LIDAR/Radar & Camera Fusion

Autonomous Vehicles – ECE-6460

Group 6 - Fall 2022

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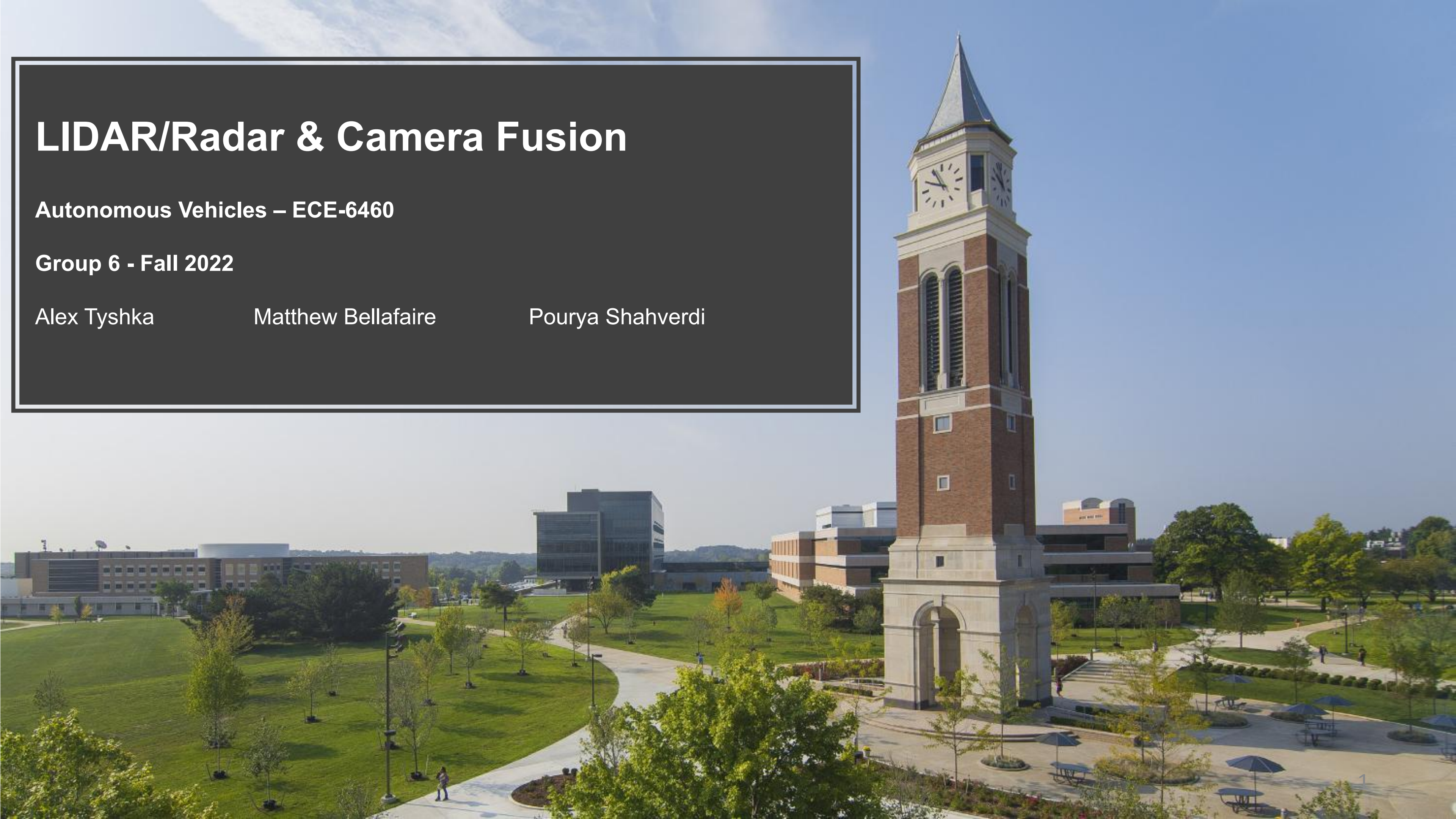


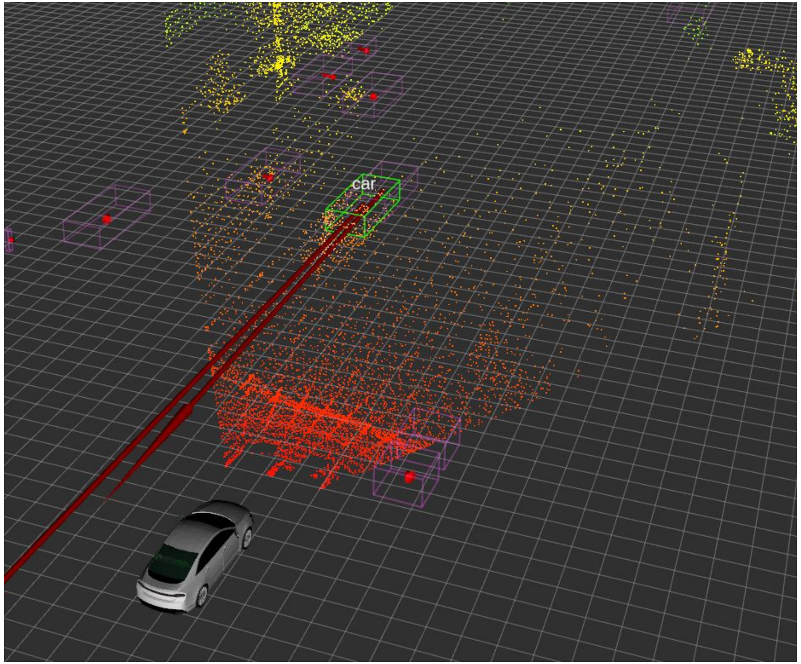
Overview

- The goal of this project is to create a 3D object tracker that is capable of tracking and identifying objects.

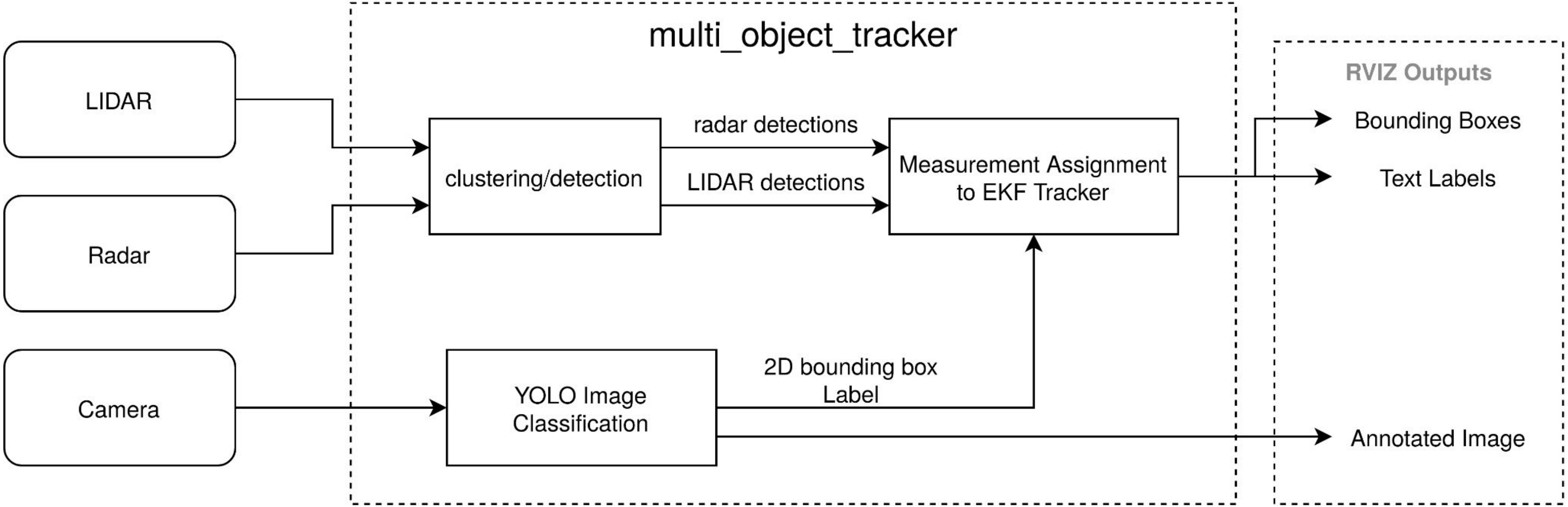
    - Object locations are tracked by LIDAR/Radar fusion
    - Object identification is performed by YOLO image classification

Overview

- Both Lidar and Radar generate noisy boxes off the road
- This project focuses on tracking only dynamic objects (e.g. vehicles)



Overview



LIDAR
Radar
Camera
multi_object_tracker
clustering/detection
radar detections
LIDAR detections
Measurement Assignment to EKF Tracker
YOLO Image Classification
2D bounding box Label
RVIZ Outputs
Bounding Boxes
Text Labels
Annotated Image

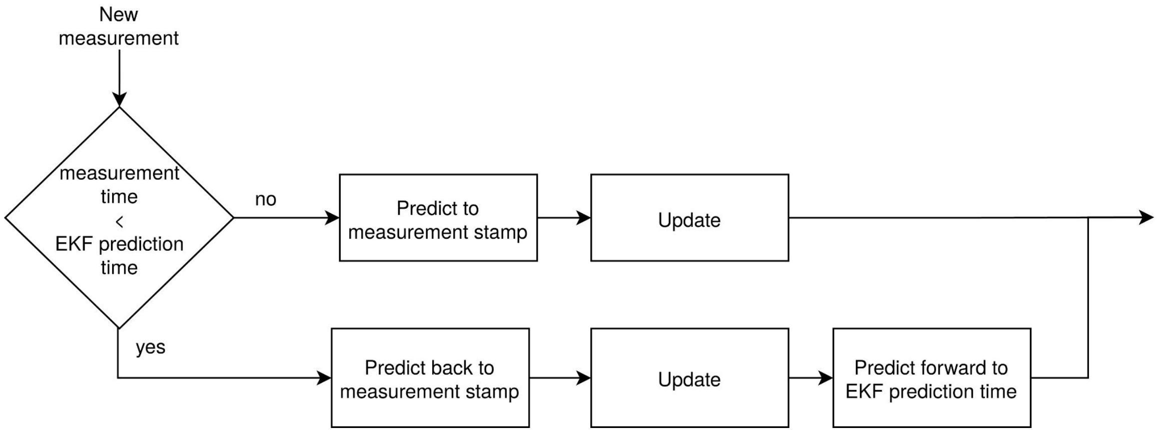
Extended Kalman Filter

- The EKF was adapted from the object tracker in Homework 4.
- The state transition was adapted to compensate for the tracked objects movement when the vehicle is turning.

$$X_{k+1} = \begin{bmatrix} \dot{x}t + t\left(-\dot{\psi}x\sin\left(\dot{\psi}t\right) + \dot{\psi}y\cos\left(\dot{\psi}t\right)\right) + x \\ \dot{x} \\ \dot{y}t + t\left(-\dot{\psi}x\cos\left(\dot{\psi}t\right) - \dot{\psi}y\sin\left(\dot{\psi}t\right)\right) + y \\ \dot{y} \end{bmatrix}$$

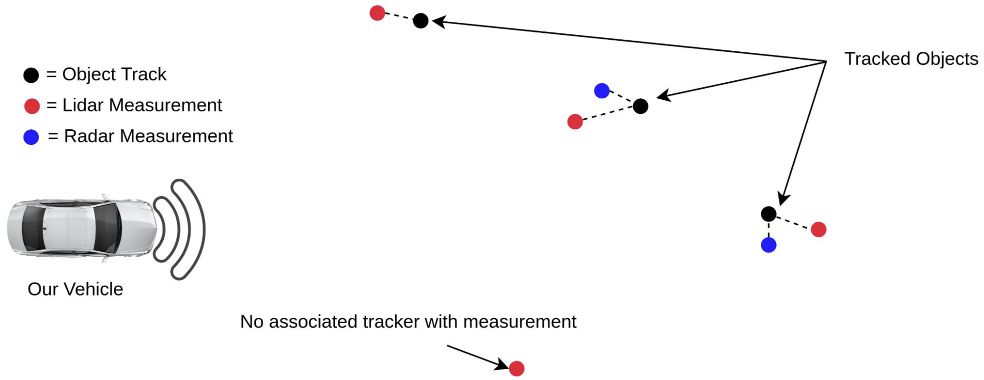
Sensor Fusion

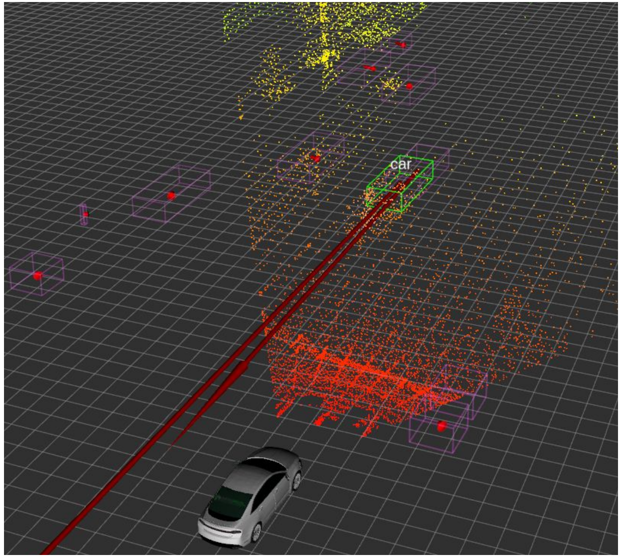
- LIDAR and radar are not time synced
- The EKF projects back to the time of the measurement before incorporating the information. Then project the state forward again.



Radar Filtering

- Radar objects are filtered out if they
  - Do not correspond to a YOLO object and
  - Do not have a velocity





Sensor Noise Calculation

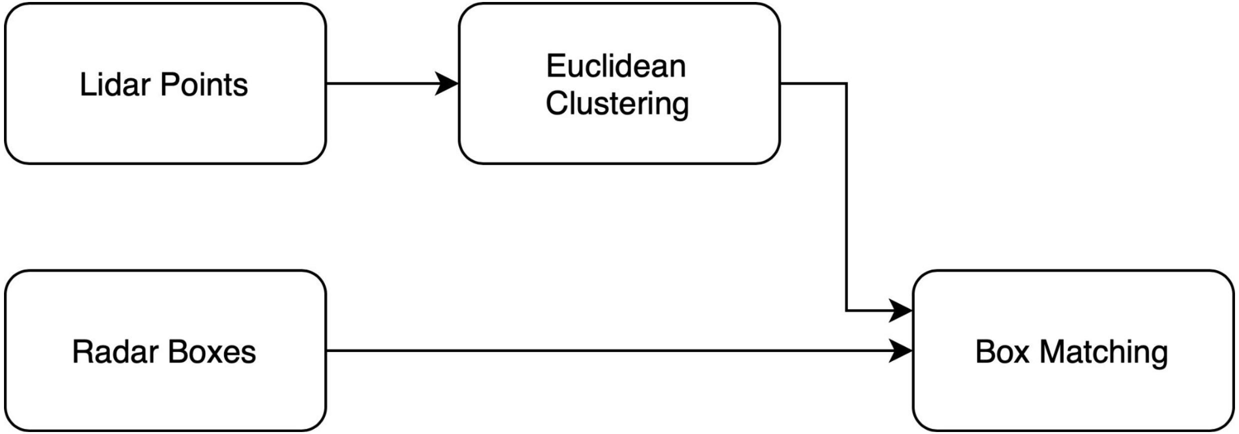
- For the LIDAR the sensor noise is adaptive to the number of points in the point cloud. The R matrix is calculated as:

$$R_{lidar} = \begin{bmatrix} \frac{r_{lidar}}{\lceil n/100 \rceil} & 0 \\ 0 & \frac{r_{lidar}}{\lceil n/100 \rceil} \end{bmatrix}$$

- where n = number of points, and r_{lidar} is the base noise value for the lidar information.

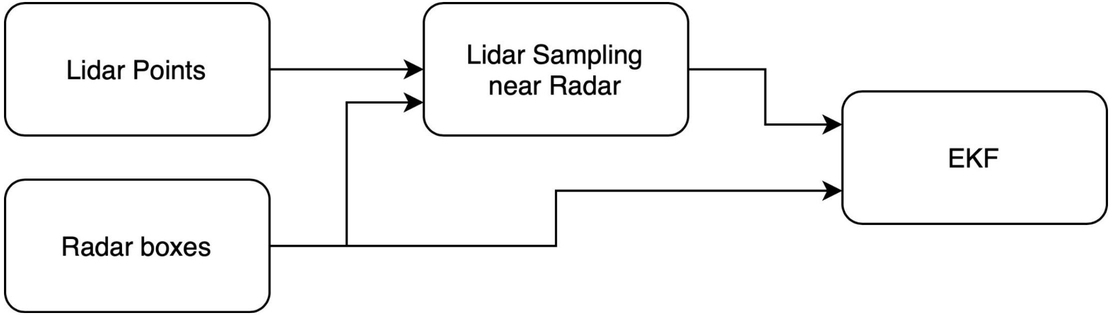
LIDAR Segmentation (original)

- Original lidar approach used Euclidean clusters from HW3
- Lidar boxes noisy (objects frequently split/merge together)



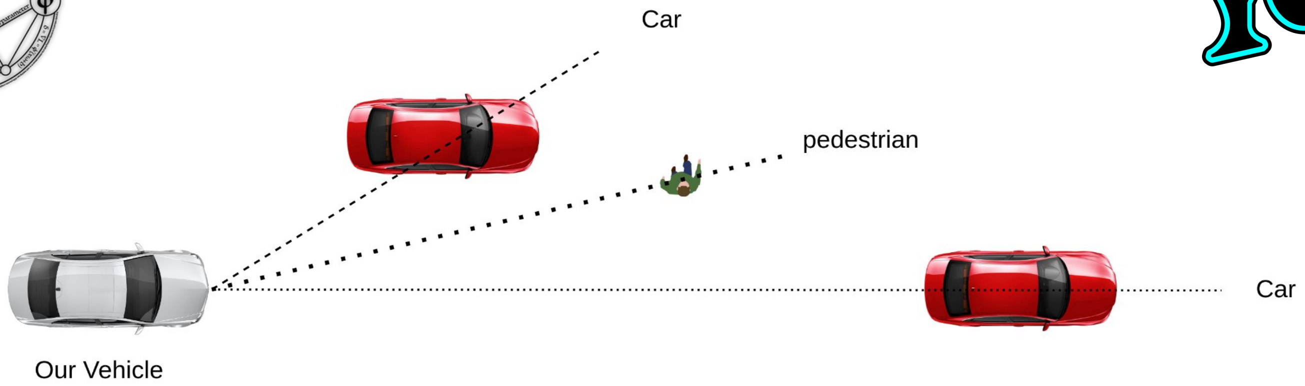
LIDAR Segmentation

- LIDAR segmentation utilizes radar information to more efficiently perform clustering
  - LIDAR points sampled near radar measurements
  - Bottom 20% of the cloud for each object is removed
  - LIDAR object centroids update the EKF



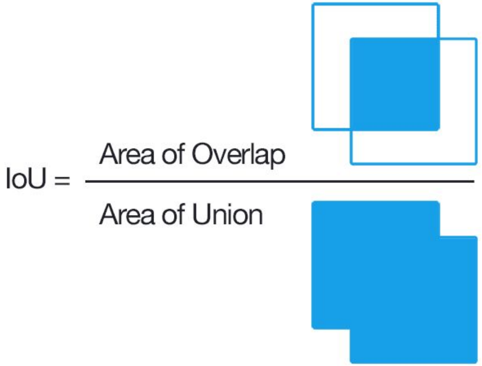
Object Identification

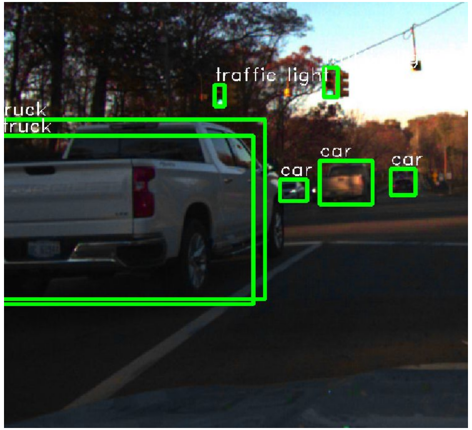
- Objects are identified through YOLO image classification using the camera feed from the vehicle.

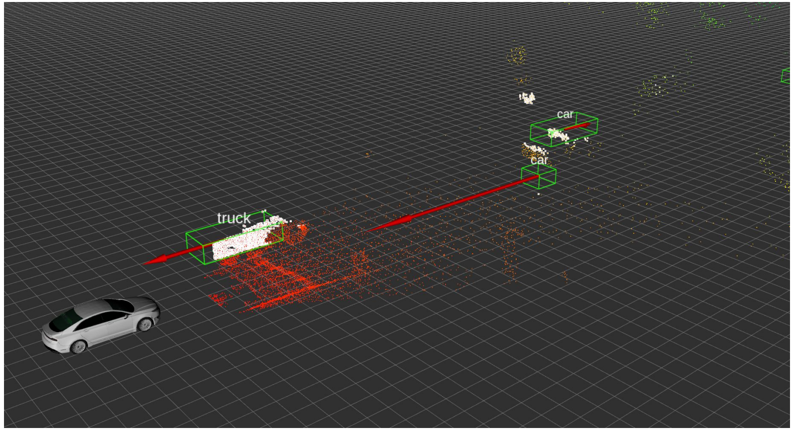


Object Correlation

- Objects in the camera frame are correlated to the 3D objects tracked by the system using intersection over union (IoU)

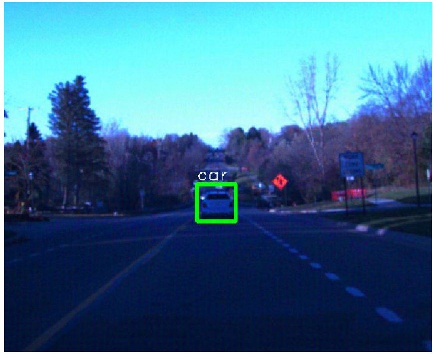


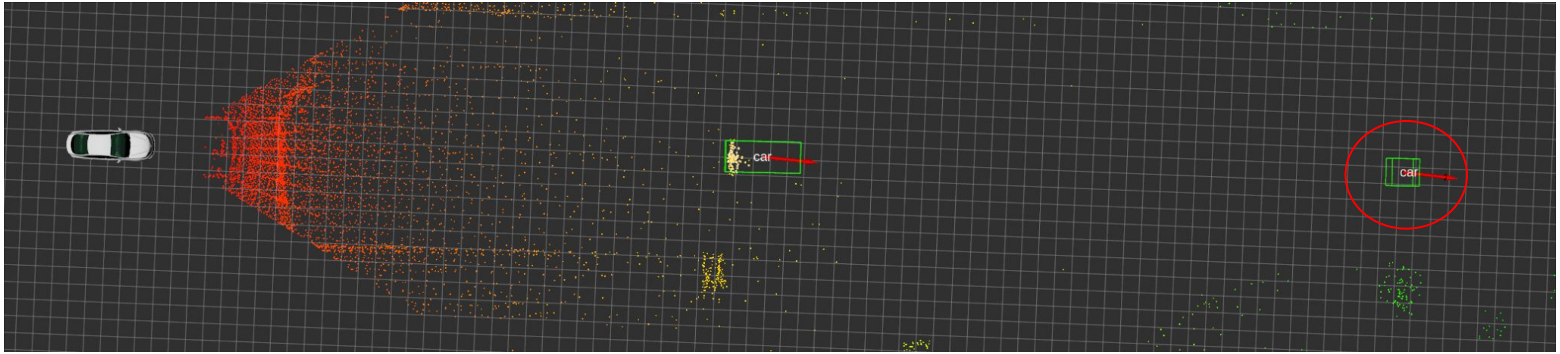




Object Correlation

- 3D objects projected to a 2D plane & aligned with the detections of the YOLO Classification.
- The class labels are stored in the object
- Object labels persist after they have left the camera view:





Demonstration

- ❖ Running system on road_data_sample_with_labels.bag
- ❖ Tracks and labels vehicles in the environment
- ❖ Merges lidar and radar information

Challenges

- Radar/LIDAR positions do not match perfectly
- Timing issues with Radar readings vs LIDAR, needed compensation in filter
- Ideal object detection pipeline would fuse raw LIDAR, Radar, and camera before box discretization, e.g. with a neural network

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