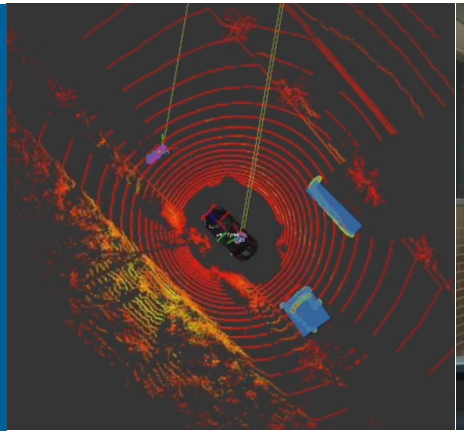
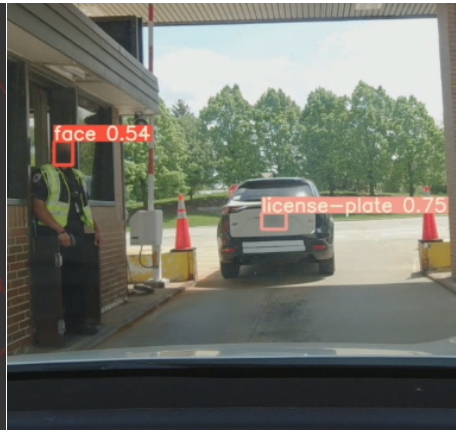
LEARNING OFF THE LAWN

Argonne NATIONAL LABORATORY

DEVELOPING A MOBILE DATA ACQUISITION PLATFORM FOR AUTOMATED VEHICLES WITH AUTOWARE





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MOTIVATION

Mobile DAQ

- Connected and automated vehicles (CAVs) have become increasingly popular
- Energy impact of CAVs needs to be evaluated in real-world, on-road scenarios
- To do this we need to collect environmental data while operating these vehicles

2020 Tesla Model 3
with Autopilot

2019 Cadillac CT6
with Super Cruise

MOBILE DAQ

Hardware

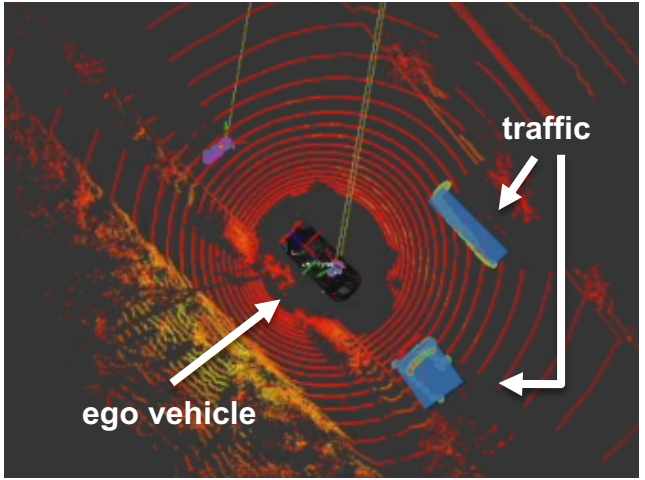
- Perception kit mounted on top of vehicle
  - Cameras
    - FLIR Blackfly
    - GoPro 360
  - Lidar
    - Velodyne VLP 32C
- Record raw image and point cloud data to be processed in real-time

Cadillac CT6 with roof rack for sensor mounting

AUTOWARE

Traffic Detection

- Autoware: open-source autonomous driving software built on ROS
- Prototyped Autoware system to record traffic activity surrounding ego vehicle
  - Perception
    - Lidar data
      - Cluster class-agnostic object detection
      - Object shape estimation and tracking
    - Camera data
      - YOLOv3 vehicle object detection
    - Merged to place vehicles in 3D map



Lidar data shown in red and object bounding boxes displayed in blue

AUTOWARE

Data Recording

- Prototyped Autoware system to record traffic activity surrounding ego vehicle
  - Write data to CSV file in real-time during driving
    - Avoids large data files
    - Human readable
  - Needs verification and accuracy measurement

Time (secs)	ID	Position x	Position y	Position z	Orientation x	Orientation y	Orientation z	Orientation w	Dimension x	Dimension y	Dimension z	Variance x
1427157794.48	20	-1.044251	0.013561	-0.57178	0	0	0.207912	0.978148	0.44728	1.178589	0.427584	0
1427157794.48	21	-7.687272	0.117432	-0.55582	0	0	0.642788	0.766044	2.245484	2.705877	1.597653	0
1427157794.48	33	7.156793	-0.29261	-0.84064	0	0	0.622515	0.782608	1.384883	0.428781	0.850952	0
1427157794.48	37	-3.920772	-4.63531	-0.95027	-0.026759	-0.014401	0.997757	0.059639	4.532834	1.753307	0.592813	0
1427157794.58	20	-0.890976	-0.02507	-0.5354	0	0	0.67559	0.737277	1.057964	0.439395	0.377269	0
1427157794.58	21	-7.676481	0.117356	-0.54343	0	0	0.642788	0.766044	2.2222	2.680096	1.599237	0
1427157794.58	33	7.176007	-0.30424	-0.71406	0	0	0.580703	0.814116	1.341551	0.435246	0.689603	0
1427157794.58	37	-5.005026	-4.46092	-0.64115	-0.026491	-0.014663	0.997171	0.0688	4.432573	1.461801	0.896688	0
1427157794.68	20	-1.046431	-0.00668	-0.56968	0	0	0.199368	0.979925	0.461087	1.137473	0.3849	0
1427157794.68	21	-7.698796	0.115025	-0.53233	0	0	0.642788	0.766044	2.25009	2.728679	1.597658	0

ANONYMIZATION

Requirements

- Built traffic anonymizer to blur faces and license plates from recorded video
  - Necessary to comply with human subject research guidelines
  - Video types:
    - FLIR Blackfly
    - GoPro 360

Anonymized traffic data with classification labels

ANONYMIZATION

Object Detection

- Trained YOLOv5[1] object detection neural network
  - Datasets:
    - Faces:
      - WIDER FACE [2]
      - Pre-labeled: 32,203 images with 393,703 labels
    - License plates:
      - Berkeley DeepDrive (BDD100k) [3]
      - Hand-labeled: 2,004 images with 4,530 labels
- Wrote post-process script to blur faces/plates, scale output image, change output fps, and split 360 video

Inference size	640 pixels
Precision	0.862
Recall	0.802
mAP@.5	0.817
mAP@.5:.95	0.46
Inference speed	8.0 ms
Epochs trained	138 epochs

Trained YOLOv5m model details and performance on validation dataset (using Tesla P100 GPU)

ANONYMIZATION

Equirectangular projection of 360 video. Split and anonymized

IMMEDIATE NEXT STEPS

- Autoware:
  - Record more on-road data for testing with Autoware
  - Vehicle detection using only lidar data
    - VoxelNet [4]
- Anonymization:
  - Train model with larger input resolution
  - Setup local machine to run anonymization immediately after on-road recording

FUTURE DIRECTIONS

- Record 1,000 miles of traffic data
- Use recorded data to study traffic flow around automated vehicles

- Create digital twin of on-road experience to study vehicle behavior with simulation
  - Useful on chassis dynamometer and closed track

- Incorporate infrastructure-based components to mobile DAQ using CARMA platform

REFERENCES

- [1] Jocher, G., (2021). ultralytics/yolov5
- [2] Yang, S., Luo, P., Loy, C., & Tang, X. (2016). WIDER FACE: A Face Detection Benchmark. In *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*.
- [3] Yu, F., Chen, H., Wang, X., Xian, W., Chen, Y., Liu, F., Madhavan, V., & Darrell, T. (2020). BDD100K: A Diverse Driving Dataset for Heterogeneous Multitask Learning. In *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*.
- [4] Yin Zhou, & Oncel Tuzel. (2017). VoxelNet: End-to-End Learning for Point Cloud Based 3D Object Detection.

THANKS!
QUESTIONS?