
# Introduction to LiDAR for Machine Perception

deepen

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# About Deepen AI

- Deepen AI specializes in autonomous AI tools and services

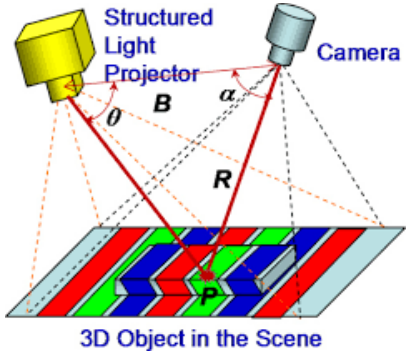
Eve: 3D fused sensor annotation, visualization & benchmarking platform supporting LiDAR, radar, camera & other sensors.

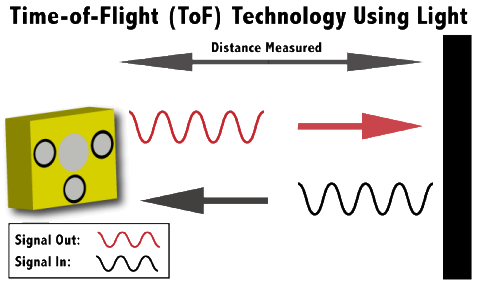
Rannotate: 2D fused sensor annotation web platform

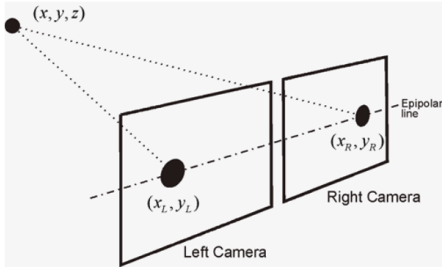
Safee: AI for quality assurance and automation of labeled data

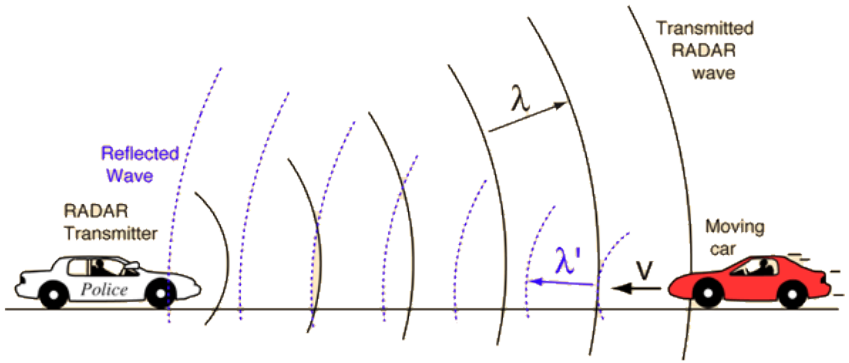
# Types of Depth Sensors

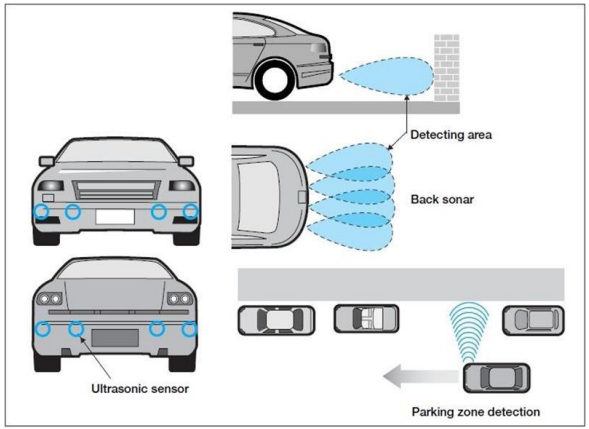
- Structured Light
- Time of Flight (ToF)
- Stereo camera
- Sonar
- Radar
- LiDAR



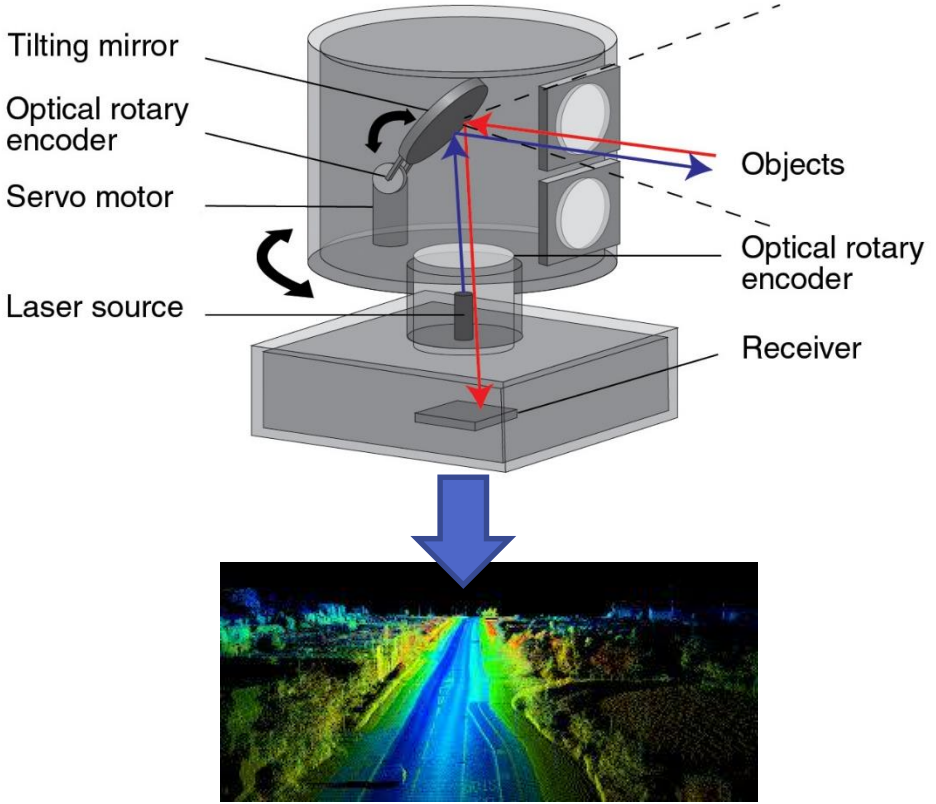



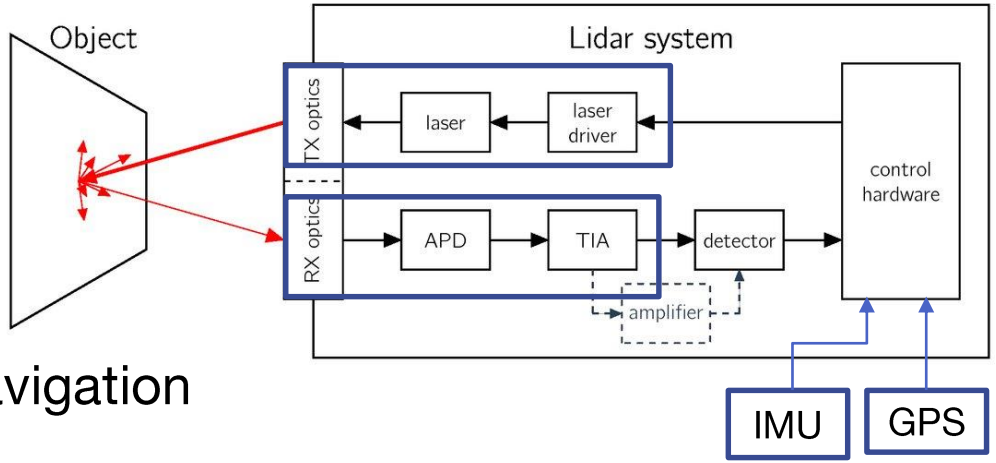
# What is LiDAR

- Laser detection & ranging
- Fires laser beams in all directions
- Measures ToF to get distance
- Well-collimated light gives much better location accuracy
- You get:
  - 3D Point Cloud
  - XYZ coordinates
  - Location of an object in space



# What is LiDAR (cont)

- LiDAR uses light (ultraviolet, visible, infrared) depending on the use case
- By measuring return times and wavelengths, you can generate the 3D point cloud of the target area
- Typical system composition:
  - Laser
  - Scanner
  - Photodetectors
  - GPS & IMU for position & navigation
  - Control hardware



# How LiDARs work

- Short pulses give you better resolution
  - Limited pulse width gives better resolution
  - You need to space the pulses to increase sensitivity
  - Depth resolution = k (delta T * C) / 2
    - K is dependent on the receiver sensitivity & material
    - Divide by 2 for the light to reflect back
    - Delta T = minimum pulse width
    - C: speed of light
- Depending on K & delta T, you get various ranges, frame rates & resolutions

# How LiDARs work (cont)

- Finer spacing between the beams impacts XY resolution & reduces sparsity
- More beams => less spacing
- XY resolution is affected by
  - FOV & Orientation
  - LiDAR physical properties
    (pulse rate, spacing, wavelength)
  - Speed
  - Software


VLS-128

# How LiDARs work (cont)

- To process a LiDAR image you need:
  - The image to be stored in the point cloud format
  - Convert points to a Triangular Irregular Network (TIN) model of the surface
  - Convert TIN model to a raster model of the surface to end up with
    - Digital Elevation Models (DEM)
    - Digital Surface Models (DSM)
- Range, resolution, frame rate, compute, power, durability, size and cost are the primary factors to differentiate the various LiDARs

# Sample properties

| | Radar | Sonar | Stereo | LiDAR | SSD LiDAR |
|---|---|---|---|---|---|
| Range | ~0.15 – 250m | ~5m | ~250m | ~250m | ~250m |
| Resolution | Average | Poor | Very good | Good | Very good |
| FOV | < 90 | Varies | Wide | 360 | Varies |
| Works in the dark | Very good | Very good | Poor | Very good | Very good |
| Weather reliability | Very good | Very good | Poor | Average | Good |
| Speed detection | Very good | Poor | Poor | Good | Good |

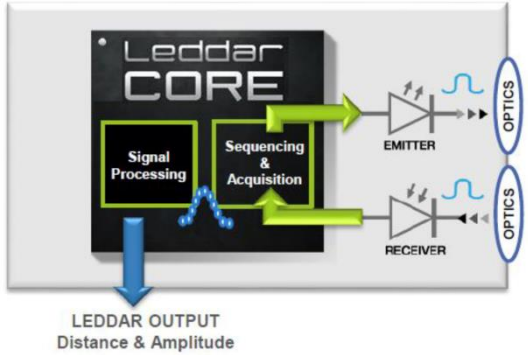
# Types of LiDARs

- Mechanical LiDARs
  - Up to 128 lasers
  - Cost vs range/resolution

Velodyne

- Solid-State LiDAR
  - Multiple VCSELs ~8
  - Vertical cavity surface emitting lasers
  - Better cost / lower range

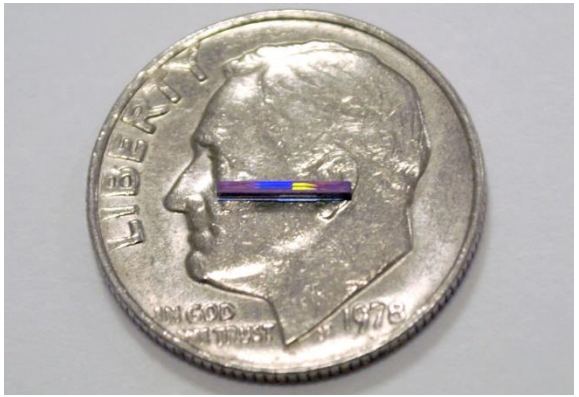
LeddarTech

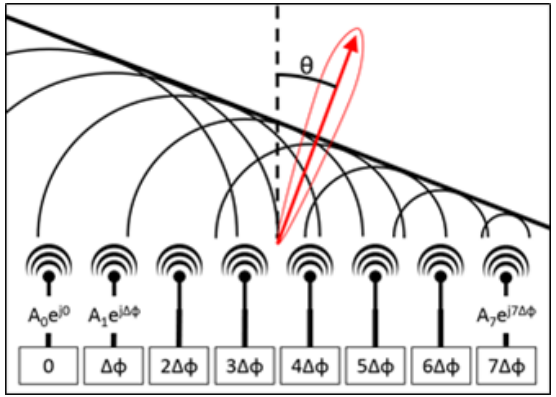


# Types of LiDARs

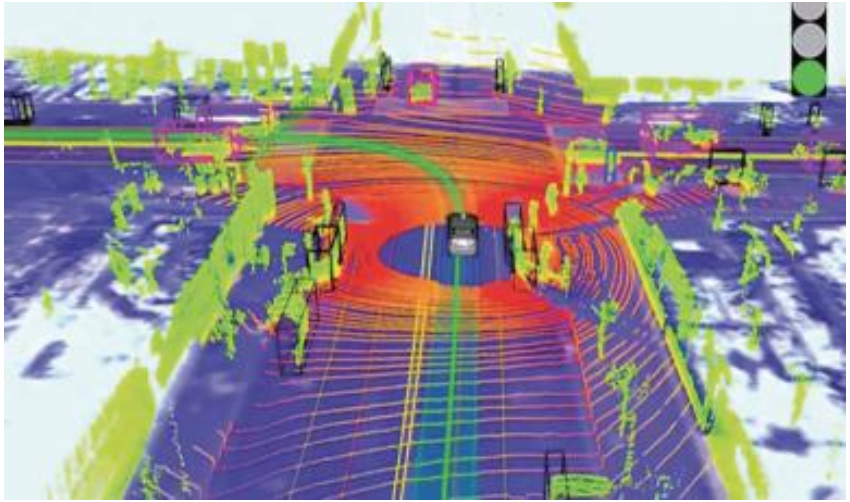
- MEMs LiDAR
  - More robust
  - Mirror scans an entire xy plane


- Phased array
  - Short range (5cm)
  - Set of beams
  - Coordinated phase



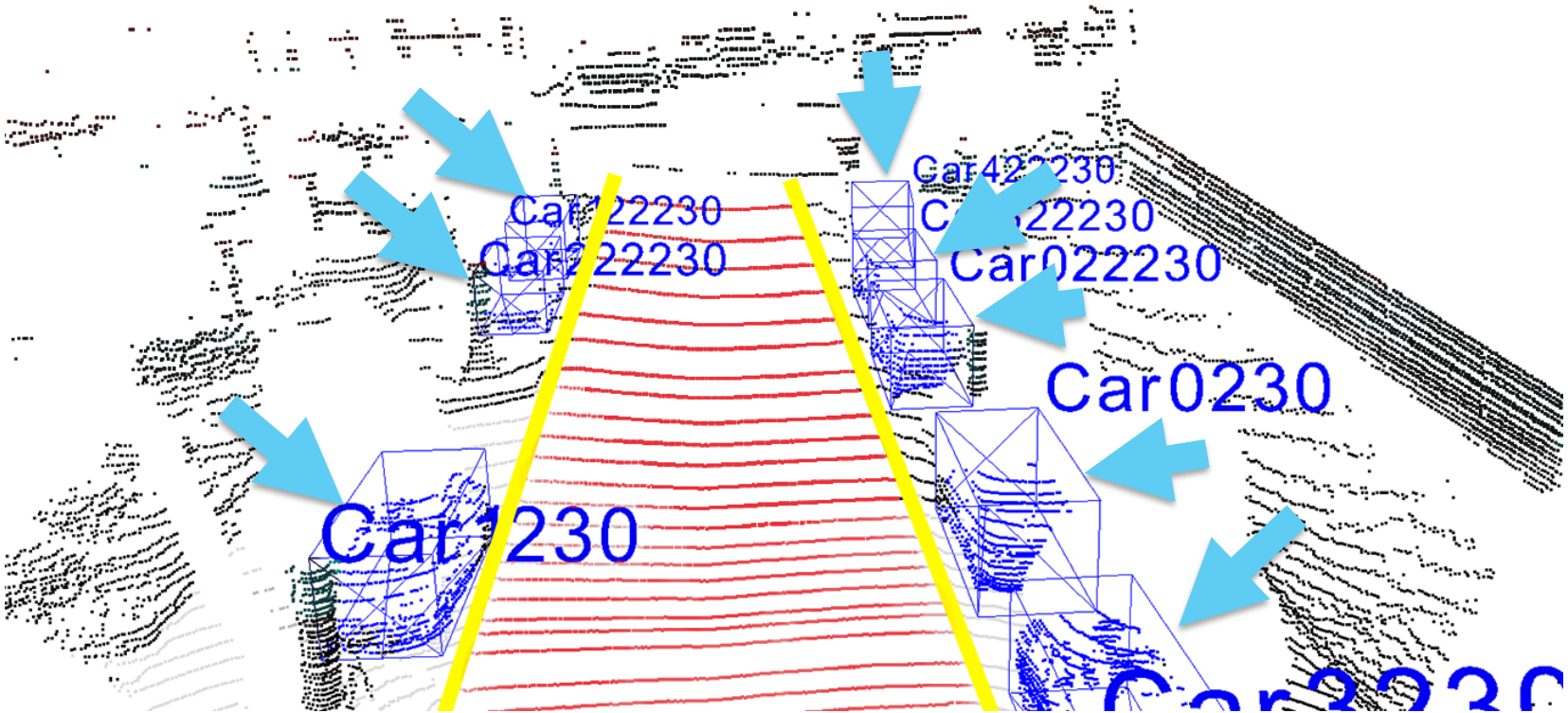


# Mapping & localization use case



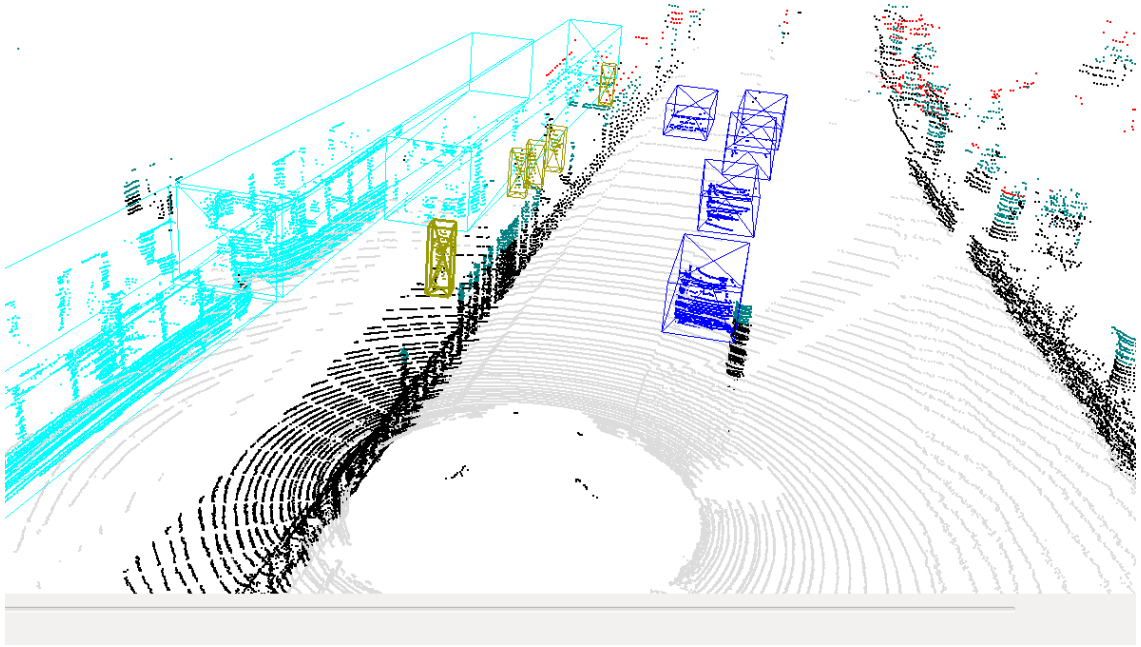
- Mapping & localization
- LIDAR allows you to generate huge 3D maps (its original application!)
- Predictability of upcoming traffic signs helps the autonomous car plans ahead correctly.
  - This is part of the localization process.

# HD Mapping – removal of dynamic objects



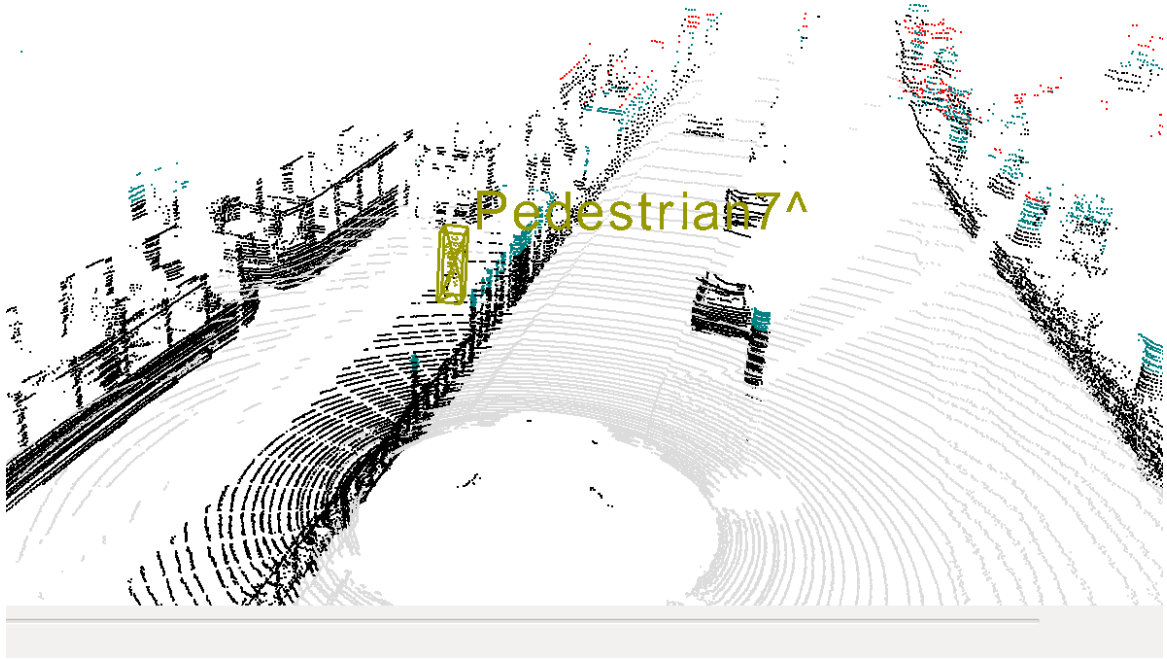
# Perception use case (detection)

- 3D object detection



# Perception use case (classification)

- 3D object classification



# Perception use case (semantic segmentation)

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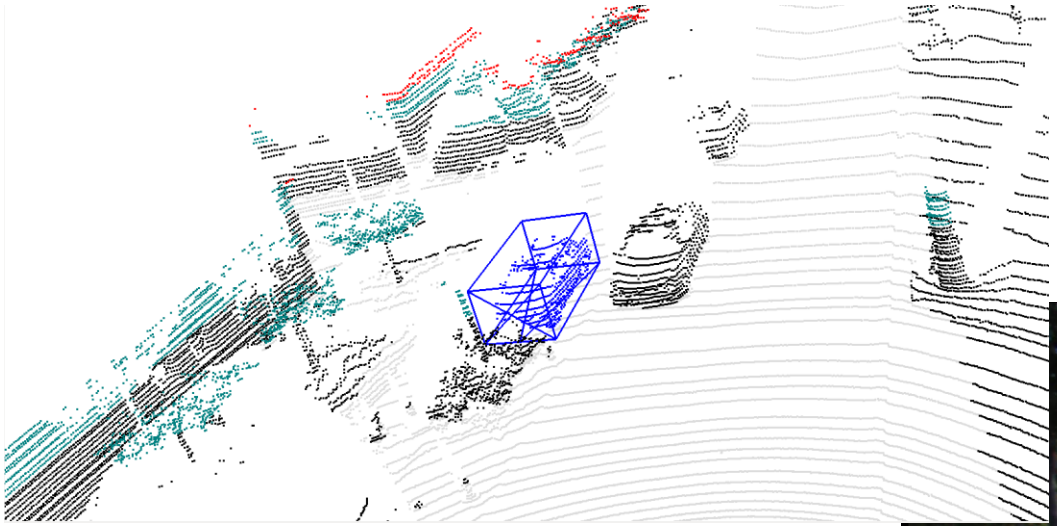
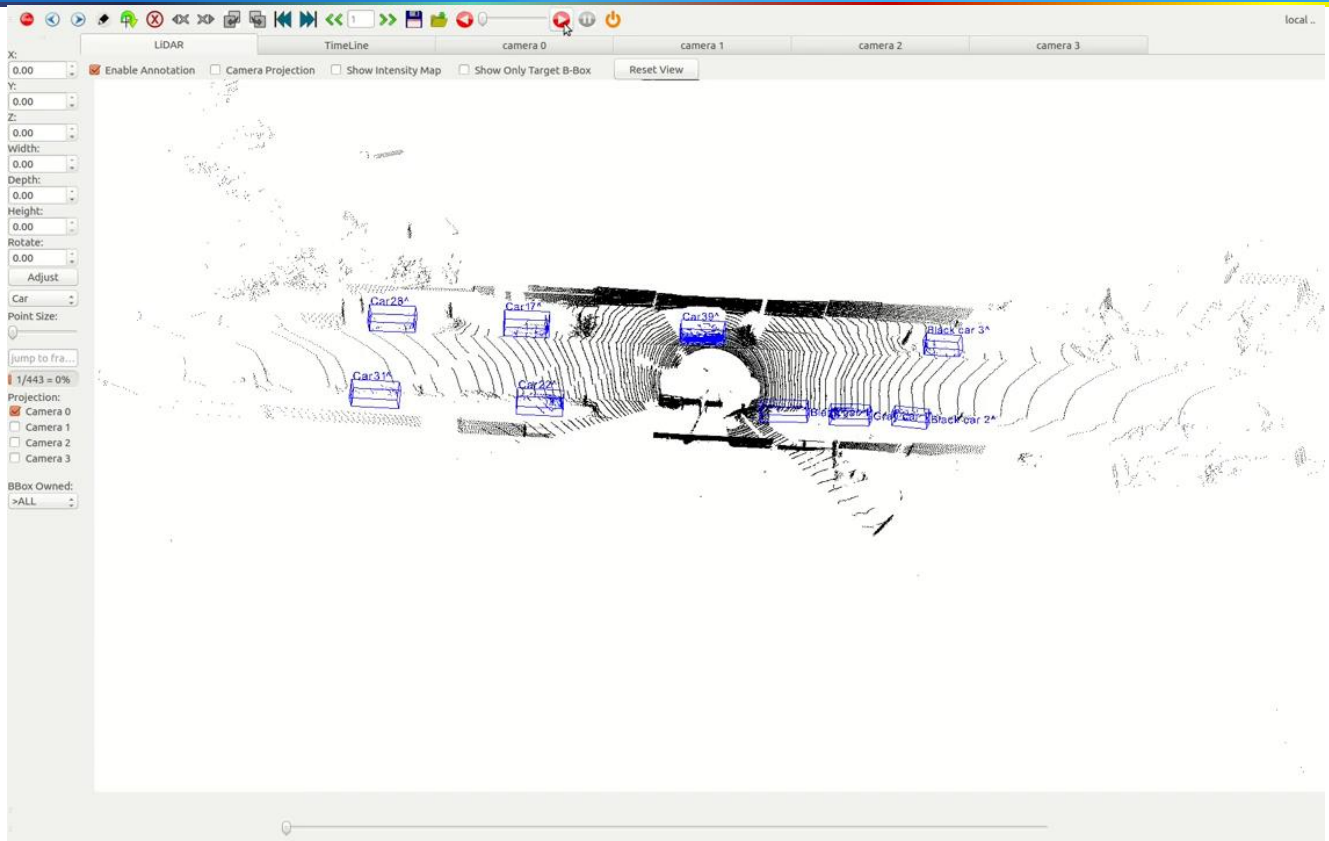


# Perception use case (tracking)



# Benefits of a LiDAR

- Pros
  - Continuous 360 degrees of visibility
  - Precise distance (to an accuracy of ±2 cm) of object's depth in relation to the sensor

- Cons
  - Scan point sparsity & missing points
  - Affected by weather (rain, snow)
  - Cost

# Summary

- LiDAR is great for
  - Localization & mapping
  - Tracking, detecting, and classifying 3D objects
  - Richer output than other depth sensors can provide
- Barriers
  - Cost
  - Weather
  - Sparsity
  - Availability of AI models & open data sets

# Resource Slide

- These slides are at the Embedded Vision Alliance web site
- Deepen AI web site: www.deepen.ai
- What is LiDAR (high level Wired article & video)
- Comet labs article on depth sensor comparison
- Multi Planar LiDAR & Computer Vision Calibration paper
- A Survey of Computer Vision Research for Automotive Systems
- IEEE comparison of 3D scanning techniques
- Top LiDAR perception papers here & here
- Please contact me if you have any questions: moh@deepen.ai