Perception for Autonomous Driving

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SWCS2020

Perception? Autonomous Driving?

Autonmous Systems

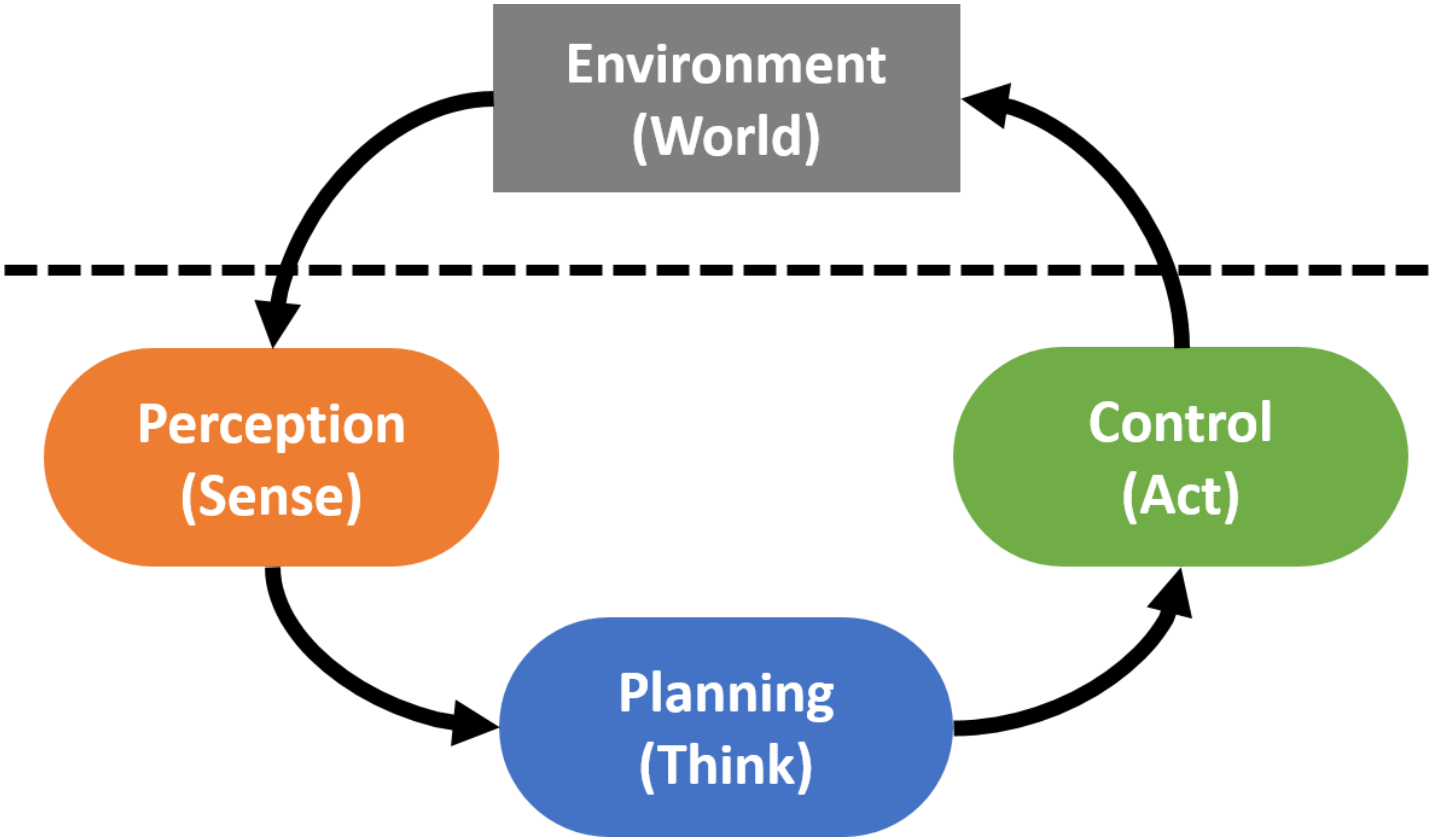
Boston Dynamics - Spot

DJI - Phantom 4

Waymo Self-Driving Car

Naverlabs - M1

Three Blocks of Autonomous Systems

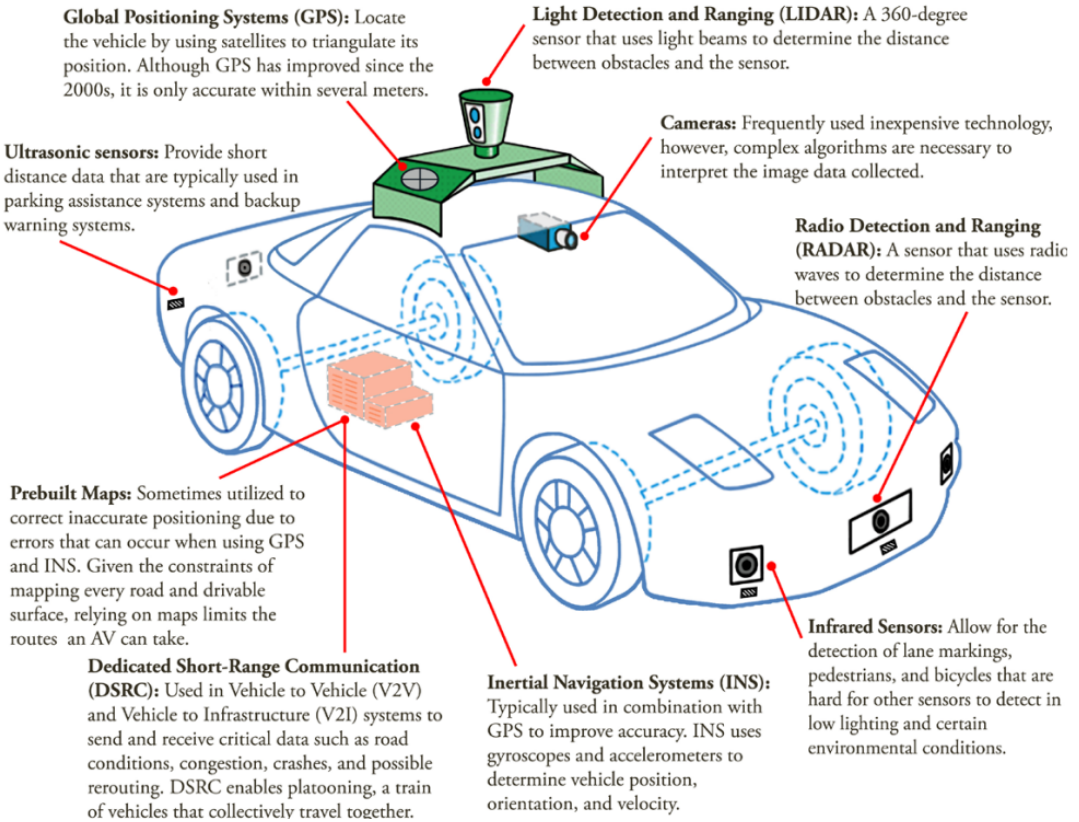


Three Blocks of Autonmous Systems

```
void main()
{
    // Initialization
    setup();

    // Infinite loop
    while(true)
    {
        // Step 1: perception
        sense();

        // Step 2: planning
        think();

        // Step 3: control
        act();
    }

    // Finalization
    shutdown();
}
```

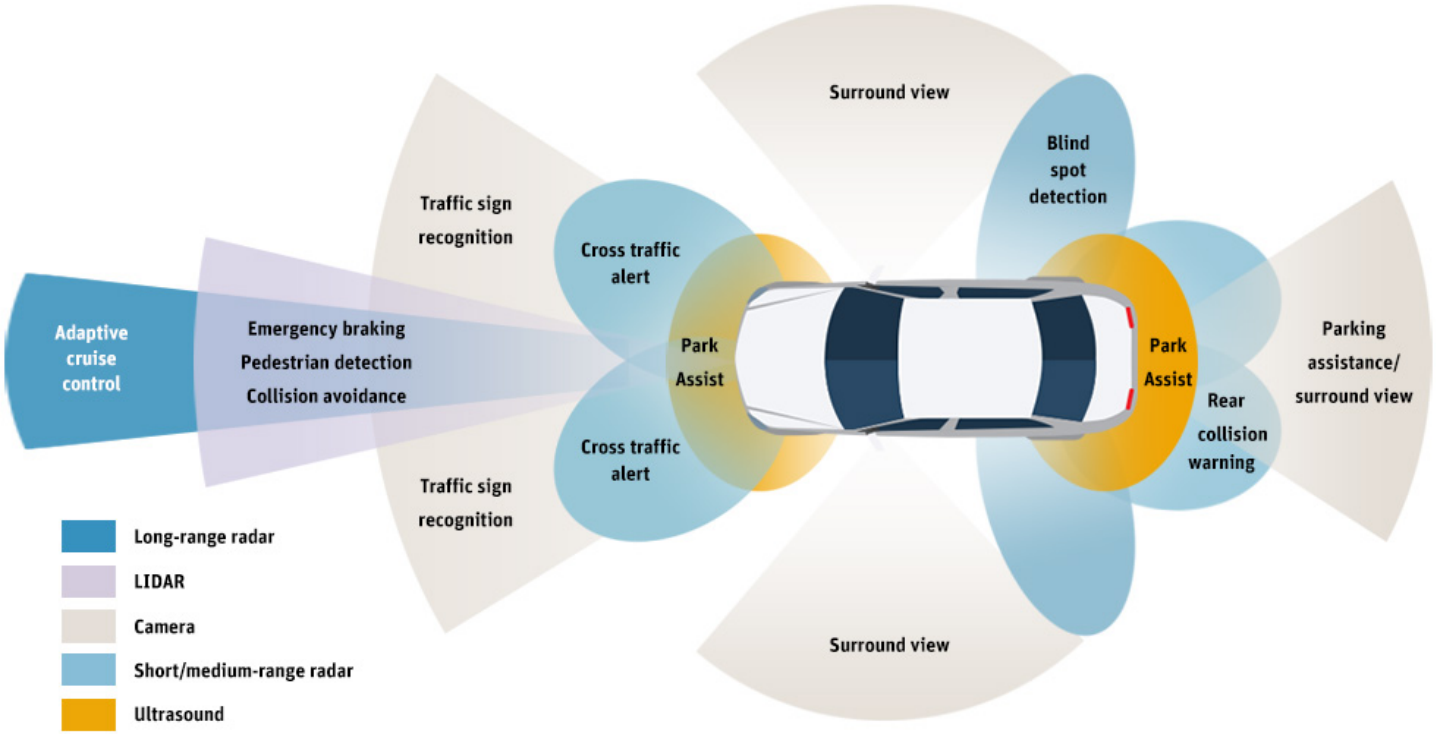
Sensors!

Sensors for Self-Driving Cars



Autonomous Vehicles, Factsheets - Center for Sustainable Systems, University of Michigan

Sensors for Self-Driving Cars



https://www.ansys.com/about-ansys/advantage-magazine/volume-xii-issue-1-2018/autonomous-vehicle-radar

GNSS and IMU

Global Navigation Satellite System

NovAtel - GPS-704-X[1]

[+] Global position, all weather

[-] Issues in downtown

Inertial Measurement Unit

Xsens - MTi-100[1]

[+] Egomotion, cheap, all weather

[-] Very noisy, bias

1. https://novatel.com/products/antennas/high-performance-gnss-gps-antennas/gps-704-x
2. https://www.xsens.com/products/mti-100-series

Other Sensors

- Odometry sensors
- Ultrasonic sensors
- Thermal cameras
- Solid-State LIDAR

Perception for Autonomous Driving!

Perception for Autonomous Driving

1. Localization
2. Detection
3. Tracking
4. Estimation
5. Prediction

1. Localization

2. Detection

3. Tracking

4. Estimation

5. Prediction

Summary

Perception for Autonomous Driving

- Three Blocks
  1. Perception
  2. Planning
  3. Control
- Sensors
  1. LIDAR
  2. RADAR
  3. Camera
  4. GNSS, IMU
  5. Sensor Fusion
- Perception
  1. Localization: HD Maps
  2. Detection: objects
  3. Tracking: feature/object
  4. Estimation: depth
  5. Prediction: object trajectories

Thanks!

https://github.com/soohwank/SWCS2020/

LIDAR (LIght Detection And Ranging)

Velodyne Lidar - Alpha Prime[1]

Velodyne Lidar - Alpha Prime[2]

Pros

- Generates point clouds
- Accurate point positions
- Works well even at night

Cons

- Very expensive
- Sparse points
- Issues in fog, rain and snow

1. https://velodynelidar.com/products/alpha-prime/
2. https://www.youtube.com/watch?v=tZ8WbSNsNaU

RADAR (RAdio Detection And Ranging)

Aptive - ESR 2.5[1]

Texas Insrument - AWR1642[2]

Pros

- Long operating distance
- Effective for relative speeds
- Works in fog, rain, snow, night

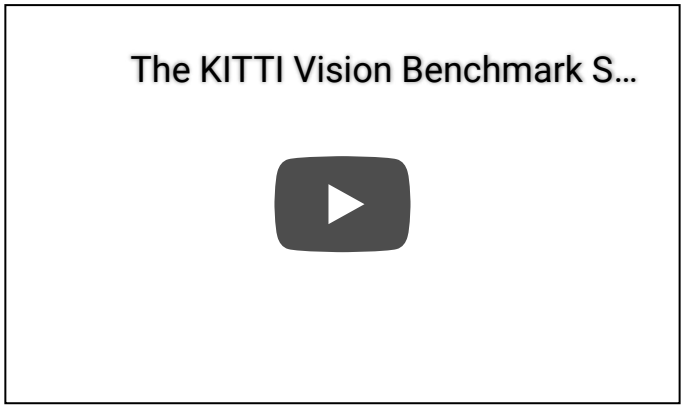
Cons

- Low resolution
- Very sparse
- Noisy and less accurate

1. https://autonomoustuff.com/product/aptiv-esr-2-5-24v/
2. https://www.youtube.com/watch?v=ziQjbVXcSts

Camera

Continental - SVC210[1]



KITTI Vision Dataset[2]

Pros

- Rich texture information
- Very affordable

Cons

- No depth information
- Issues in sun glare and shadow

1. https://www.continental-automotive.com/en-gl/2-Wheeler/Safe-Mobility/Sensors/Surround-View-Camera-SVC210
2. https://www.youtube.com/watch?v=KXpZ6B1YB_k

LIDAR vs. Camera

Velodyne Lidar - Lidar vs Camera Comparison[1]

Google vs. Tesla?

1. https://www.youtube.com/watch?v=y3Q7v5a0lnI

LIDAR vs. Camera

Waymo Self-Driving Car[1]

We Need Sensor Fusion!

1. https://www.youtube.com/watch?v=B8R148hFxPw

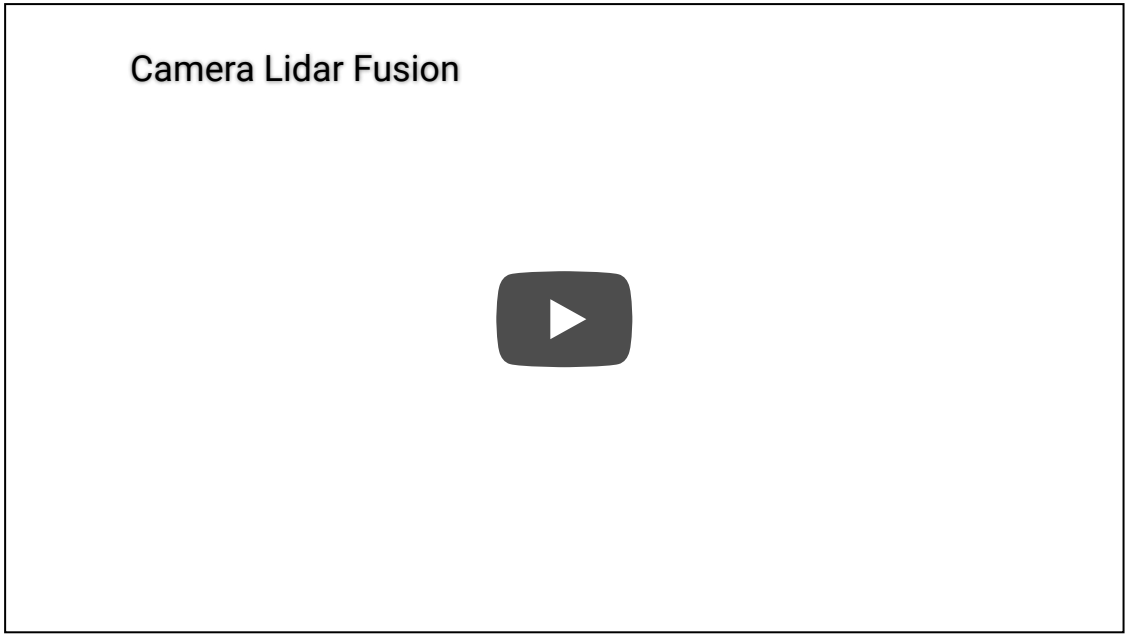
Camera-RADAR Sensor Fusion

NVIDIA (6 Cameras and 8 RADARs) [1,2]

Detection + Position, Velocity and Acceleration

1. https://www.youtube.com/watch?v=cMlGyIJH5L8
2. https://developer.nvidia.com/blog/autonomous-vehicle-radar-perception-in-360-degrees/

LIDAR-Camera Sensor Fusion



LIDAR-CAMERA Fusion [1]

1. https://www.youtube.com/watch?v=XzLE-RW9wv8

HD Maps

TomTom - HD Maps[1]

- SLAM using sesor fusion (LIDAR, camera, RADAR, GNSS, IMU, odometry)
- Lanes, center lines, road boundaries, intersections
- Traffic signs, traffic lights, poles, road markings

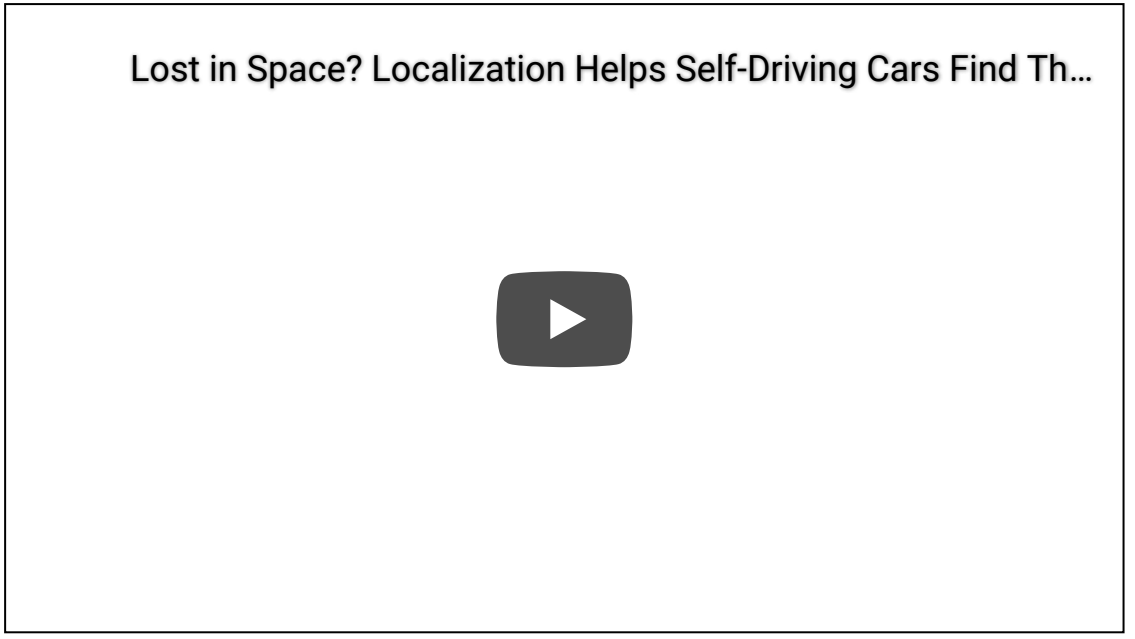
1. https://www.youtube.com/watch?v=ga5fW-QSXp0

GNSS+INS vs. HD-map Based Localization

Naver Labs - HD Map Based Localization[1]

1. https://www.youtube.com/watch?v=PIf5fh2-3z4
2. https://www.youtube.com/watch?v=s0GK2EBpGZ8

Localization using Cameras

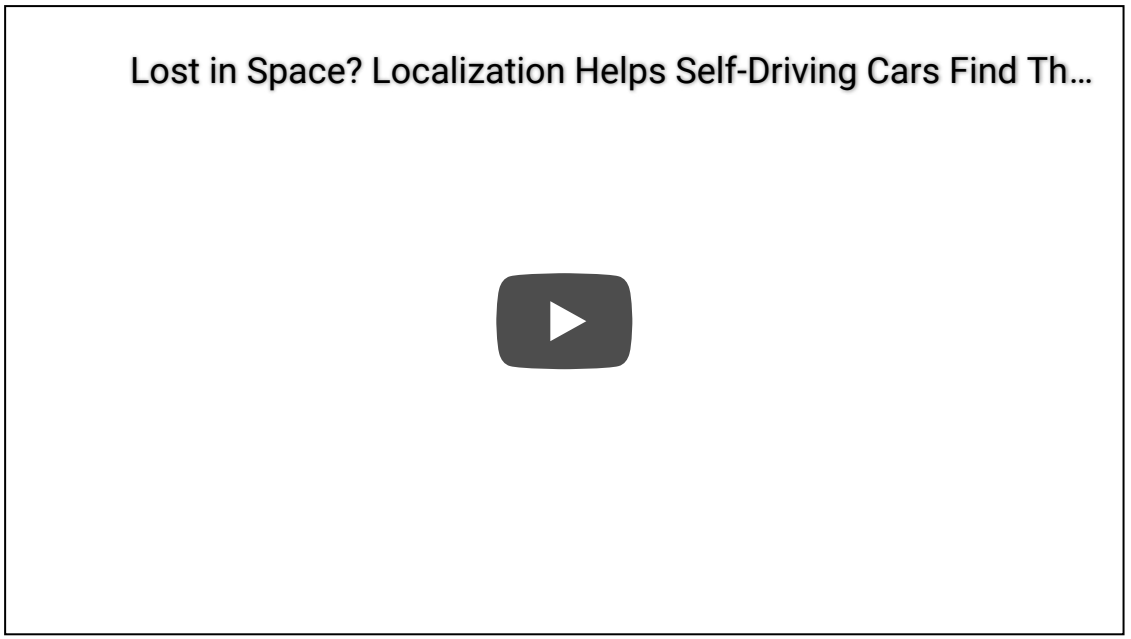


NVIDIA using cameras[1]

- Ego lane lines, center of ego lane, road boundaries
- Intersection lines, poles, traffic signs, traffic lights

1. https://www.youtube.com/watch?v=jcKnb65wpWA
2. https://www.youtube.com/watch?v=5IydCAYB5N0&t=20s

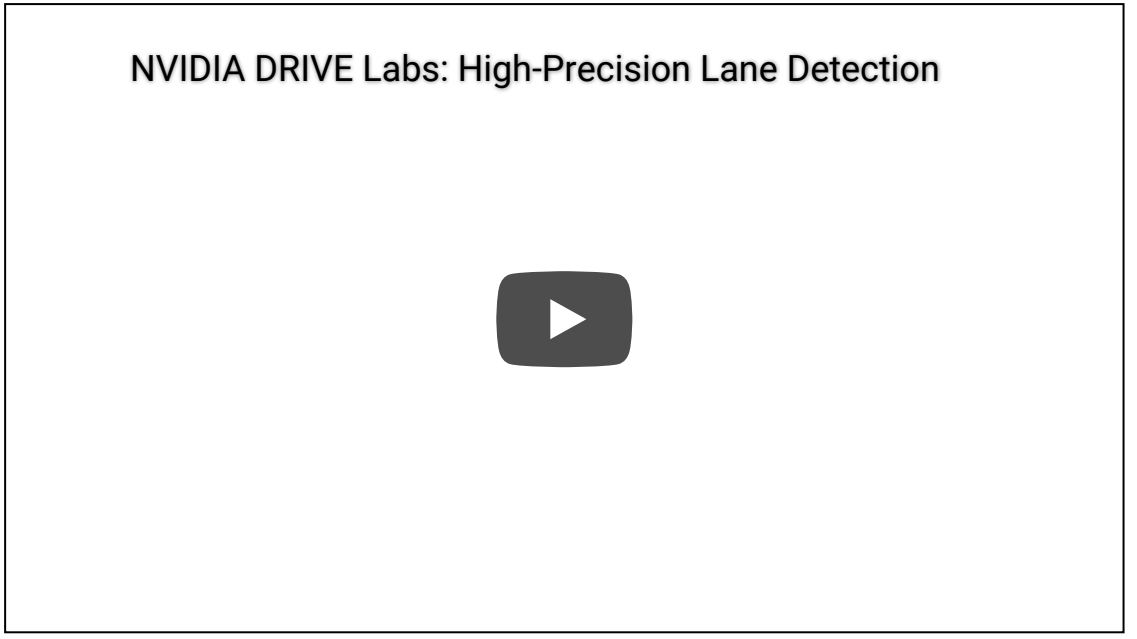
Localization using Sensor Fusion



NVIDIA - Localization using camera, lidar, and radar layers[1]

1. https://www.youtube.com/watch?v=jcKnb65wpWA

Lane Detection

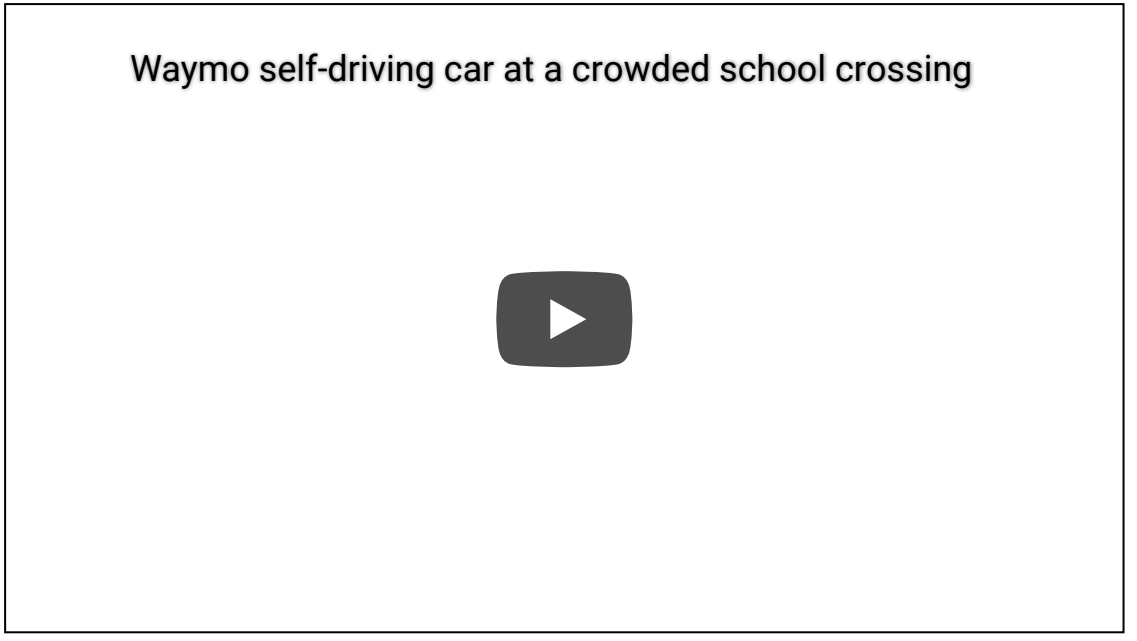


NVIDIA - LaneNet[1]

- Solid lane lines, dashed lane lines

1. https://www.youtube.com/watch?v=IzvlqCEYjg4

Object Detection

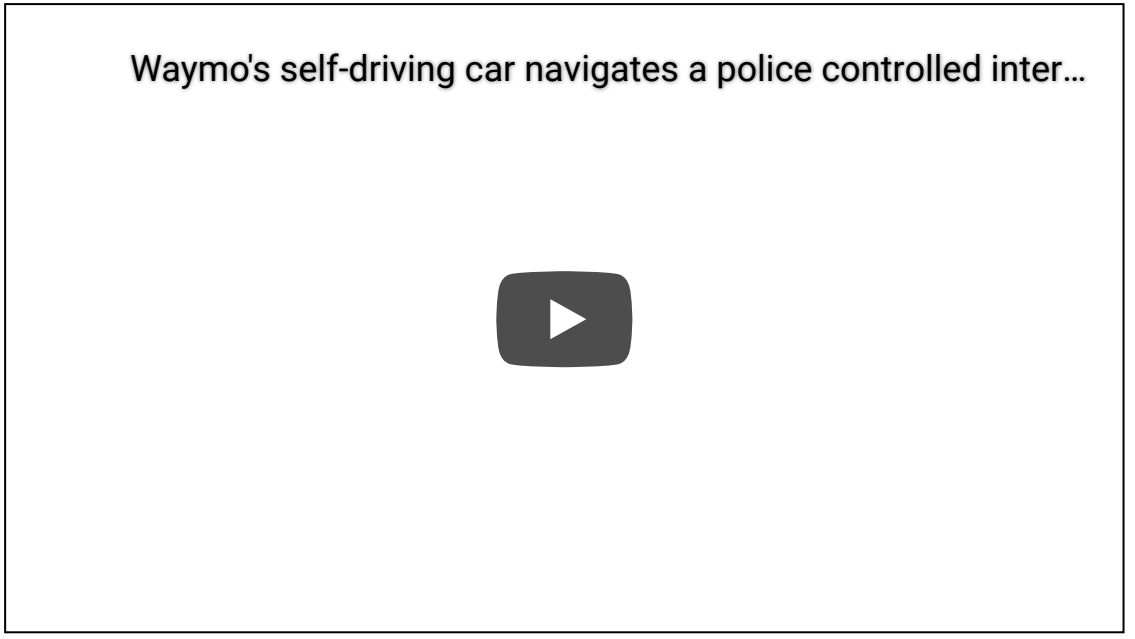


Waymo Self-driving Car at a Crowded School Crossing[1]

- Cars (back), cars (front)
- Pedestrians
- Traffic signs

1. https://www.youtube.com/watch?v=Vu8gmFhiGko

Object Detection



Waymo Self-driving Car Navigates a Police Controlled Intersection[1]

- Cars
- Pedestrians
- Traffic cones, intersections

1. https://www.youtube.com/watch?v=Vu8gmFhiGko

Map Feature Detection

NVIDIA - MapNet[1]

- Lanes: Road boundaries, dashed lines, solid lines
- Intersections: Intersections, cross-traffic intersections
- Others: Poles, road markings

1. https://www.youtube.com/watch?v=dl8MI4vZmUY

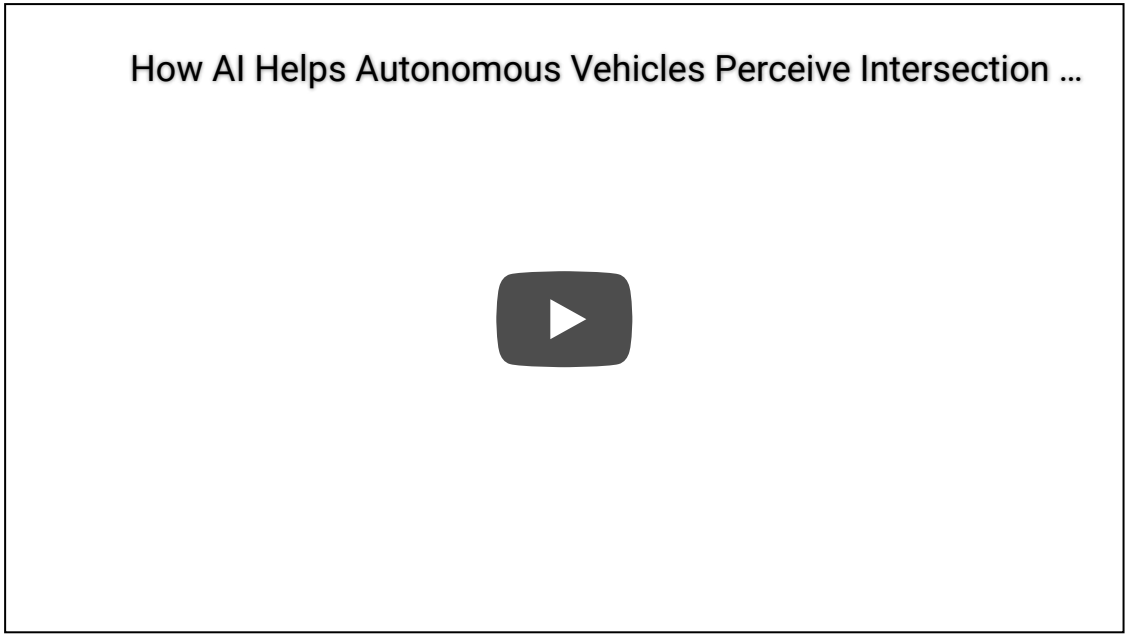
Traffic Sign and Traffic Light Detection

NVIDIA - WaitNet, LightNet, SignNet[1]

- WaitNet: intersections
- SignNet: traffic signs
- LightNet: red light, green light

1. https://www.youtube.com/watch?v=Uz5mIdRtdeA

Intersection Detection



NVIDIA - Intersection Detection[1]

Where to stop and exit?

1. https://www.youtube.com/watch?v=KPLTA4S_3Yo

Parking Space Detection

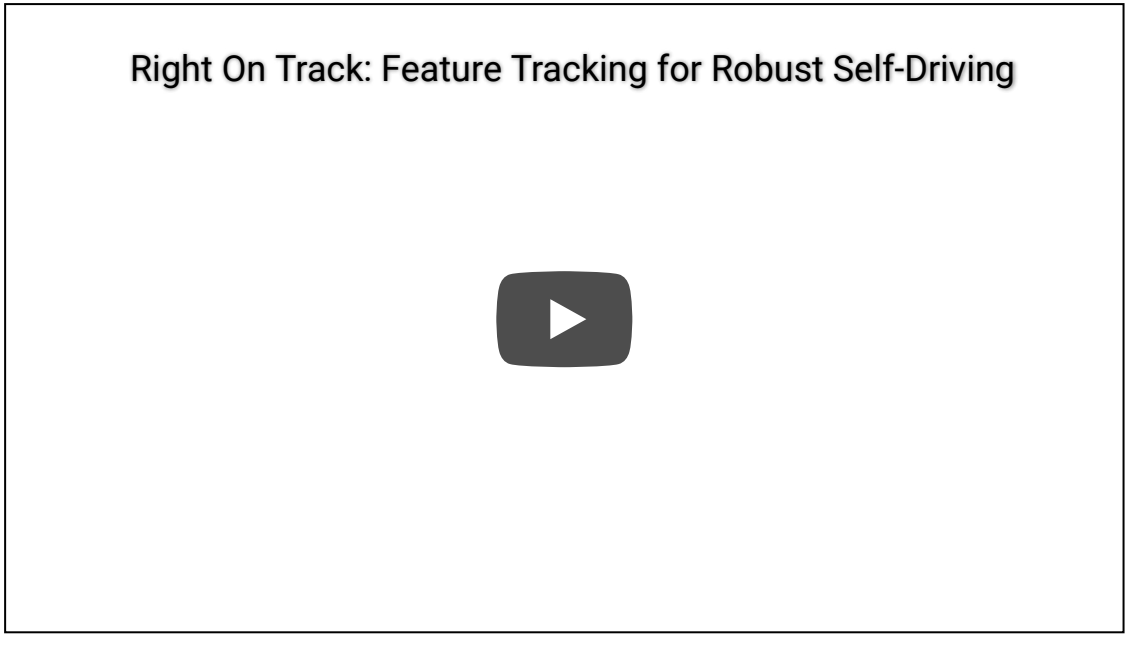
NVIDIA - ParkNet[1]

Where to park? How to enter?

- Parking lines, entry lines

1. https://www.youtube.com/watch?v=Bzfmc-PDwtM

Feature Tracking



NVIDIA - Feature Tracking[1]

- Tracked features: features, feature track histories
- Detected Objects: moving away, getting closer, urgent

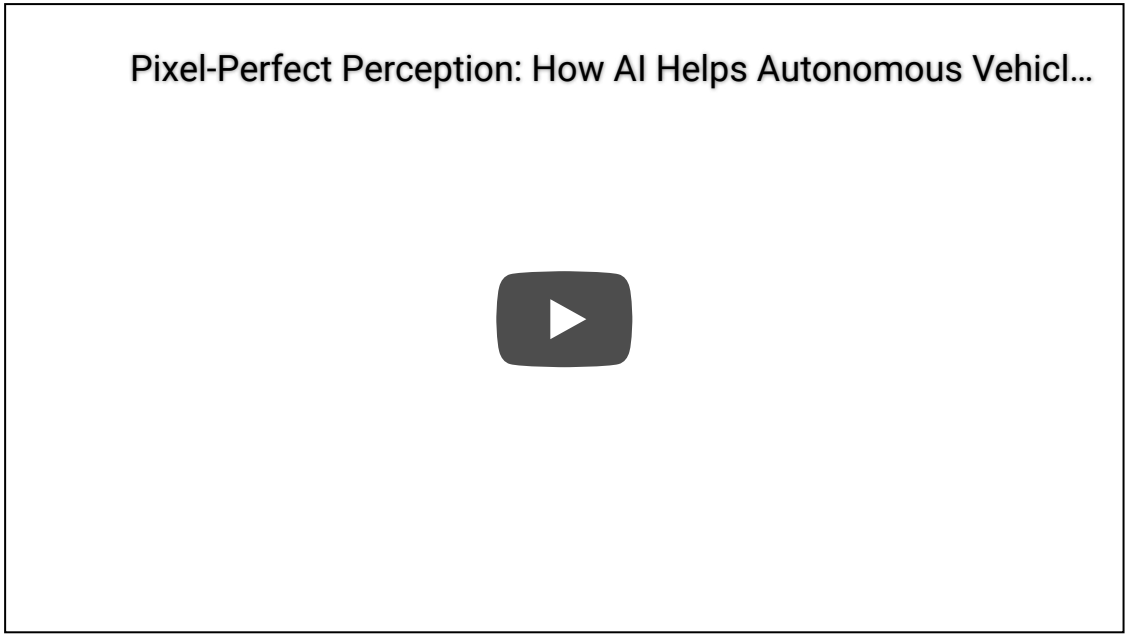
1. https://www.youtube.com/watch?v=y2X_7KwppoI

Object Tracking

NVIDIA -Surround Camera Object Tracking[1]

1. https://www.youtube.com/watch?v=aQwqD5cB2ck

Pixel-level Object Detection and Tracking

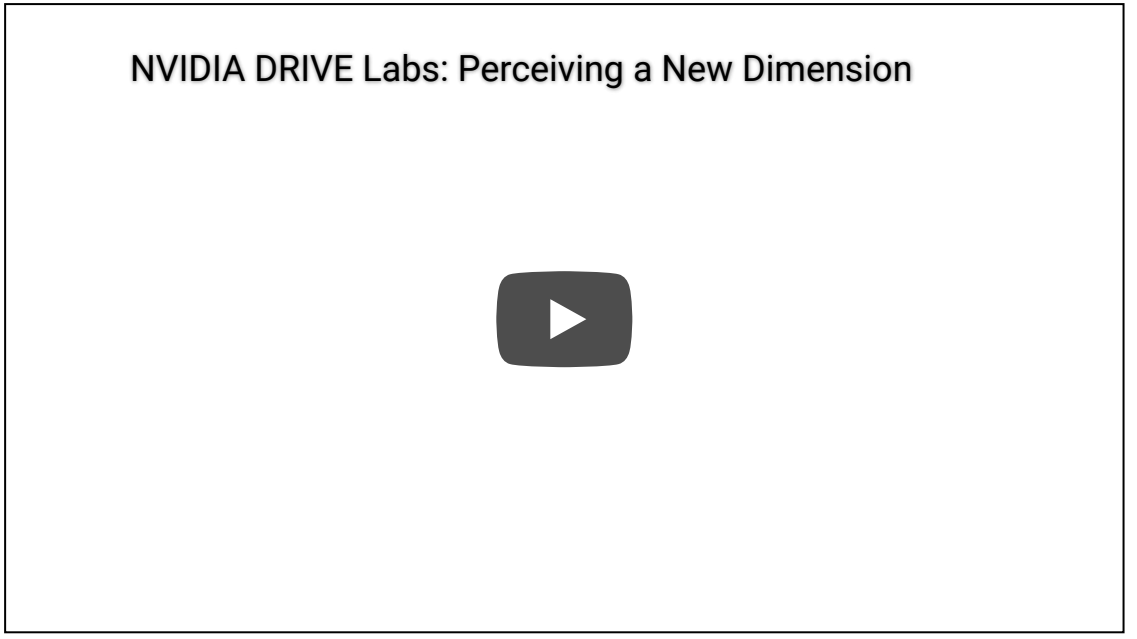


NVIDIA - Pixel-Perfect Perception[1]

- Detection (top): Cars, Pedestrians, Drivable space
- Tracking (bottom): object id (unique numbers and colors)

1. https://www.youtube.com/watch?v=HS1wV9NMLr8

Depth Estimation from Single Camera



NVIDIA - Depth Estimation from Single Camera[1]

- Cars
- Pedestrians

1. https://www.youtube.com/watch?v=ftsUg5VlzIE

Car Trajectories

NVIDIA - Predicting moving objects using camera and radar[1]

1. https://www.youtube.com/watch?v=NG_O4RyQqGE

Pedestrian Trajectories

Waymo Self-driving Car Allowing Cyclists to Pass[1]

1. https://www.youtube.com/watch?v=NG_O4RyQqGE