



Each year, Autoliv's
products save over
30,000 lives

[autoliv.com](https://www.autoliv.com)

Autoliv

LiDAR Based Sensor Verification

Nathan Kurtz, Autoliv
Balakumar Ragunathan, Autoliv
Arvind Jayaraman, MathWorks



Overview

- Motivation
- Annotating Point Cloud Data
- Automating Object Detection with Deep Learning
- Results
- Workflow Benefits
- Future Work
- Conclusion

Motivation

- Verifying accuracy of sensors in vehicles can be a very tedious
- We use alternative sources of ground truth, equip test vehicles with
 - Video (cameras mounted at different locations)
 - LiDAR (Velodyne HDL 32E, mounted at different locations)
 - GPS
- We look for True positives and False negatives

Verifying Critical Events for Sensor accuracy

True Positive events

- True positive events occur when an object is present and the sensor correctly detects it
- We simply look at the logs of the recorded events when the radar detected an object
- Confirm validity with video and accuracy with LiDAR

False Negative events

- False negatives occur when an object is present but the sensor does not detect it
- Involves a human analyzing hours of recorded drive data to analyze all events.
- This is a tedious and labor intensive

Motivation for LiDAR based Ground Truth

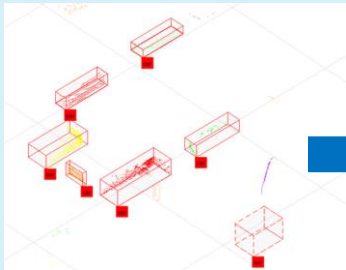
- Can we automatically detect and track objects from other sensors?
- For verifying blind spot events, distance metrics are critical
 - LiDAR provides accurate distance measurements
- Can we use LiDAR Sensors to detect objects in the blind spot zone?
 - Generate all events of interest
 - Next step, is can we automate this process?

Workflow for Automating Object Detection from LiDAR

- A MATLAB based tool to assist users to visualize, navigate, annotate and track objects with Point Clouds
- We present a workflow to automate the labeling of objects using LiDAR point cloud data
- We will look at some results
- Future work

Lidar processing application design in MATLAB

DNN design + training



Data prep,
labeling

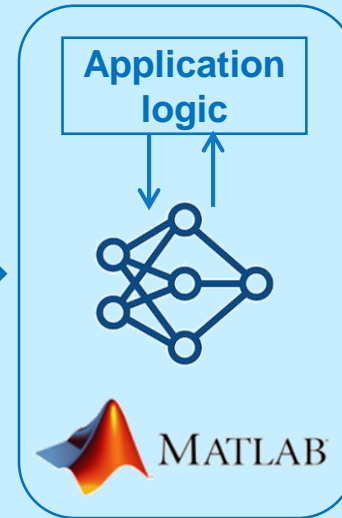


Training



Trained
DNN

Application design



Standalone Deployment

GPU Coder



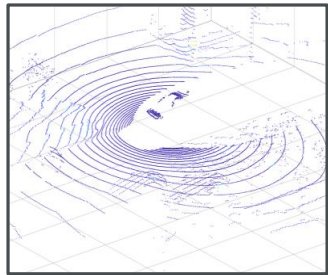
C++/CUDA
+ TensorRT



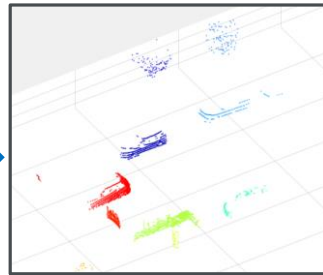
C++/CUDA
+ cuDNN

Data preparation and labeling of Lidar is a challenge

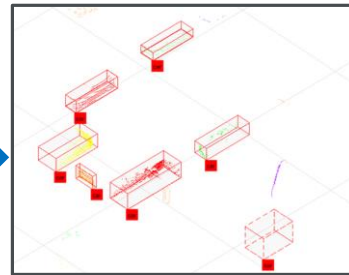
DNN
design + training



Accessing
lidar data



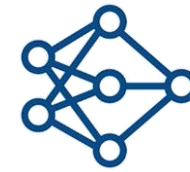
Lidar pre-
processing



Labeling
lidar data

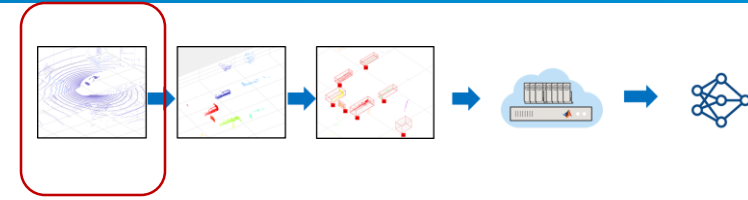


Training



Trained
DNN

Access and Visualize Lidar Data

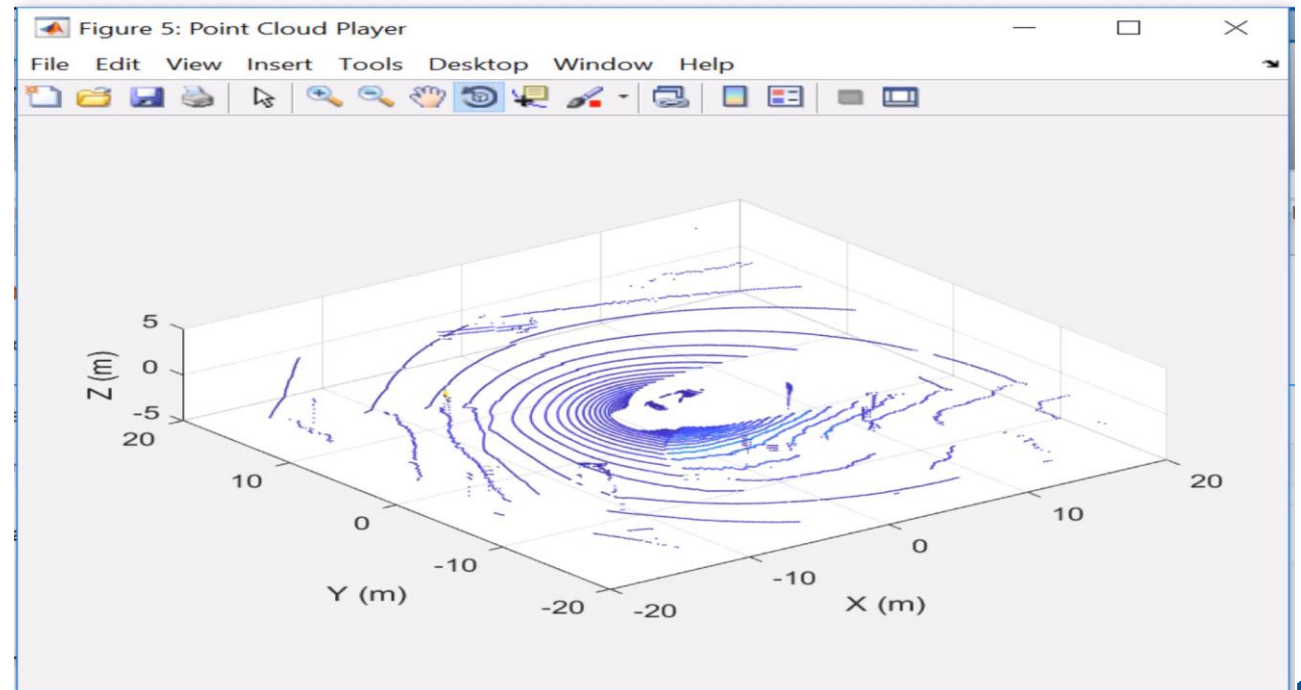


Access Stored Lidar Data

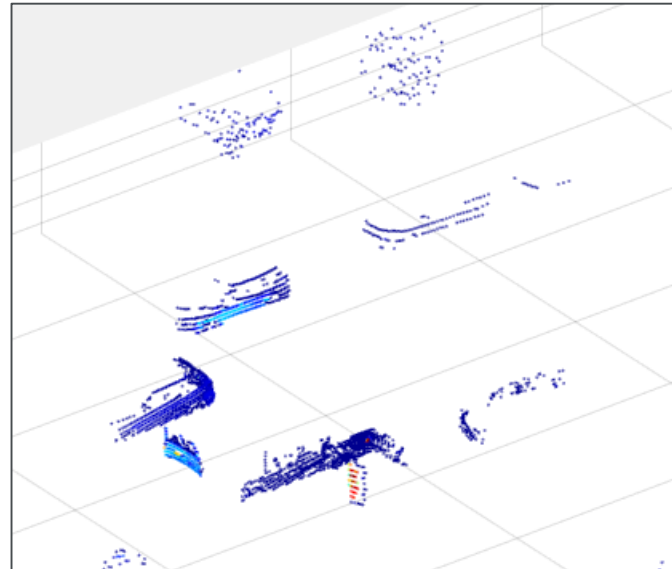
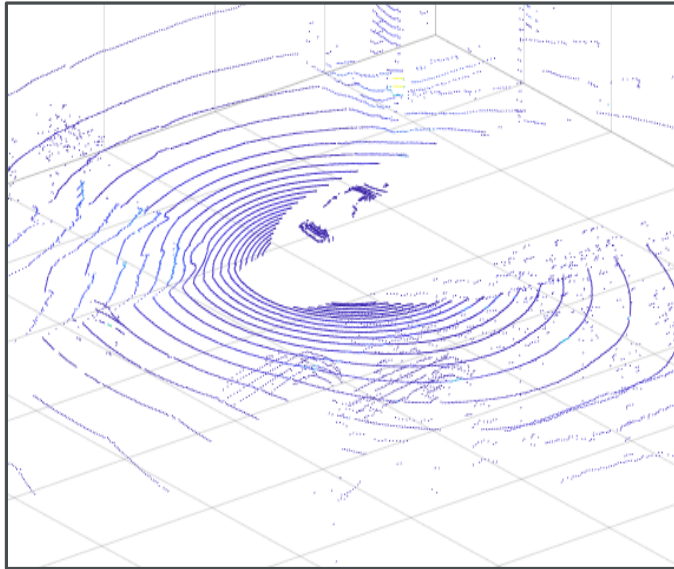
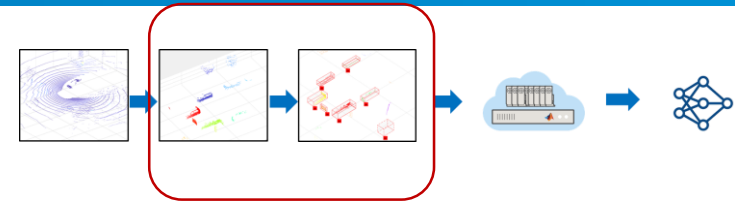
- Velodyne file I/O (.pcap)
- Individual point clouds (.pcd,ply)
- Custom binary formats

Visualize Lidar Data

- Streaming Lidar player
- Static point cloud display
- Point cloud differences

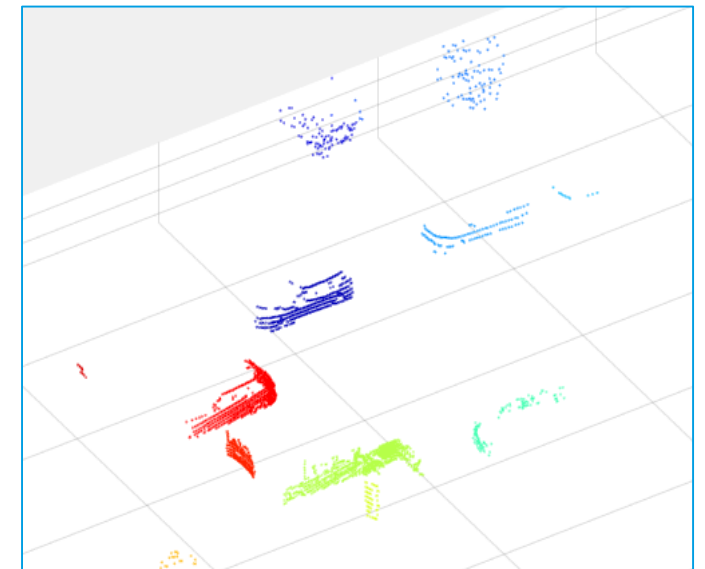


Lidar Preprocessing



Remove Ground

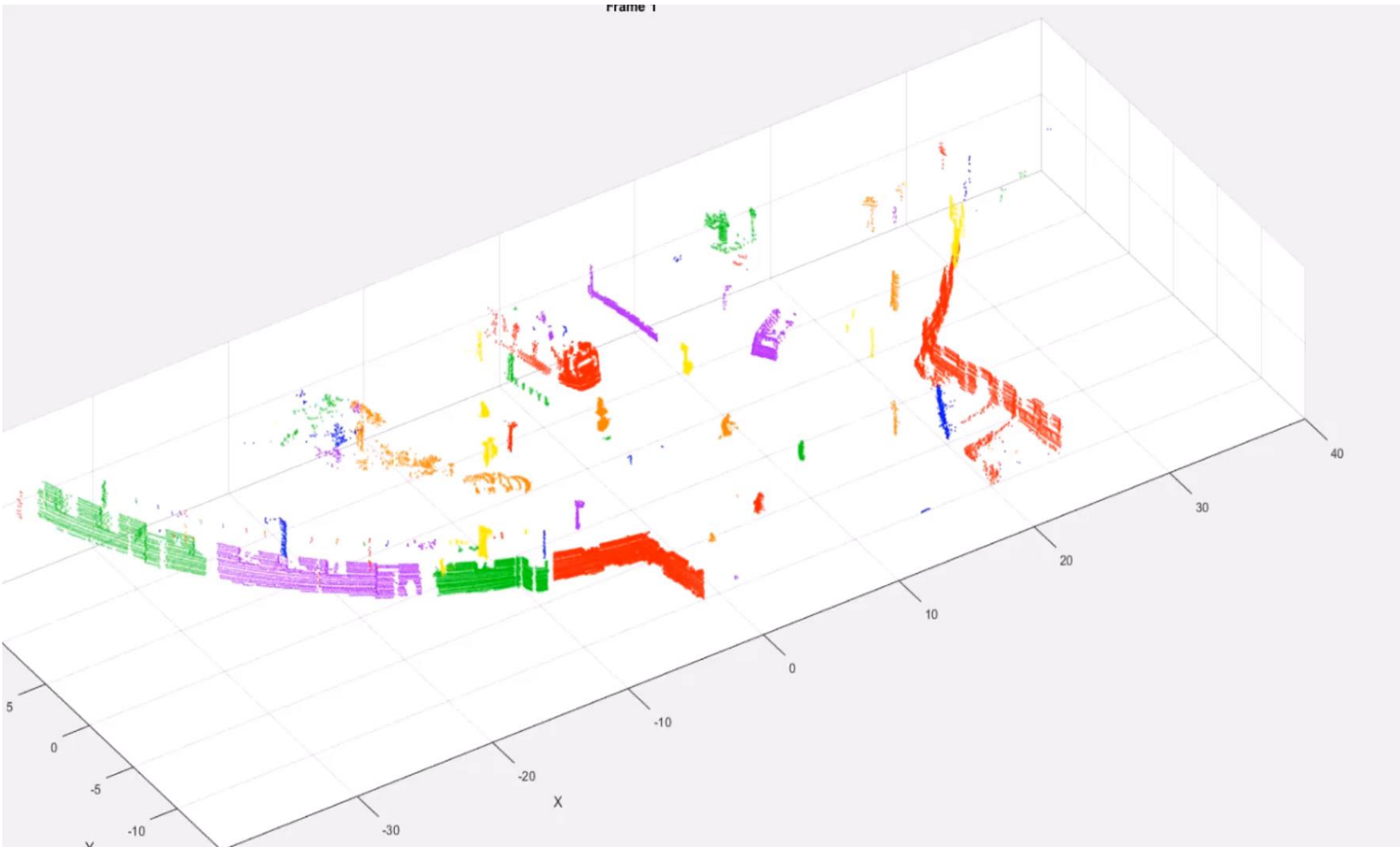
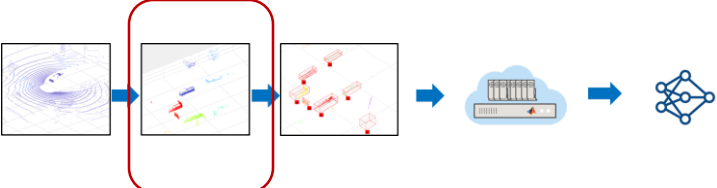
- Fit plane using RANSAC



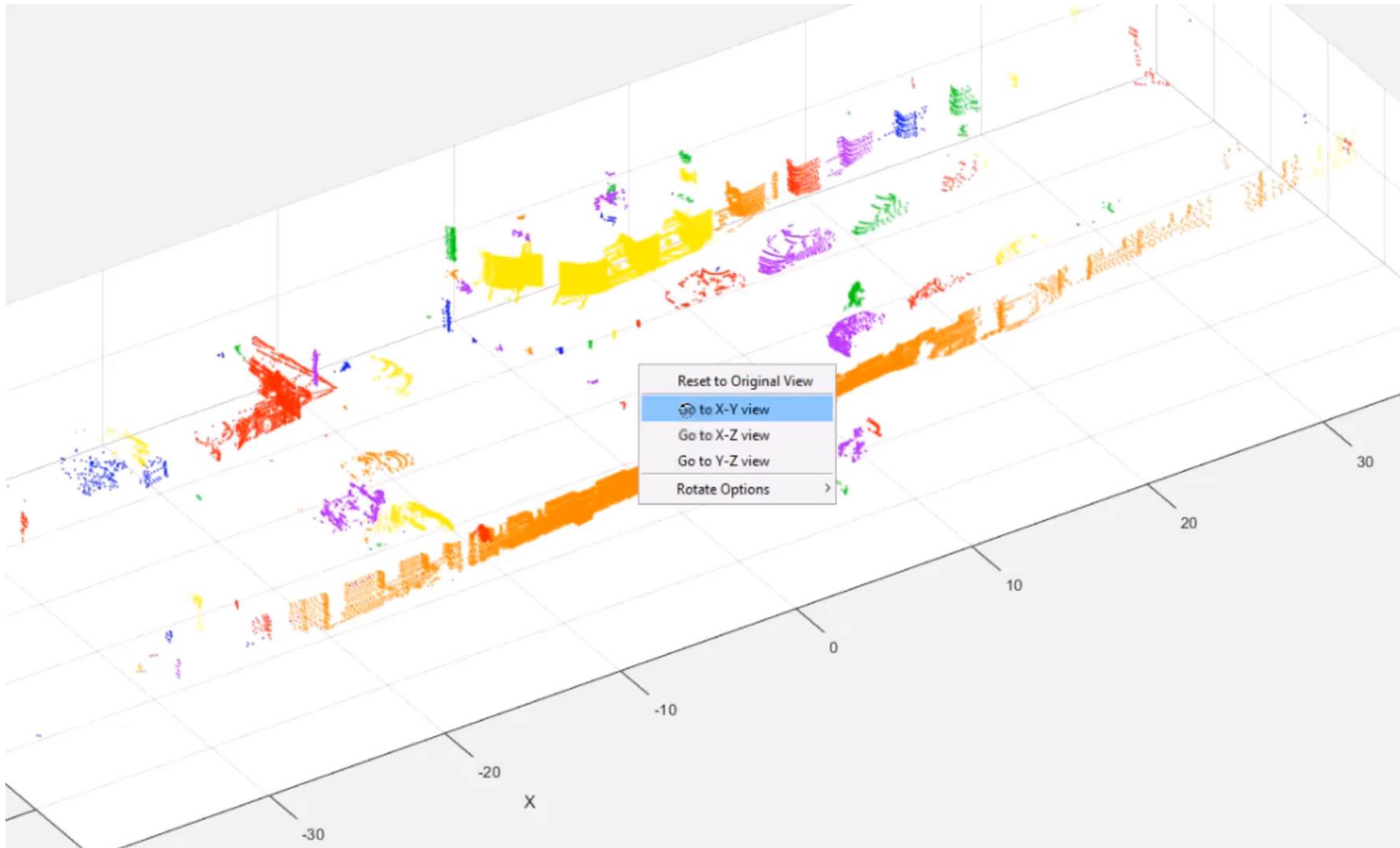
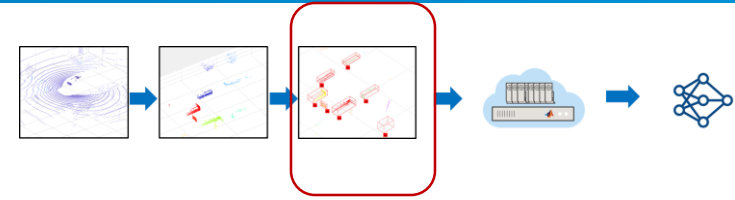
Cluster

- Segment clusters using Euclidean distance

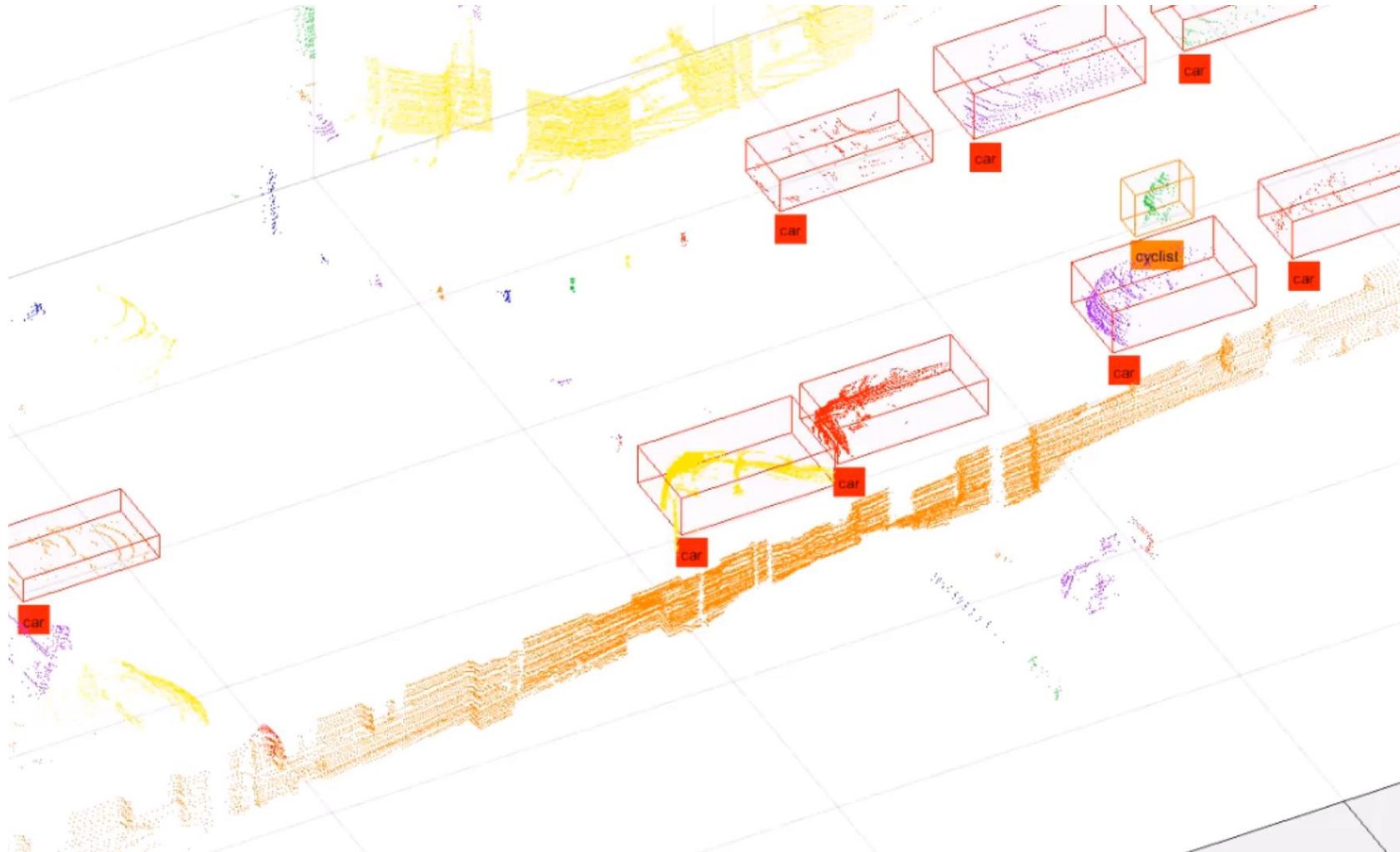
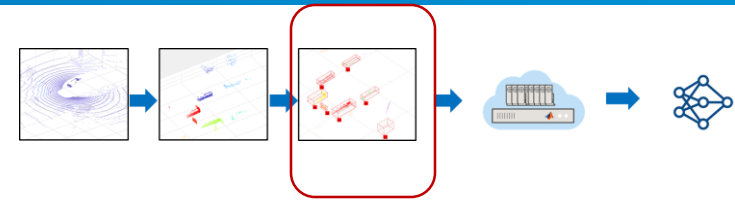
Ground Truth Labeling of Lidar Data



Ground Truth Labeling of Lidar Data



Ground Truth Labeling of Lidar Data



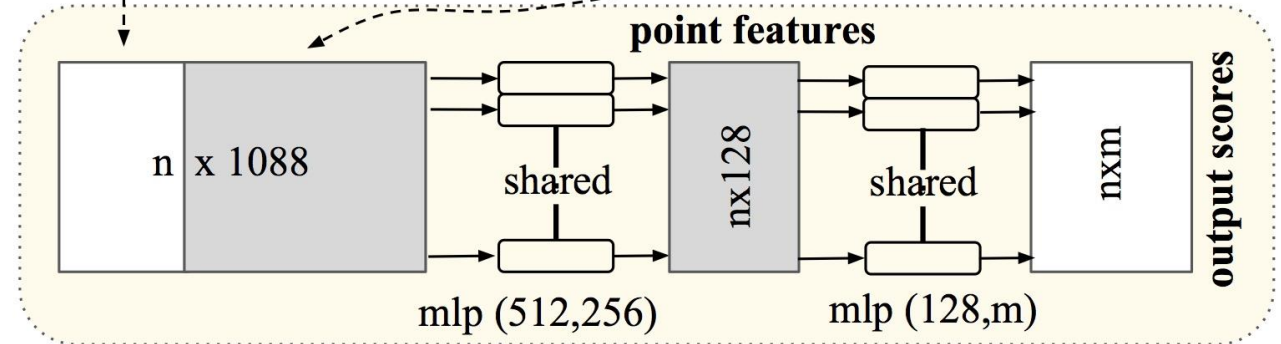
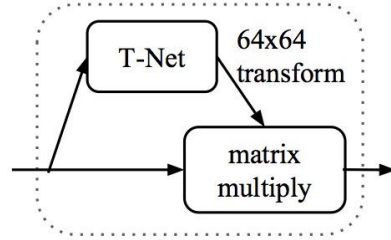
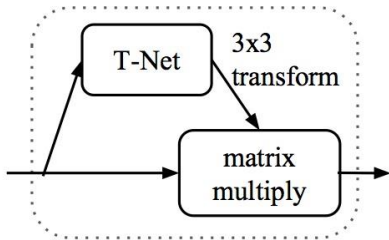
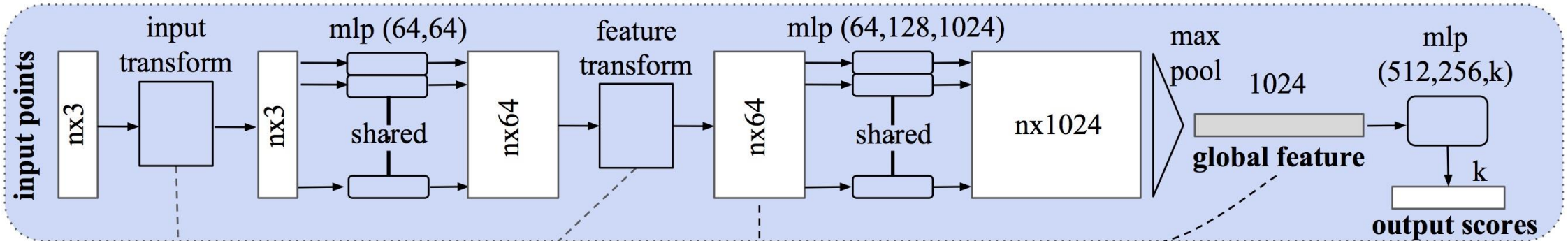
multiObjectTracker
(Automated Driving
System Toolbox)

Automating Object Detection with Deep Learning

- We collected ground truth for LiDAR point clouds
- Now we look at methods to fully automate the LiDAR point cloud annotation
- Use Deep Learning for Point Cloud Object classification
- Use Kalman Filters for creating robust tracks

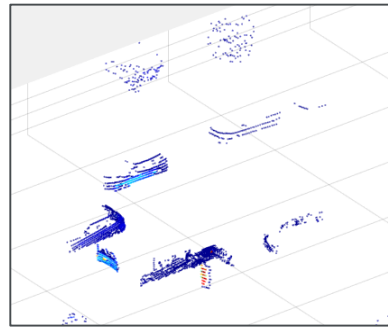
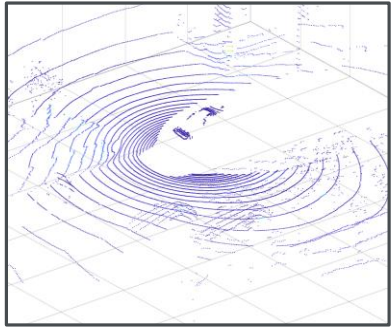
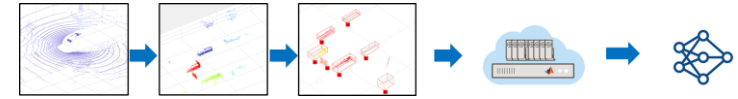
PointNet Network Structure

Classification Network

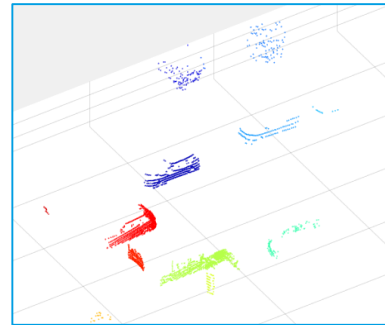


Segmentation Network

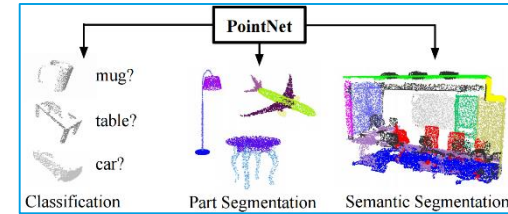
Lidar Processing Pipeline



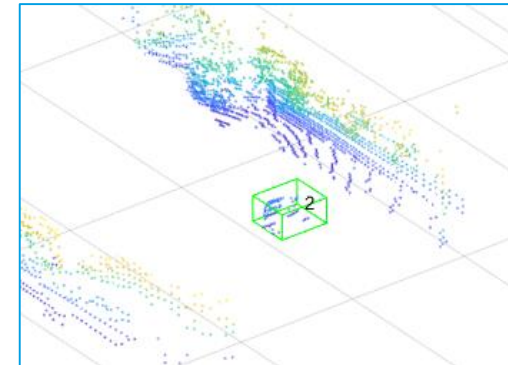
Remove Ground



Cluster



Classify



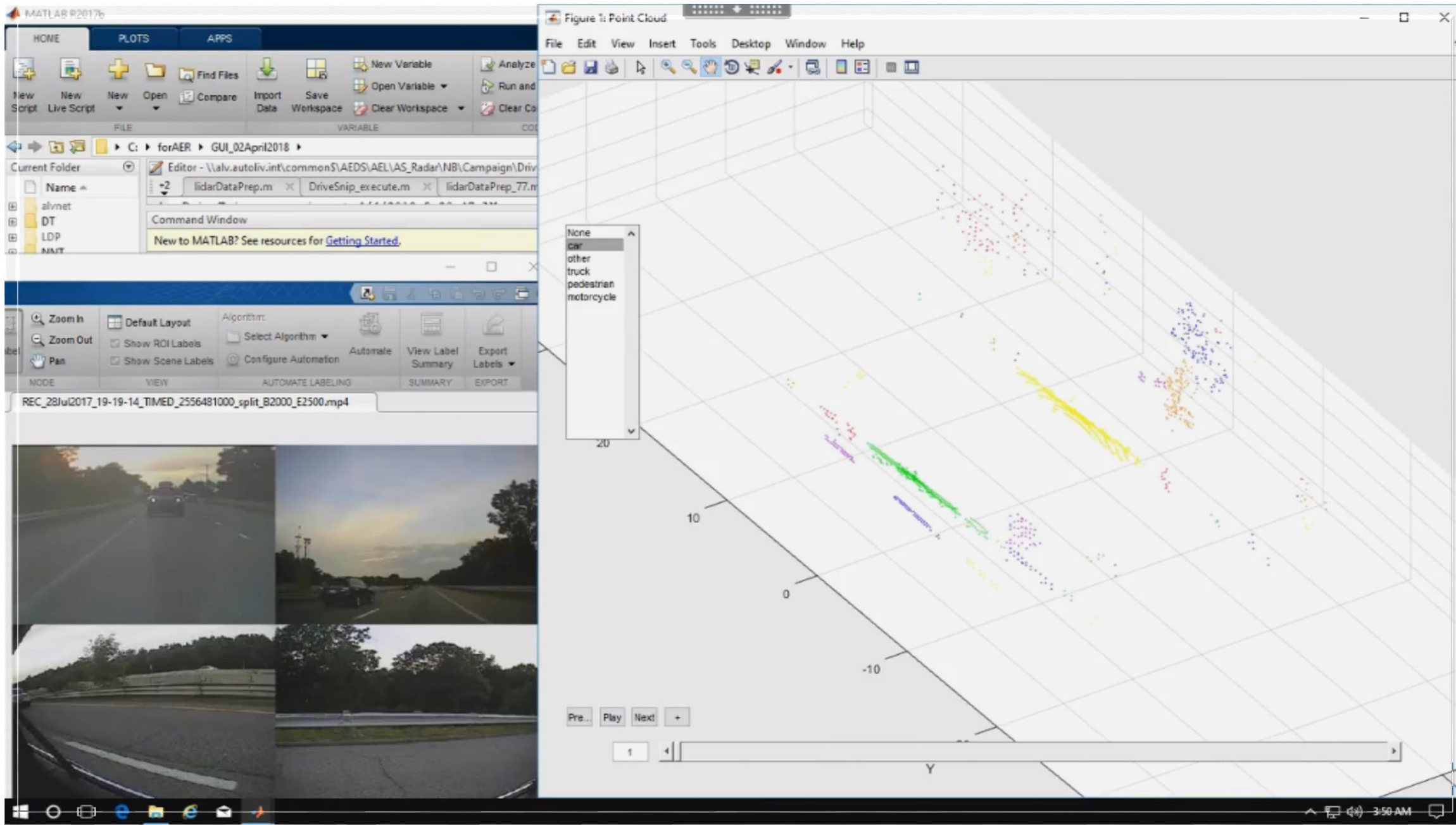
Track

multiObjectTracker

Moving Object Detection

- Classifying objects as stationary or moving
- Uses host velocity to calculate target velocity in global coordinates.
- Classifying moving objects as potential False negatives
 - False negative is when Radar fails to recognizes valid objects.

Results – Simple Scenario



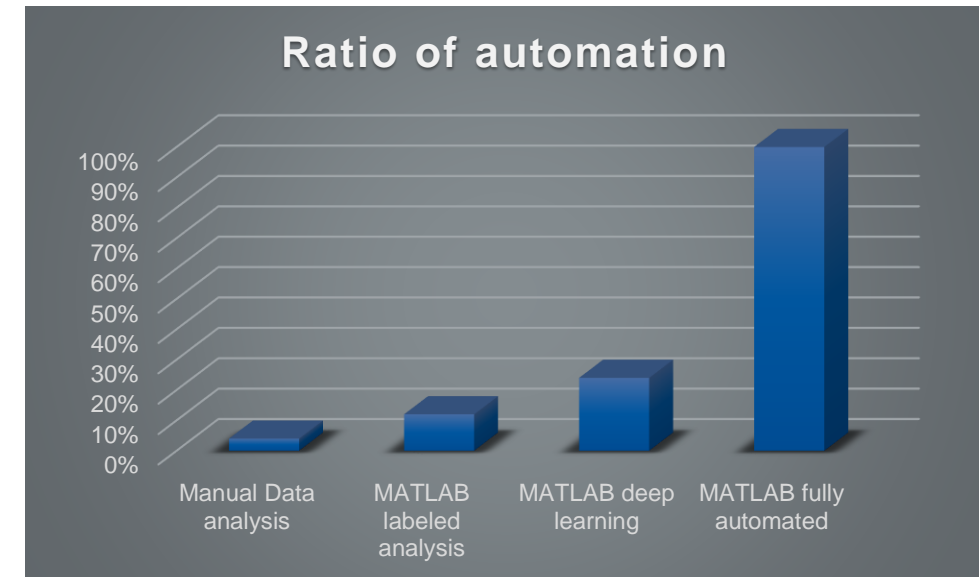
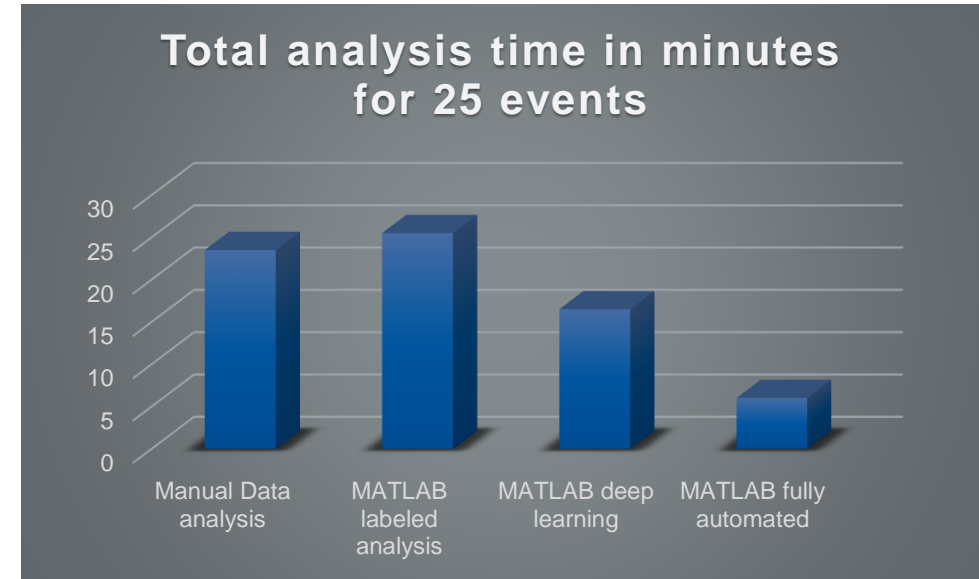
Results – Complex scenario

The image displays the MATLAB R2017b interface for video analysis. The main window is titled 'aef-of-wd0101' and contains several panes:

- Top Left:** A toolbar with options like 'HOME', 'PLOTS', 'APPS', 'EDITOR', 'PUBLISH', and 'VIEW'. Below it is a 'Layout' section with 'Algorithm' and 'Labels' tabs, and buttons for 'Select Algorithms', 'Automate', 'View Label Summary', and 'Export Labels'.
- Center Left:** A video player showing four frames of a road scene. The frames show cars and a van in various positions on a road.
- Center Right:** A 3D point cloud visualization of the scene, labeled 'Frame 12'. The point cloud is colored in red and yellow. Several bounding boxes are overlaid on the point cloud, labeled 'car' (in red) and 'other' (in yellow).
- Bottom Left:** A control panel with time markers: '00:55475' (Current), '40:08003' (End Time), and '40:08003' (Max Time). It includes playback controls (stop, play, next, previous) and a 'Zoom In Time Interval' button.
- Bottom Center:** A command window showing the message: 'time elapsed for step 3: 125.8778' and 'Paused: replay labeled data. After replaying, press enter'.
- Bottom Right:** A navigation panel with 'Pre', 'Play', 'Next', and '+' buttons, and a frame number input field set to '12'.

Workflow benefits

- Autoliv was manually analyzing LiDAR data to verify their Radar sensors.
- Using this MATLAB workflow, Autoliv is able reduce time needed to analyze LiDAR data
- As level of automation increases, the analysis time is further reduced
- A blind spot analysis is illustrated here.



Future work

- Explore other Neural Net architectures which are more accurate
- Integrating video reference data along with LiDAR to provide easier annotation and also more accurate and automated classification of objects
- Extend results to categories other than just vehicles, also try to include pedestrians and general objects

Conclusion

- Manually labeling LiDAR point cloud is labor-intensive.
- We present an automated workflow that can cut down time and costs needed for sensor verification.
- Collaborative effort between Autoliv and MathWorks.