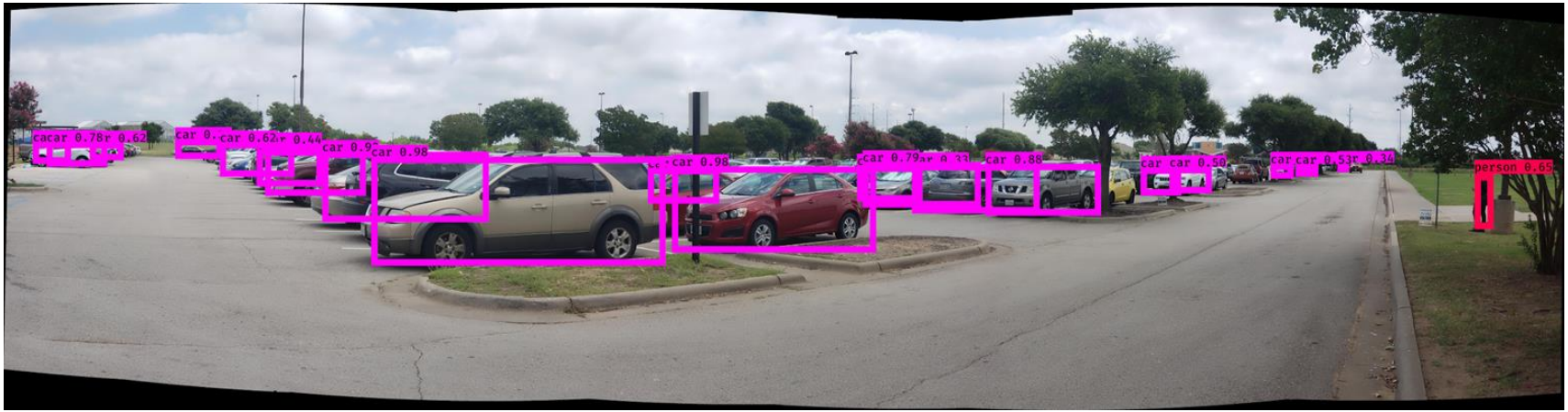






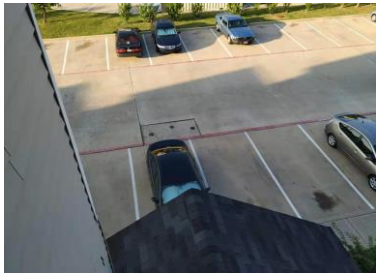


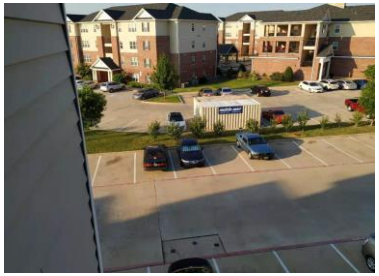
Data Fusion & Car Detection Result



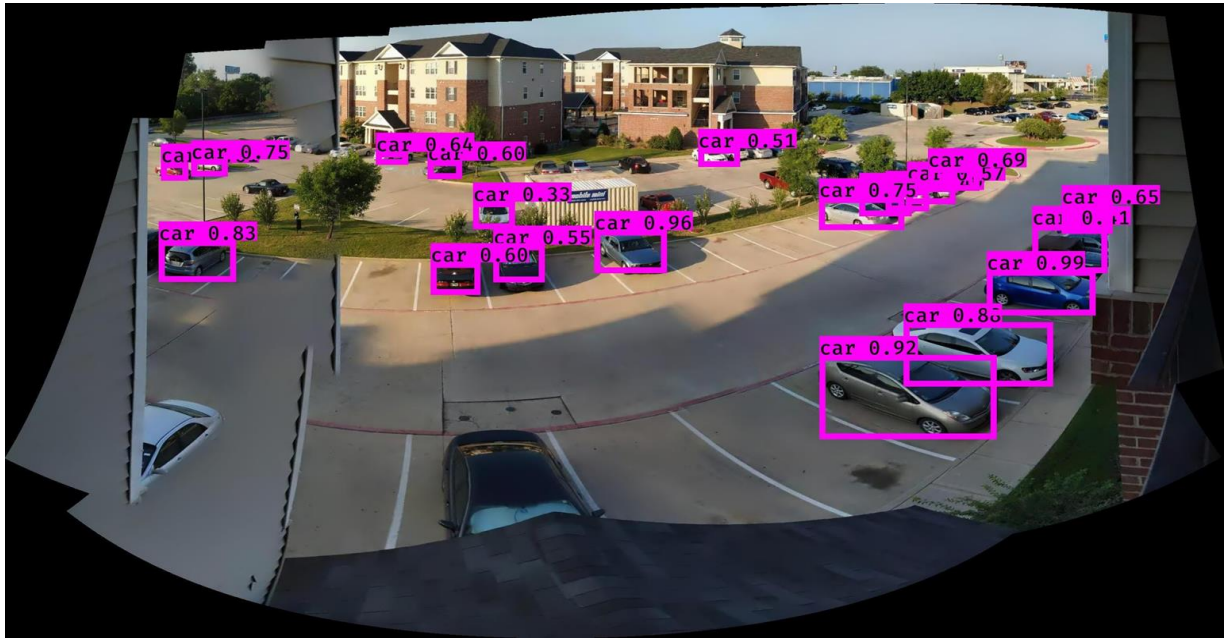
Case 2





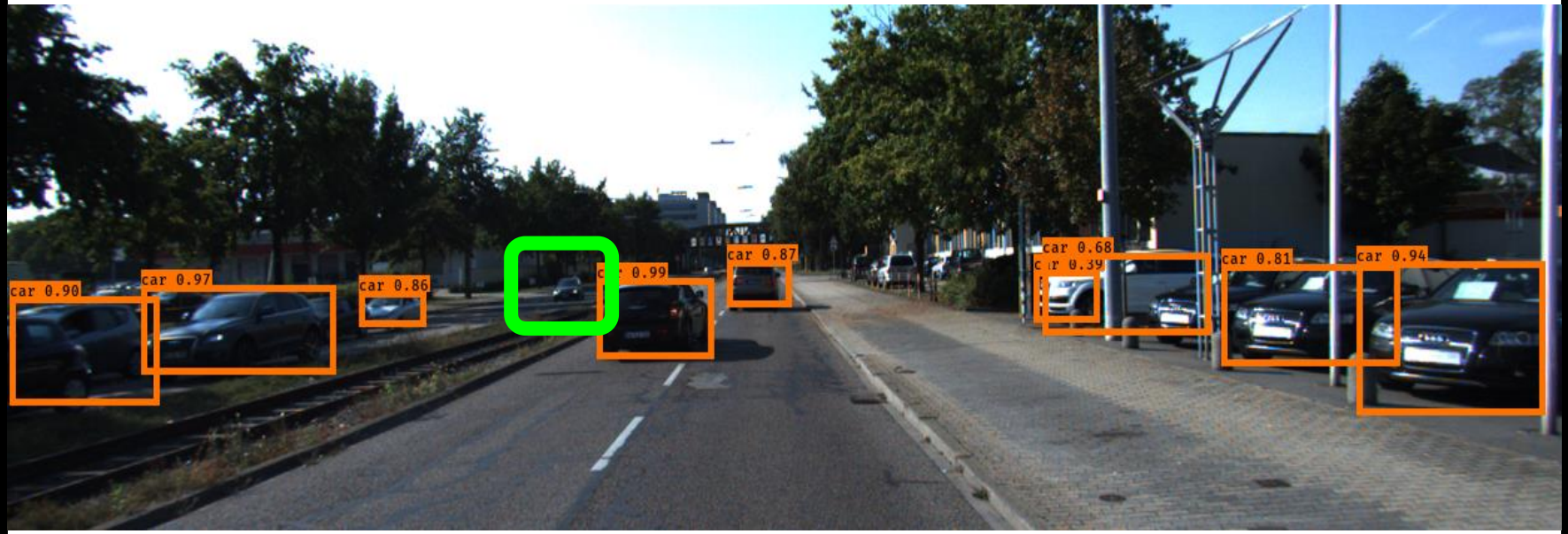
Data Fusion & Car Detection Result



Finding Blurry Vehicles

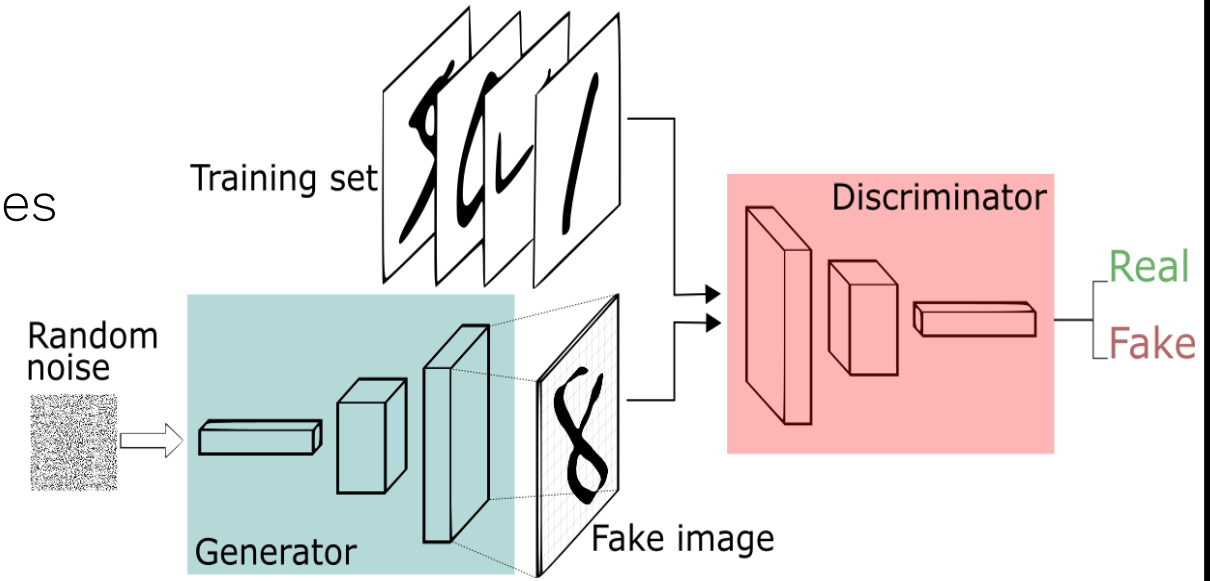
Using enhanced super resolution Generative Adversarial Network (SRGAN)

Motivation

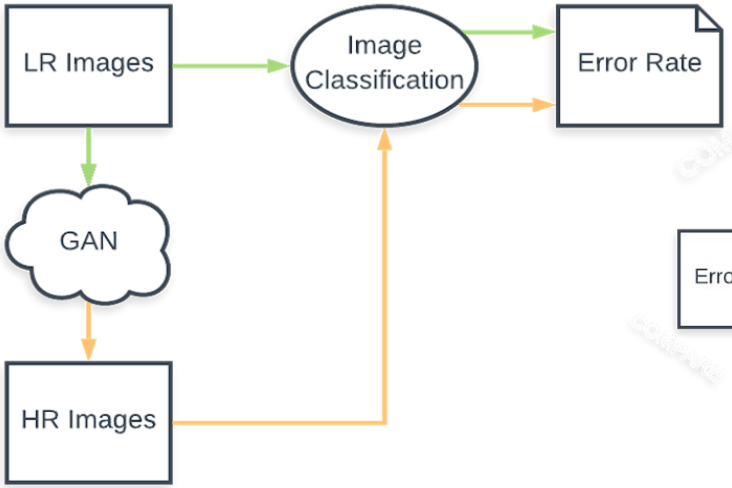


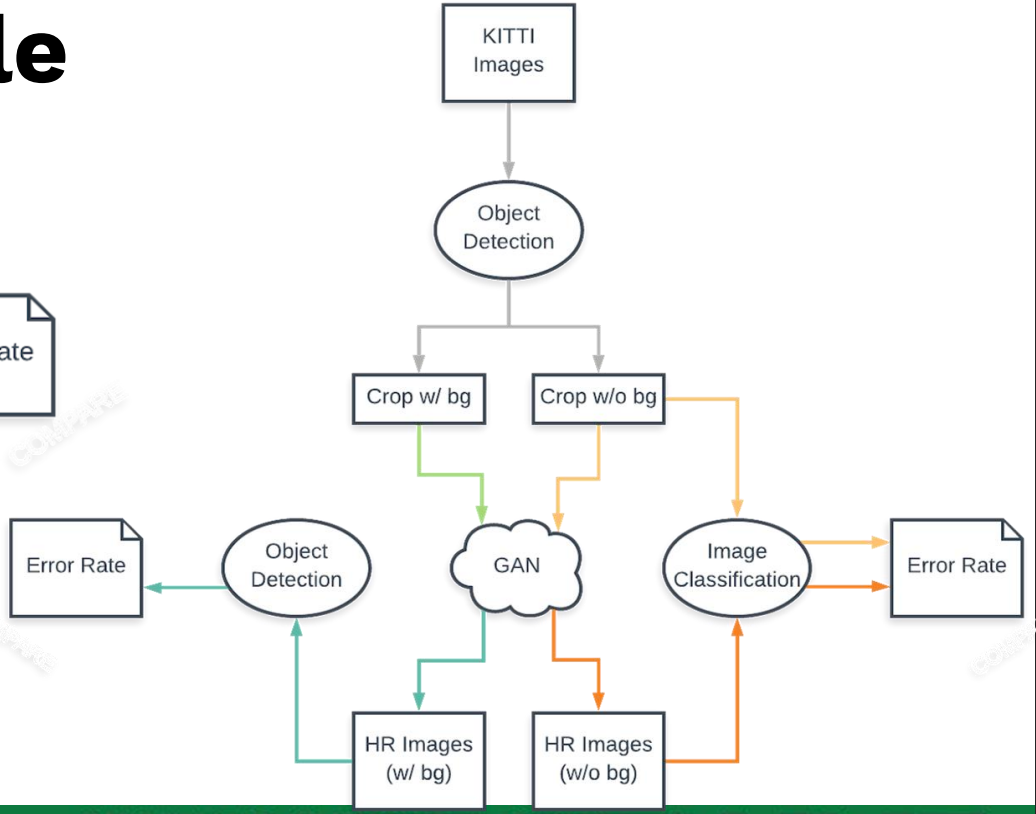
Generative Adversarial Networks

- Deep Neural Net (DNN) architectures
- It consists of two networks
  - Generator
  - Discriminator

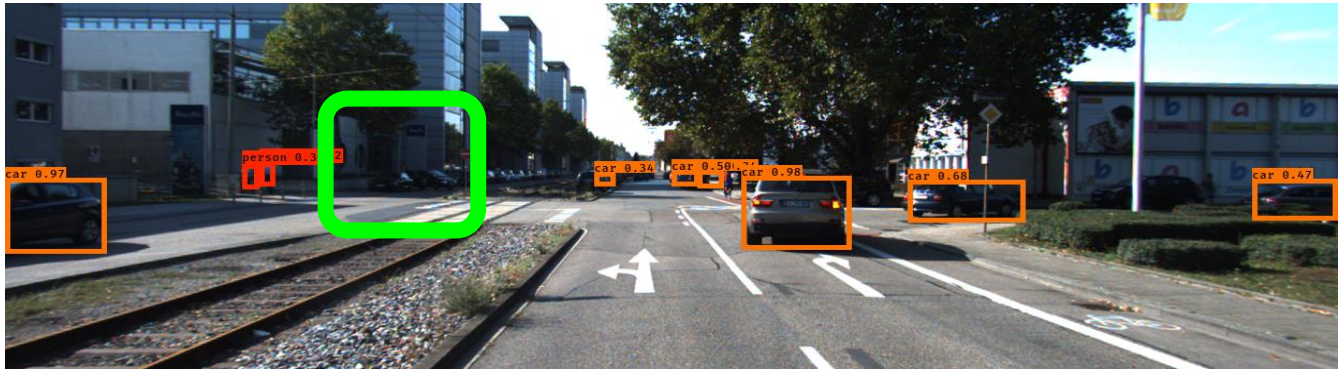


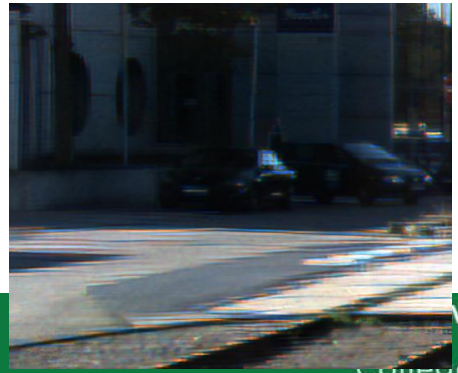
Blurry Vehicle Detection

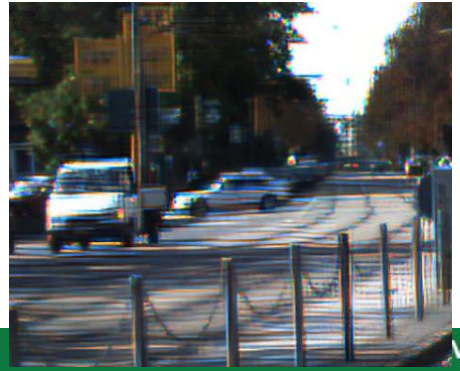




Vehicle Detection Results







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Cooperative Perception

LiDAR based data fusion for connected and autonomous vehicles

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Goals of Data Fusion

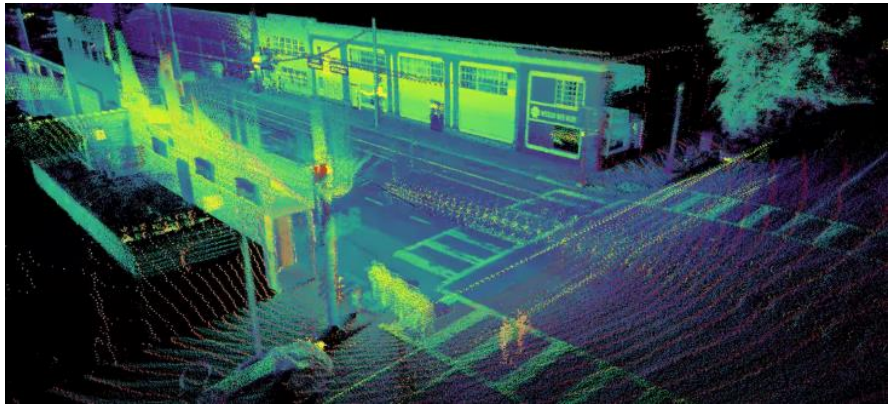
Enhances the accuracy of object detection for autonomous vehicles

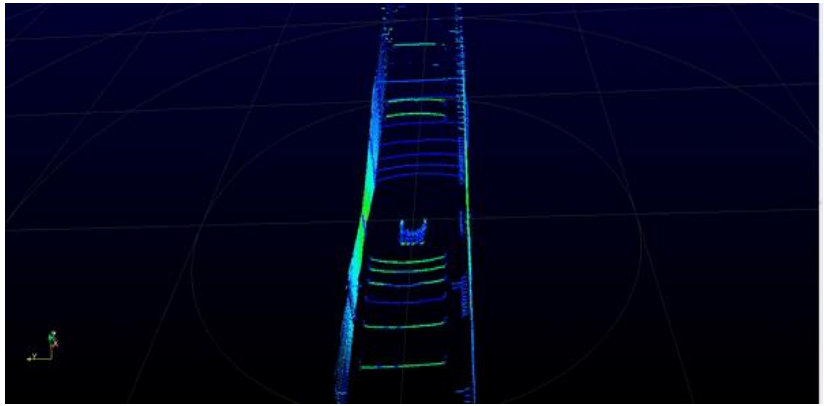
Provides real-time information for traffic management and traffic control

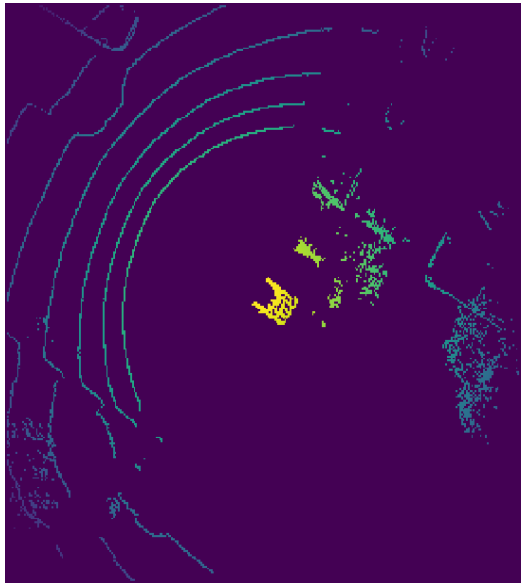
Provides anonymity of private information within the sensing range

Increases system’s reliability in case of sensor failures

Light Detection and Ranging (LiDAR)







Rotation Matrices

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$R_y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$

$$R_z(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

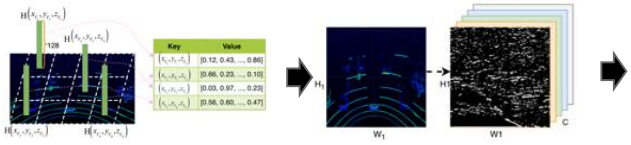
Point Cloud Rotation

SPOD Architecture

64-Beam LiDAR Frame

Point clouds preprocessing and Voxel feature extractor → Sparse Convolutional Middle Layers → Region Proposal Network

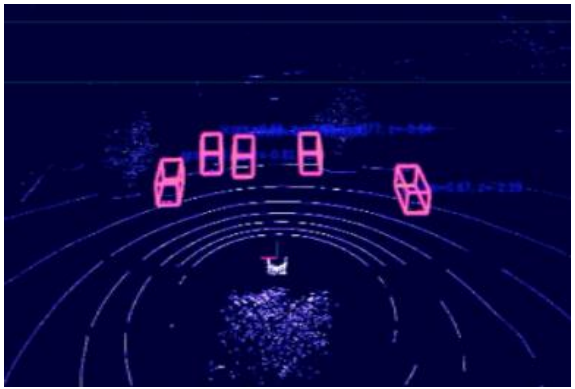
Sparse Point-Cloud Object Detection (SPOD) Architecture



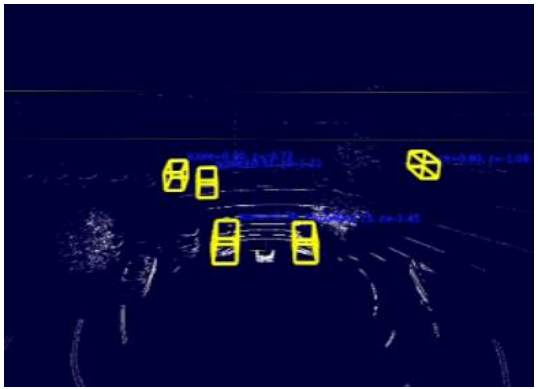
Loss function:
(1) a probability score of the proposed region of interests
(2) the locations of proposed regions

64-Beam LiDAR Frame with VoxelNet

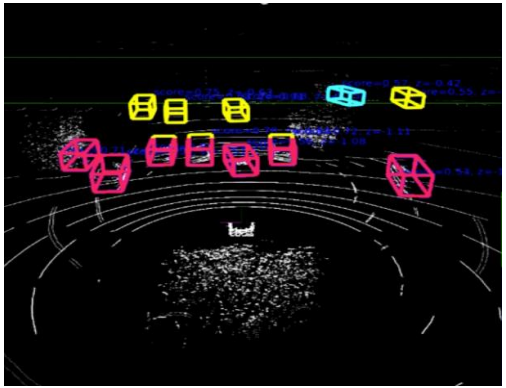
Object Detection on Fused Frames



Vehicle #1



Vehicle #2



Fused Results

Occluded Road Sign Detection

Detect occluded road signs using autonomous driving vehicle sensors

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Challenges

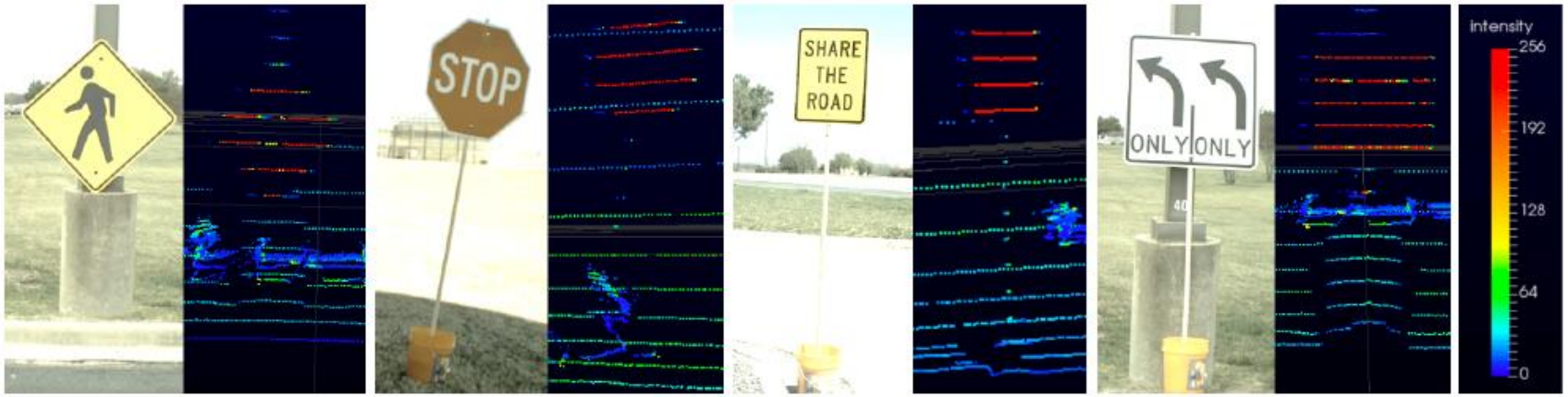
Current AV technologies are not designed for occluded sign detection

Limited amount of training dataset for occluded road signs

Existing solutions fail when they are directly applied

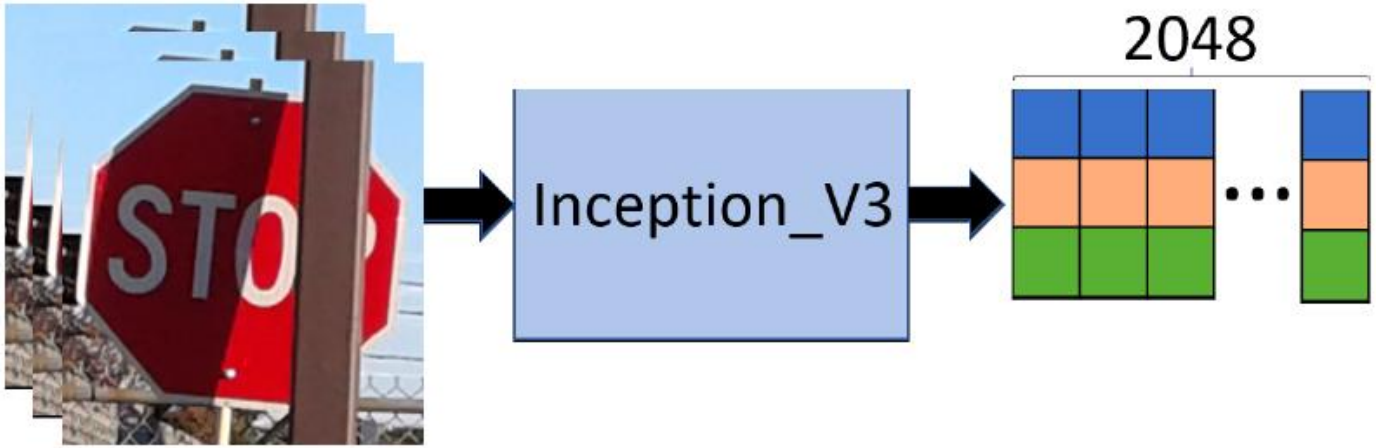
LiDAR-assisted and transfer-learning based solution

LiDAR-Assisted Detection



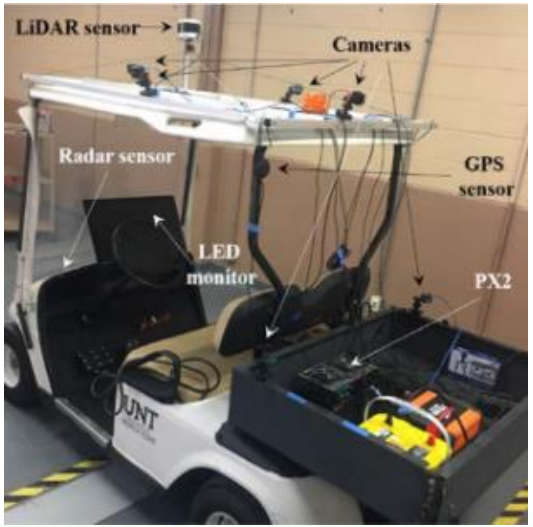
(a) Pedestrian-crossing sign (b) Stop sign (c) Share-the-road sign (d) Left-turn-only sign (e)

Transfer Learning Based Solution



Experiment Setup

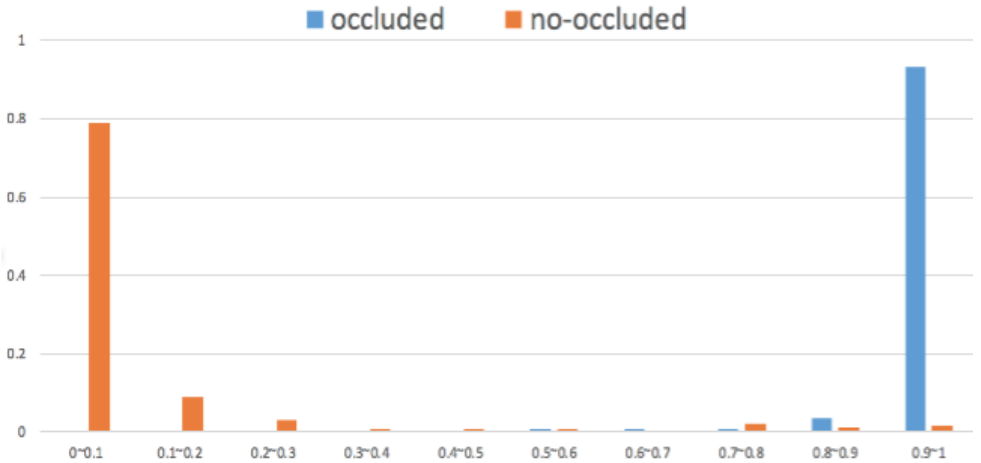
- Share-the-road sign & stop sign
- Various lighting conditions, angles, distances, backgrounds
- 500 occluded & 500 non-occluded



Experiment Results

Approaches	SSD	OSCN
mAP	51.26%	96.34%

Size \ Approaches	SSD
100	7.78s
200	14.66s
300	19.74s



Future work

- Autonomous vehicles can be leveraged to assess the road sign conditions when they are running on public roads
- A special application (APP) could be developed and deployed on autonomous vehicles which automatically detect road signs in bad conditions and reports the information to DOTs
- A crowd-sourcing based road sign inventory system becomes possible

Looking forward to collaborations!

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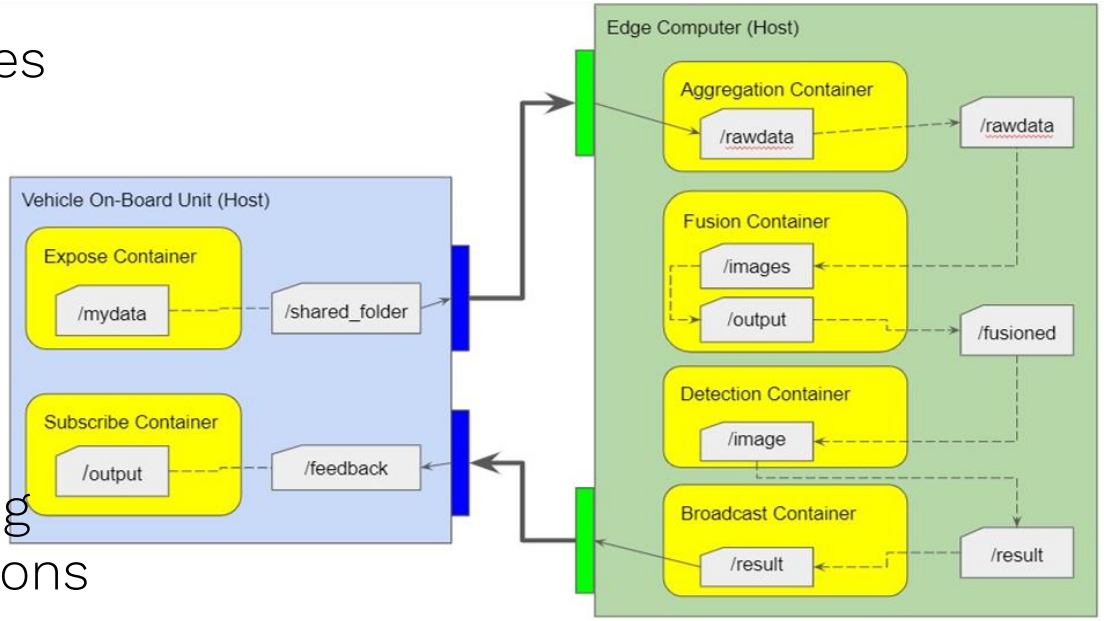
http://www.cse.unt.edu/~qingyang/

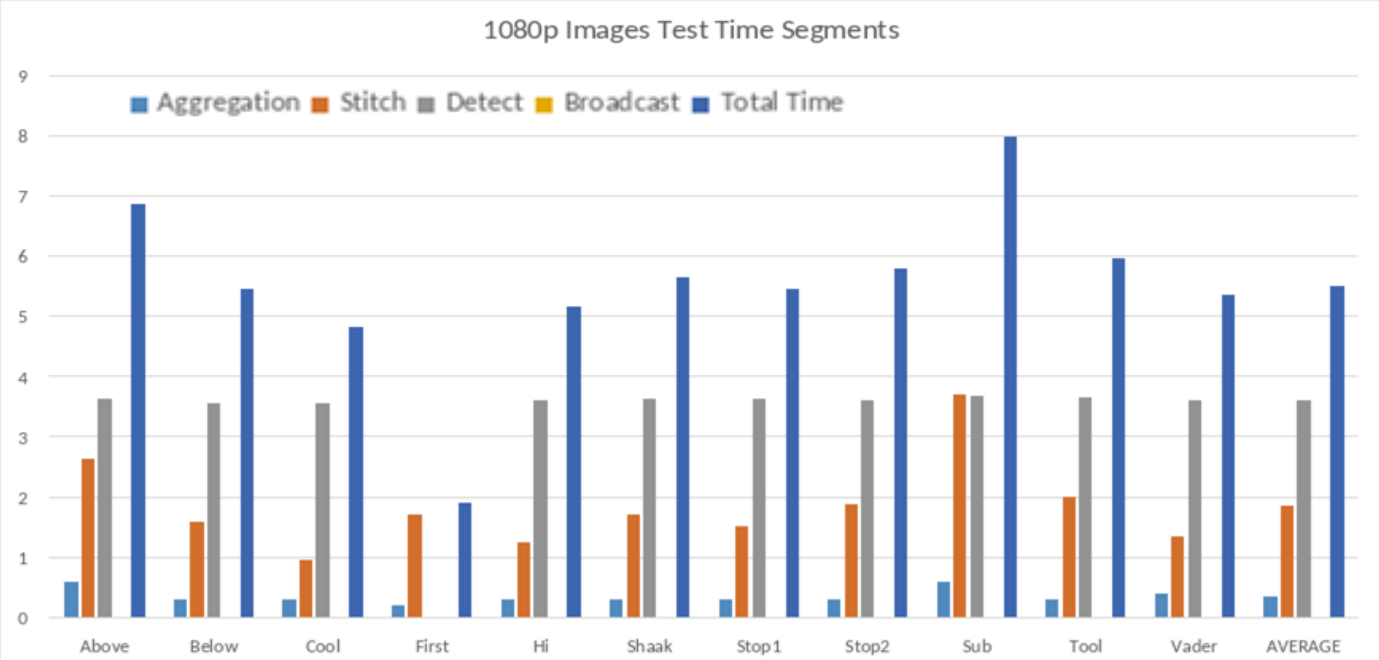
Backup Slides

Vehicle-Edge Framework

- Containers on vehicles and edge
- Functions of edge servers
  - Data aggregation
  - Data fusion
  - Object detection
  - Data broadcasting
  - Other new functions



Edge Computer Performance



Blurry Vehicle Detection Accuracy