University of Nevada, Reno

# An Automatic Procedure for Tracking Vehicles with a Roadside LiDAR Sensor

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Jianqing Wu, Graduate Research Assistant, Ph.D. Candidate

Hao Xu, Ph.D., P.E., Assistant Professor

Department Of Civil and Environmental Engineering,

University of Nevada, Reno


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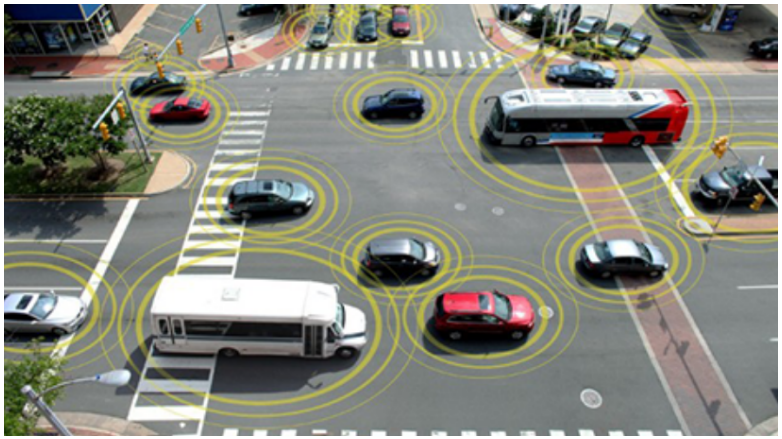
# Problem to Solve

- **Connected Vehicles (CV)** advance traffic safety, mobility and efficiency with communication between vehicles (V2V), roadside infrastructure (V2I), and everything (IoT).

- **Limitations:** full CV advantages require all roadway users communicating with each other. Currently and in the near future, the number of connected vehicles is limited on the roads.



Connected Vehicle System (picture from USDOT)

# Roadside Sensing Systems

- Filling the data gap with roadside sensors

Loop detector


Bluetooth

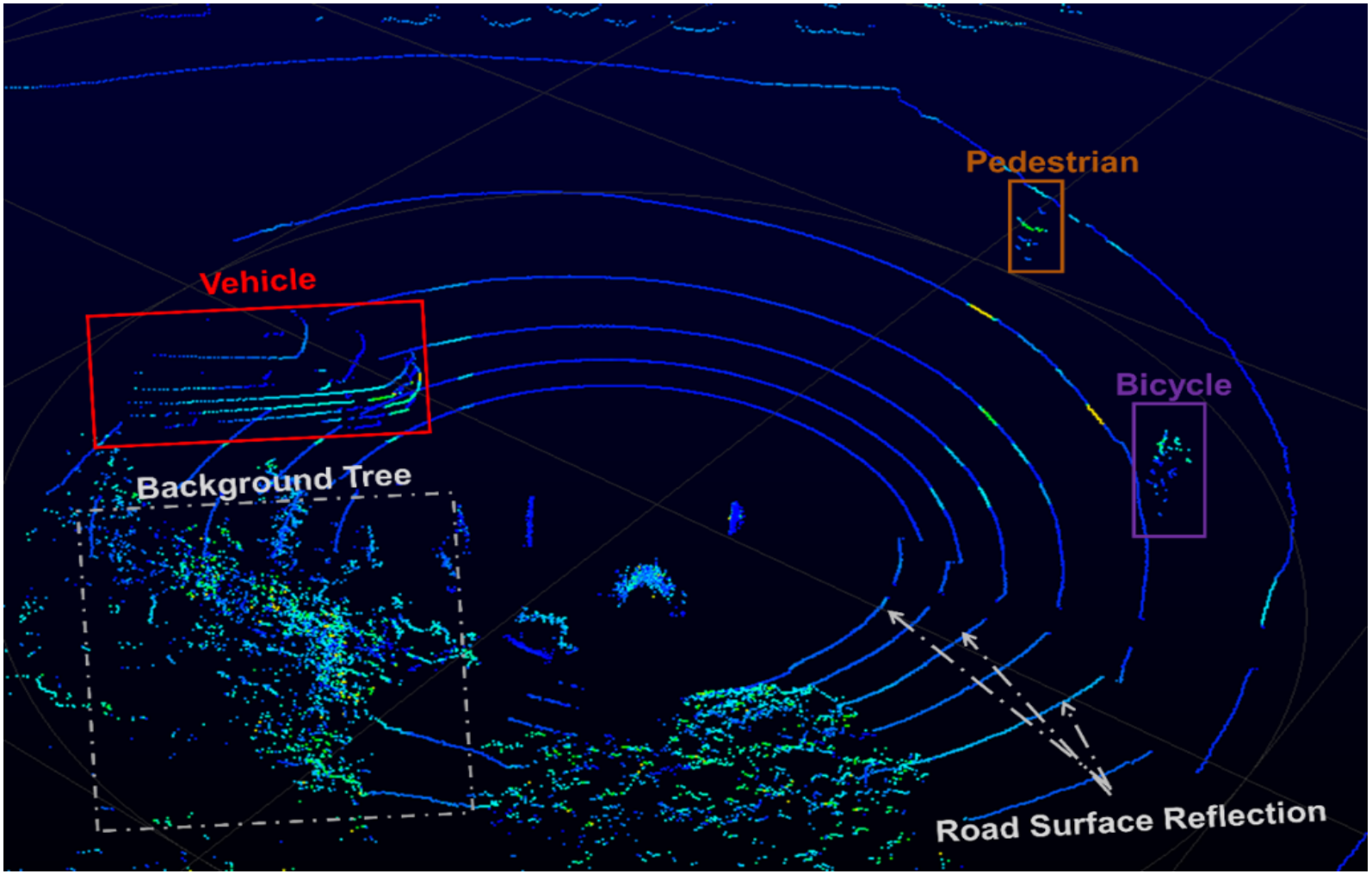
Camera

Radar


360° LiDAR

- A 360° LiDAR sensor can detect and track the precise location and speed of each object in the scanning range. Roadside LiDAR sensors can provide the high-accuracy trajectory of each road user.

# Example of Roadside LiDAR Data Frame



# Example Features of a Roadside LiDAR

| Channels | 16 |
|---|---|
| Rotational speed | 5-20 rotations per second (adjustable) |
| Horizontal Field of View | 360° |
| Vertical Field of View | 30° |
| Detection Range | Up to 100 meters<br>(useful range depends on application) |
| Return modes | Strongest, last, or dual return |
| weight | 830g |
| Compact footprint | ~Ø103 mm x 72 mm |
| Cost | $3,999 |

# Example of Roadside LiDAR Data

# Differences of Onboard and Roadside LiDAR Sensing

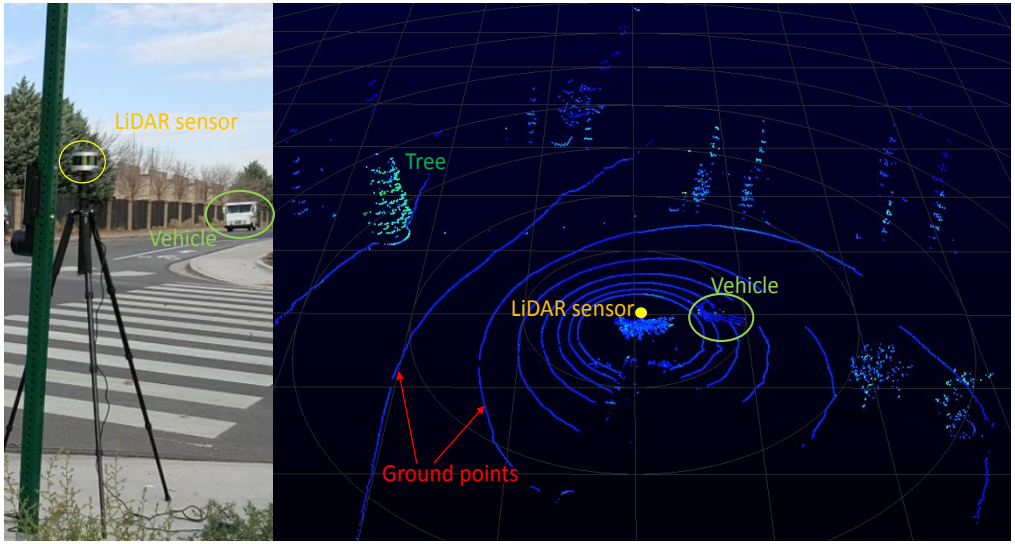
- **Onboard LiDAR sensors:** high-density LiDAR points (expensive sensors or short range), combined with onboard cameras, moving with platforms.
- **Roadside LiDAR sensors:** relatively low-density LiDAR points (cost-effective sensors or more extended range), working independently, fixed locations.


- The existing data processing algorithms used for onboard LiDAR data could not be directly used for roadside LiDAR data.

# Roadside LiDAR Deployment

- LiDAR sensors can be mounted on a tripod for short-term data collection or installed permanently for long-term data collection.

Permanent installation




Temporary installation

# Research Objectives

- To develop an **automatic background filtering** algorithm for roadside LiDAR data processing

- To **detect traffic lanes** automatically from the 3D points collected by roadside LiDAR sensors

- To **identify and track vehicles** from roadside LiDAR data

# Background Filtering

- The background can be buildings and ground surface, as well as moving objects such as waving trees and bushes.

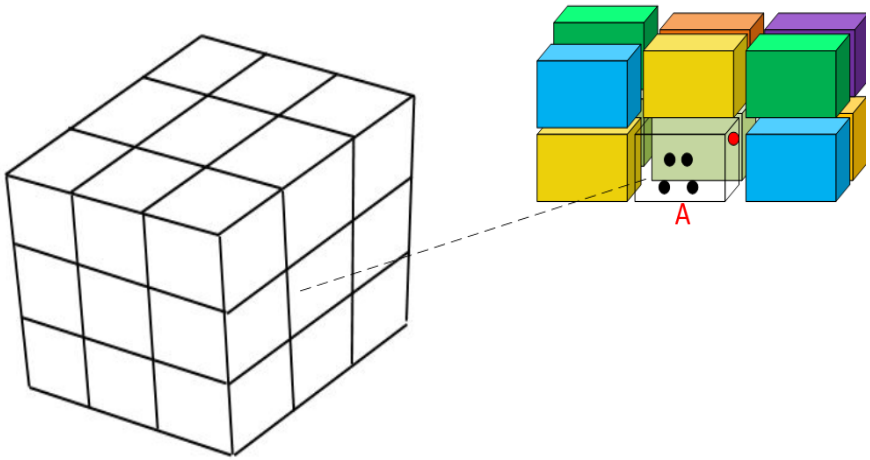
- An automatic background filtering method named 3D density statistic filtering (3D-DSF) was developed in this study to filter both static and dynamic background.

- Major difference between onboard data processing and roadside data processing

- The method can be elaborated into three steps: frame aggregation, points density statistics, and LiDAR points filtering.

# Background Filtering (Cont'd)

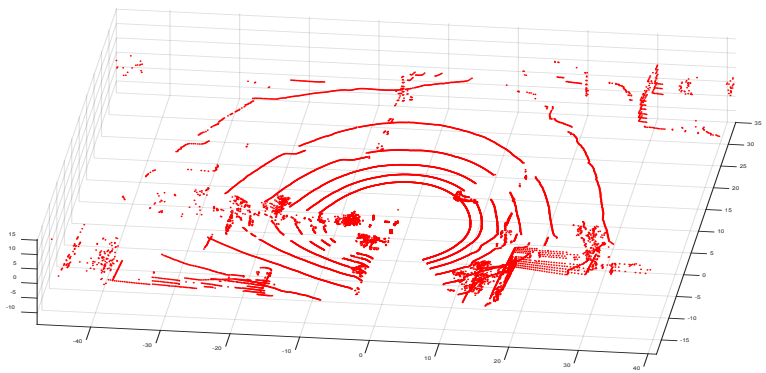
- Frame aggregation
  - Data frames collected during a period are aggregated.
  - The recommended number of frames for aggregation is between 1500 and 3000.
- Point density statistics
  - The 3D space is chopped into many small continuous cubes. These small cubes can be identified as a background space or not based on the point density.



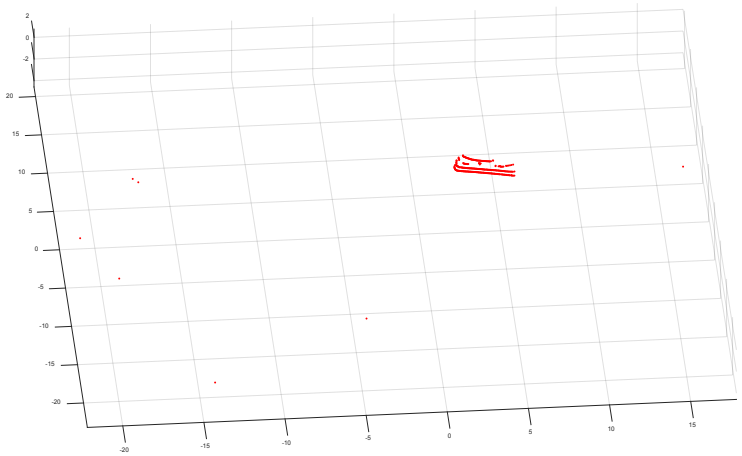

Point density statistics

# Background Filtering (Cont'd)

- LiDAR points filtering
  - The points in each frame are compared with the location of background profile. Any point found in the background profile is excluded.
  - The frame aggregation and points density statistics can be pre-processed, which can save a lot of time for real-time filtering.

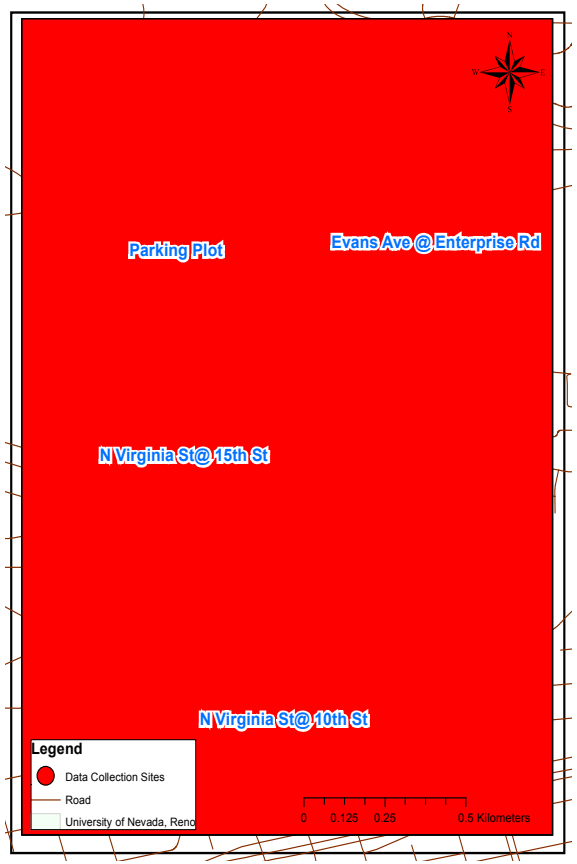


Before background filtering



After background filtering

# Case Study of Background Filtering




Case study sites

| | | Parking plot | N Virginia St@ 10th St | Evans Ave @ Enterprise Rd | N Virginia St@ 15th St |
|---|---|---|---|---|---|
| **Before** | Background points | 18316 | 45132 | 18621 | 18035 |
| **After** | Background points | 21 | 1362 | 176 | 25 |
| Filtering Percentage | | 99.8% | 97.0% | 99.1% | 99.9% |

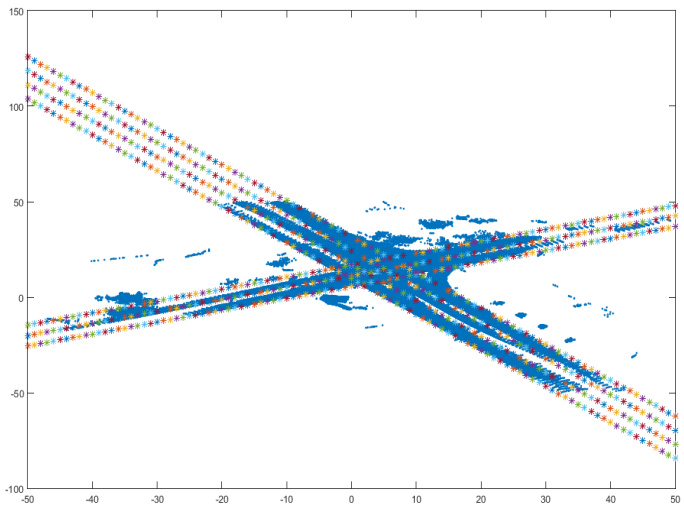
# Lane Identification

- It is important to know the lane-location of vehicles for connected-vehicle applications.

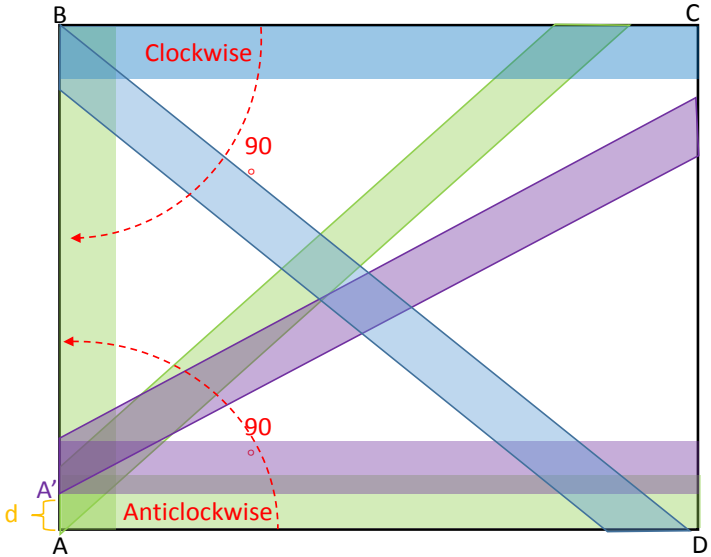
- A vehicle trajectory-based traversal scan algorithm (TBTSCAN) is developed for lane identification. The TBTSCAN consists of two main steps: frame aggregation and traversal search.

# Lane Identification (Cont'd)

- Frame aggregation
  - Similar to aggregation in background filtering, the frames after background filtering are aggregated to increase the density of vehicle points on lanes.
- Traversal search
  - The TBTSCAN uses two lines with a distance of road width to scan the space




Frame aggregation

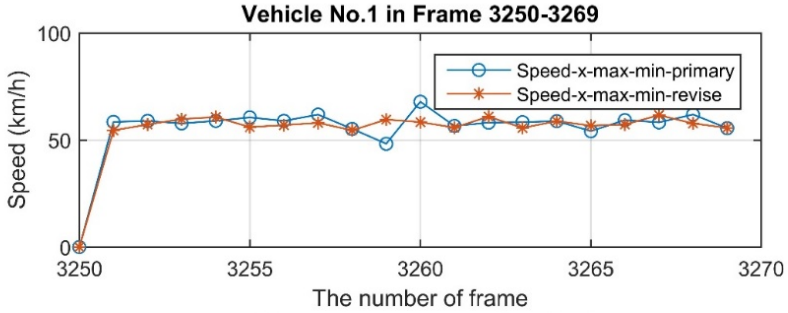


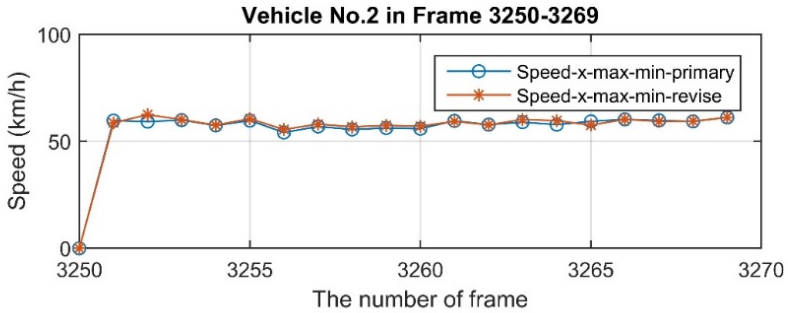

Traversal search

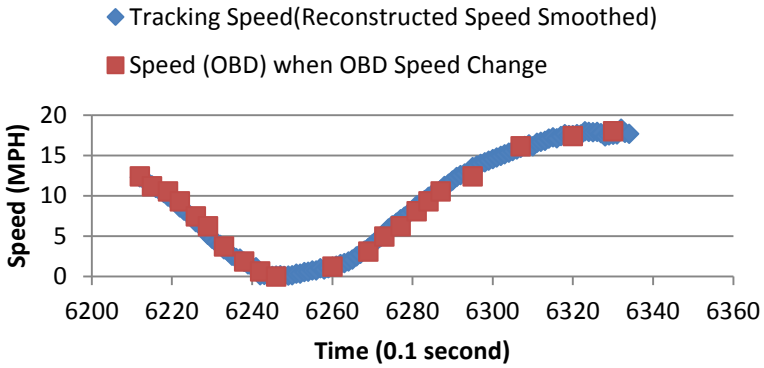
# Vehicle Clustering and Tracking

- To track the vehicles' speed and location, points belonging to one object need to be clustered into one group.
- Then the group can represent the vehicle and be continuously tracked.
- The vehicle tracking includes two parts: vehicle clustering and vehicle continuous tracking.
  - This paper applied DBSCAN algorithm for vehicle clustering considering its powerful function to process the points in spatial space.
  - This paper selected the nearest point (vehicle group) to the LiDAR as a representative point to continuously track the speed and location of vehicle.

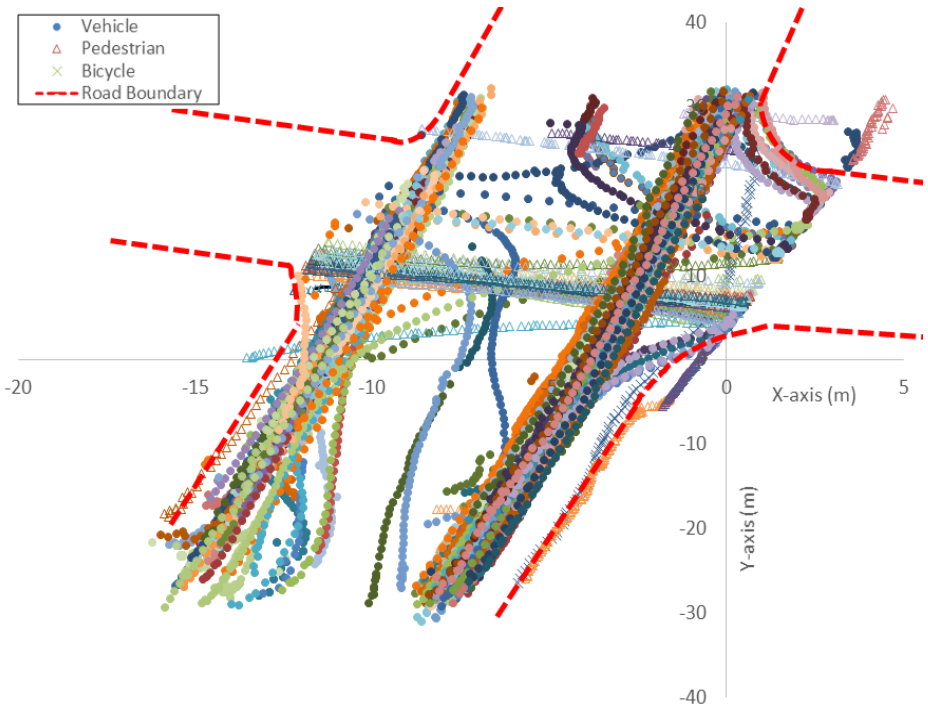
# Case Study of Vehicle Tracking




Speed evaluation




Example of trajectories

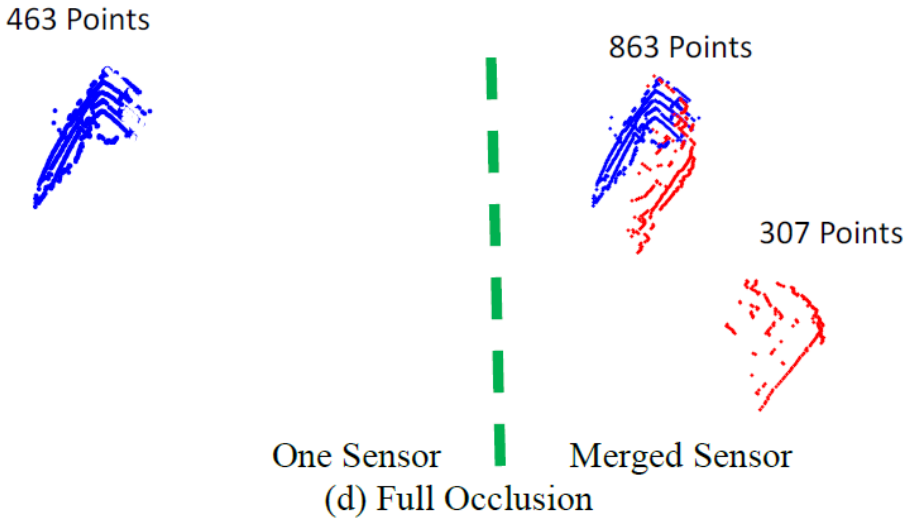
# Conclusions

- This paper introduces a process to extract background, identify lanes and track vehicles with the roadside LiDAR data.
- The developed background filtering and lane identification methods can filter background and extract road boundaries autonomously.
- The case study shows that the vehicle speed can be tracked with high accuracy using the nearest point.
- Similar methods can be used to track pedestrians and wildlife animals crossing roads

# Discussions

- By knowing the curve information of the lane, the lane identification can extract the road boundaries with curves.
- Occlusion is a major issue for one LiDAR sensor, integration of multiple sensors is the solution.


Integration of two LiDAR sensors




Comparison of one-sensor data and two-sensor data


Contact:

Hao Xu
haox@unr.edu

Jianqing (Truce) Wu
jianqingwu2015@gmail.com