Autonomous Driving: Overview

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Autonomous Driving

- Autonomous vehicle: a motor vehicle that uses artificial intelligence, sensors and global positioning system coordinates to drive itself without the active intervention of a human operator
- Focus of enormous investment [80+ bn USD as of 2017]

Tesla

Waymo

Nutonomy

Autonomous Driving: Motivation

- Cars are ubiquitous
  - ~ 1 bn vehicles for a global population of ~7 bn [est. 2010]
- Car accidents can result in catastrophic costs [NHTSA study 2010]
  - 94% serious crashes are due to human error
  - 594 bn USD due to loss/decrease in life quality
  - 242 bn USD in economic activity
- Health costs
    - 33k fatalities, 2 million+ injuries in 5.4 million crashes in U.S. [2010]
    - Premature deaths due to pollution inhalation

Autonomous Driving: Levels of Autonomy

- 0: Standard Car
- 1: Assist in some part of driving
  - Cruise control
- 2: Perform some part of driving
  - Adaptive CC + lane keeping
- 3: Self-driving under ideal conditions
  - Human must remain fully aware
- 4: Self-driving under near-ideal conditions
  - Human need not remain constantly aware
- 5: Outperforms human in all circumstances

Autonomous Driving

- Urban driving is particularly challenging

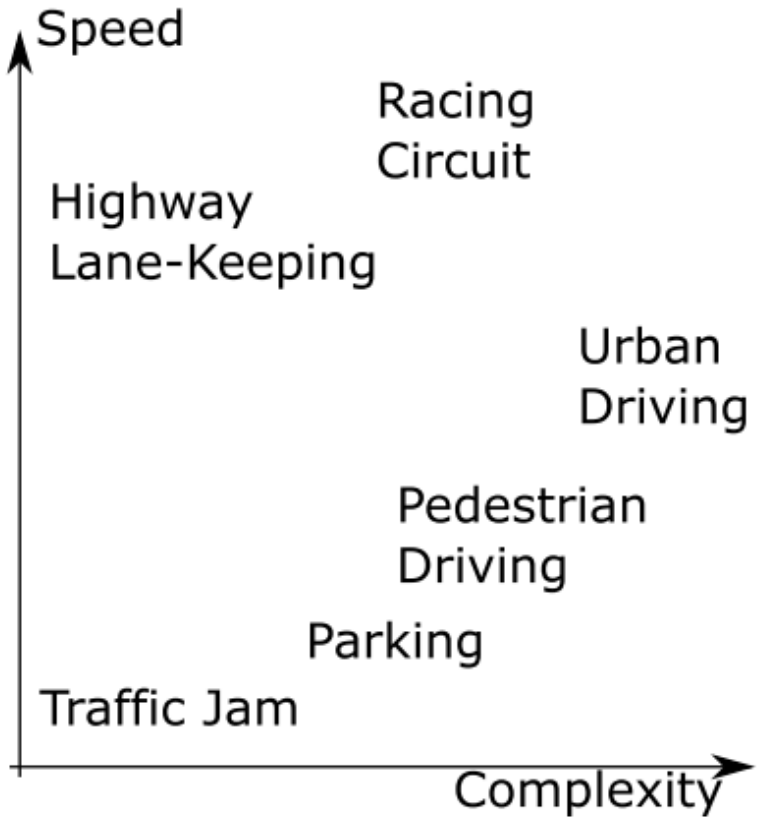


Figure 1. Complexity and operating velocity for various driving scenarios.

Structure

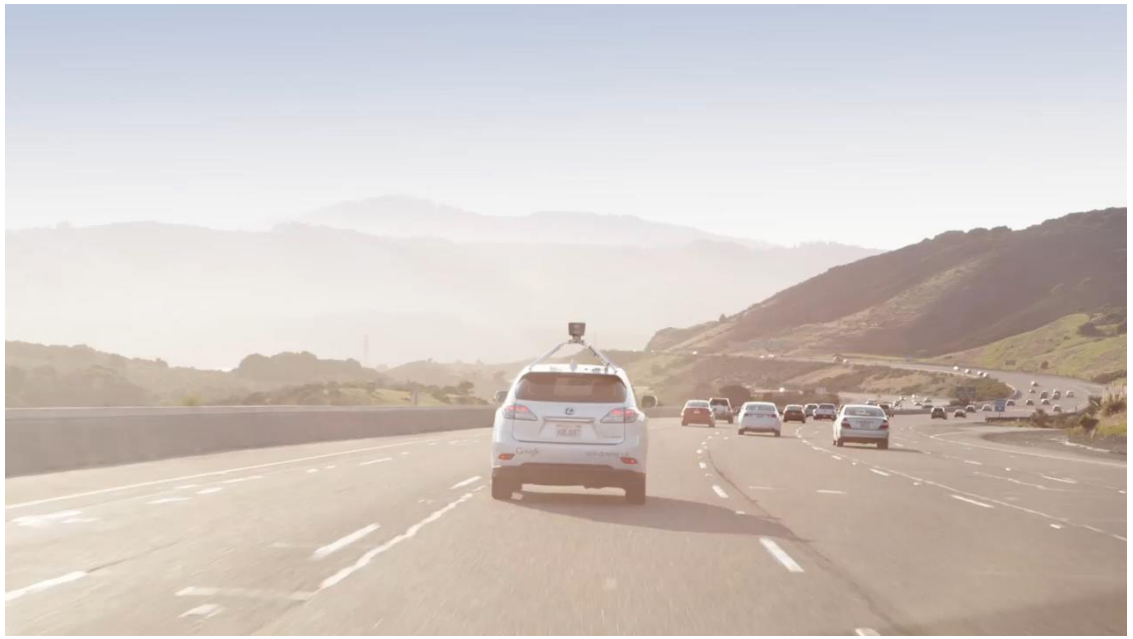
- History of Autonomous Driving
- Main Components
- Other Approaches
- Other Issues

Autonomous Driving: 1980's - 2010

- 1980's
  - Ernst Dickmann's VaMoRs
  - CMU NavLab
- 1990's
  - PROMETHEUS project: VaMP car
- 2000's
  - DARPA Grand Challenge 2004: 150 mile offroad coarse
  - DARPA Grand Challenge 2005: 132 mile offroad coarse
  - DARPA Grand Challenge 2007: 60 miles urban driving

Autonomous Driving: State of the Art Today

- Mercedes Benz – historic Bertha route in Germany
- Tesla Autopilot System
- Google's self-driving car (WayMo)



Structure

- History of Autonomous Driving
- Main Components
  - Perception
  - Planning
  - Control
- Other Approaches
- Other Issues

Autonomous Driving: Main Components

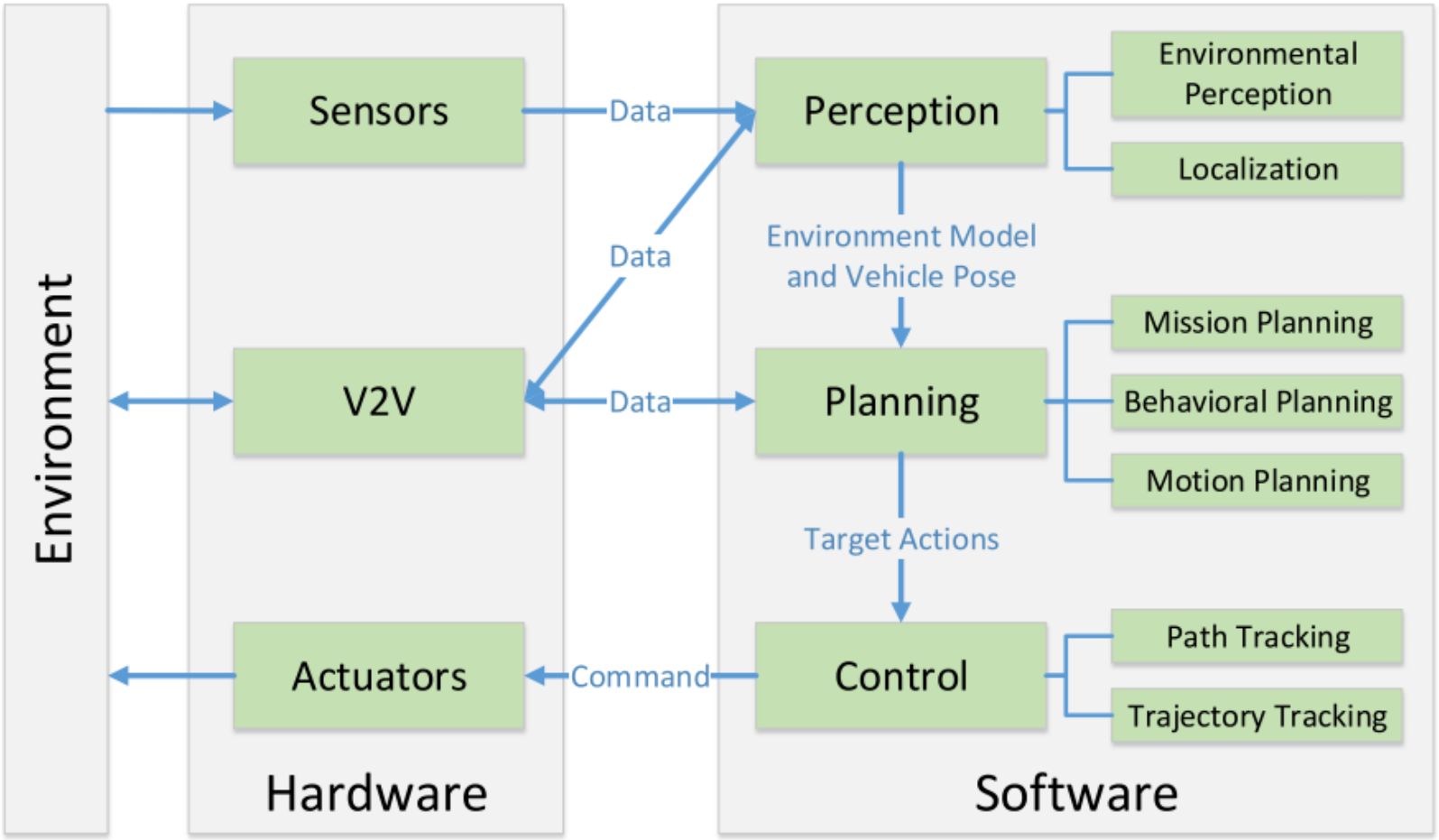
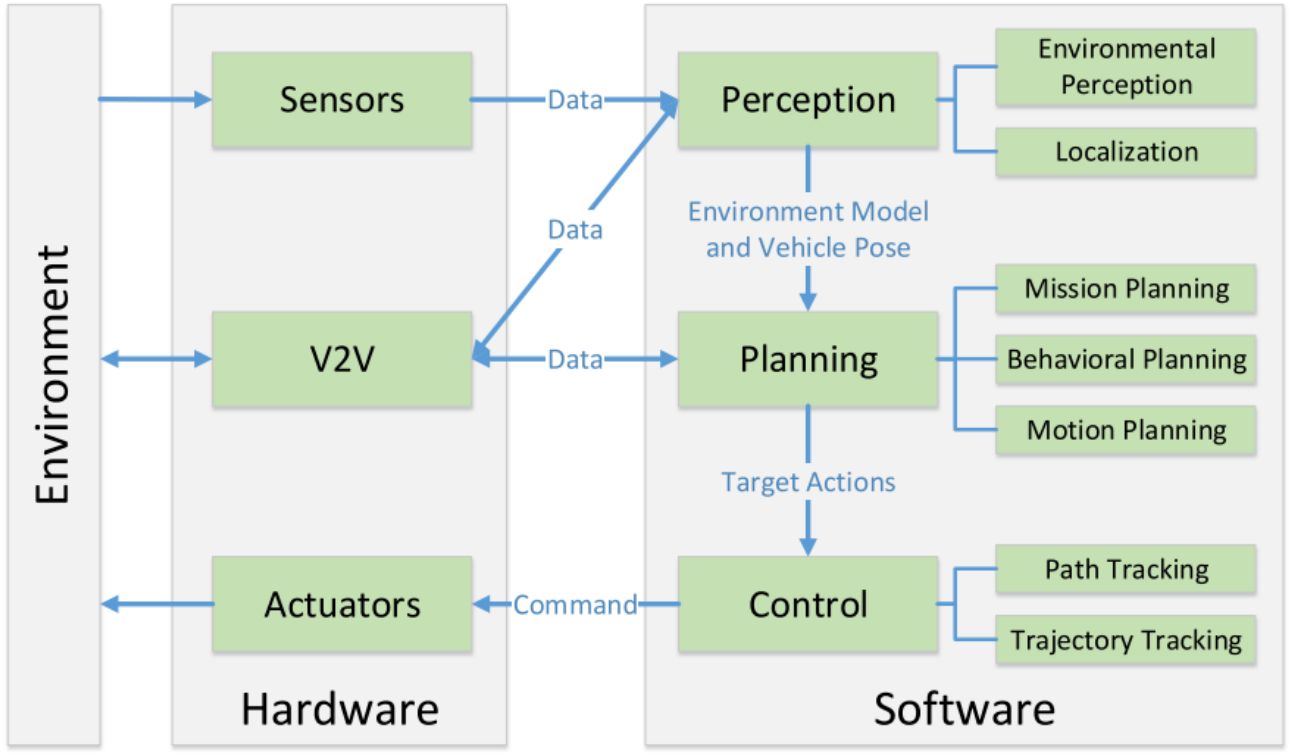


Figure 2. A typical autonomous vehicle system overview, highlighting core competencies.

Autonomous Driving: Main Components

- Perception
  - collect information and extract relevant knowledge from the environment.



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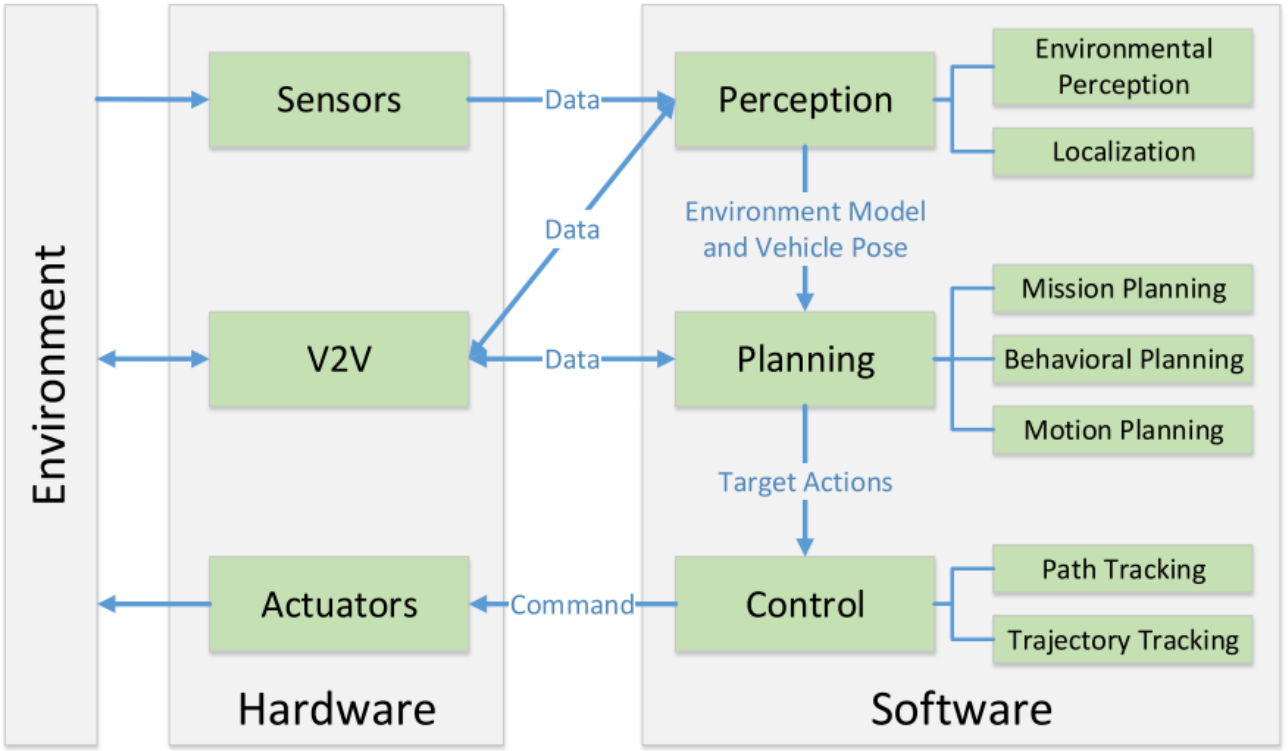
Autonomous Driving: Main Components

- Planning
  - Making purposeful decisions in order to achieve the robot's higher order goals



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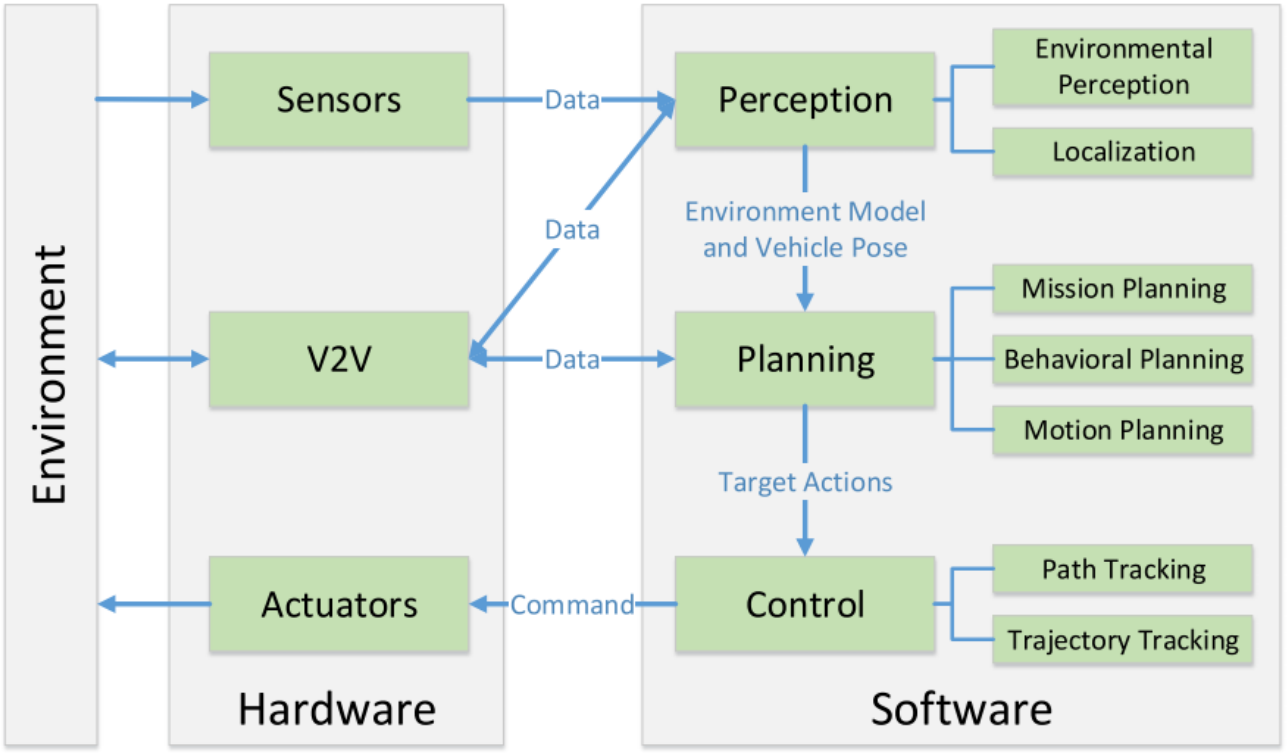
Autonomous Driving: Main Components

- Control
  - ⑩ Executing planned actions



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Structure

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  - Planning
  - Control
- Other Approaches
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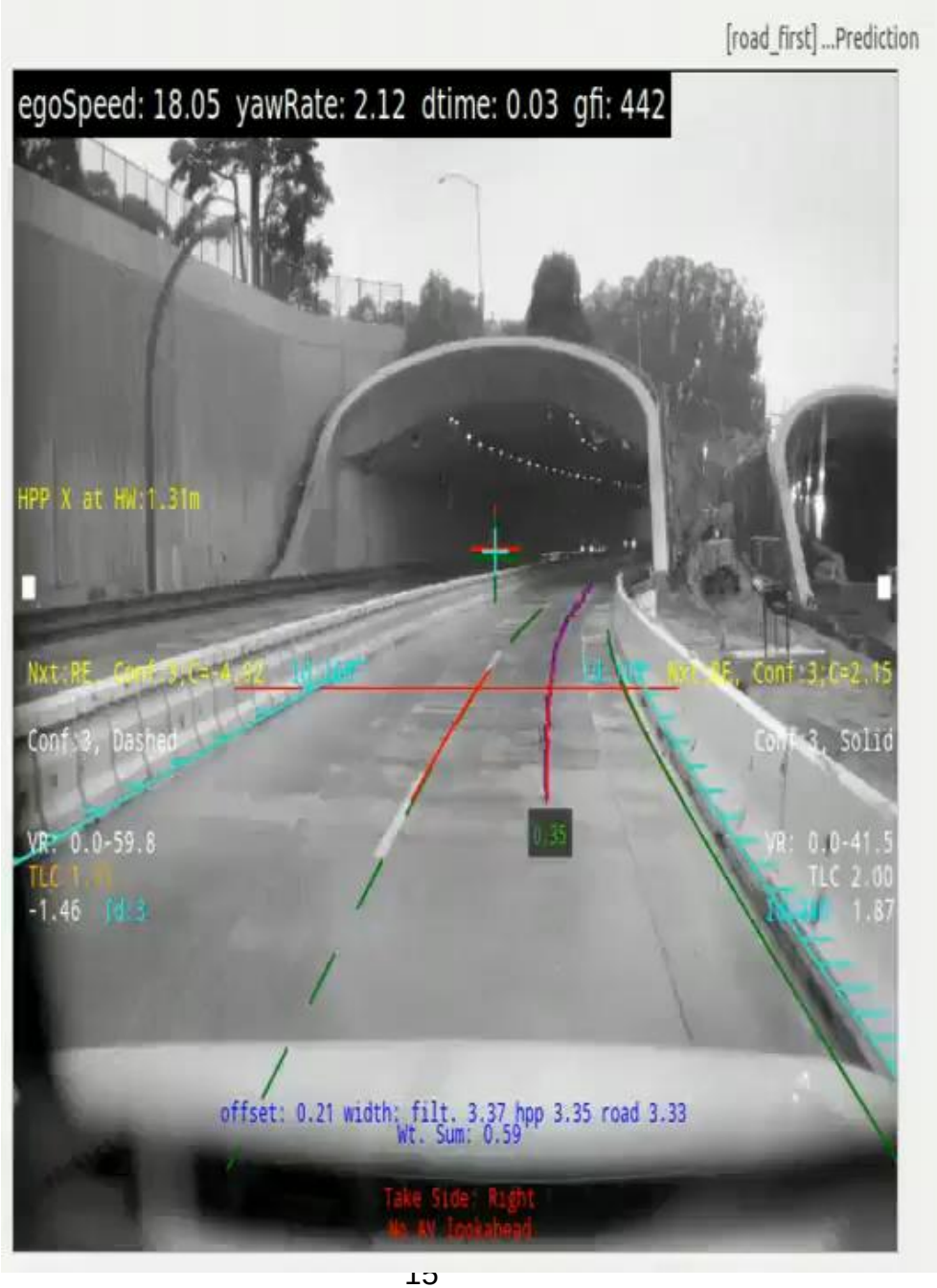
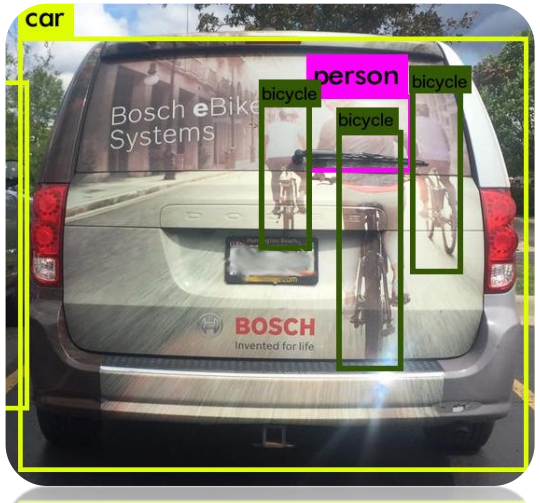
Autonomous Driving: Perception

- Sensing Challenges
  - Sensor Uncertainty
  - Sensor Configuration
  - Weather / Environment



Autonomous Driving: Challenges in Perception

- Sensor Misclassification
  - "When is a cyclist not a cyclist?"
  - When is a sign a stop sign?
  - Whether a semi or a cloud?

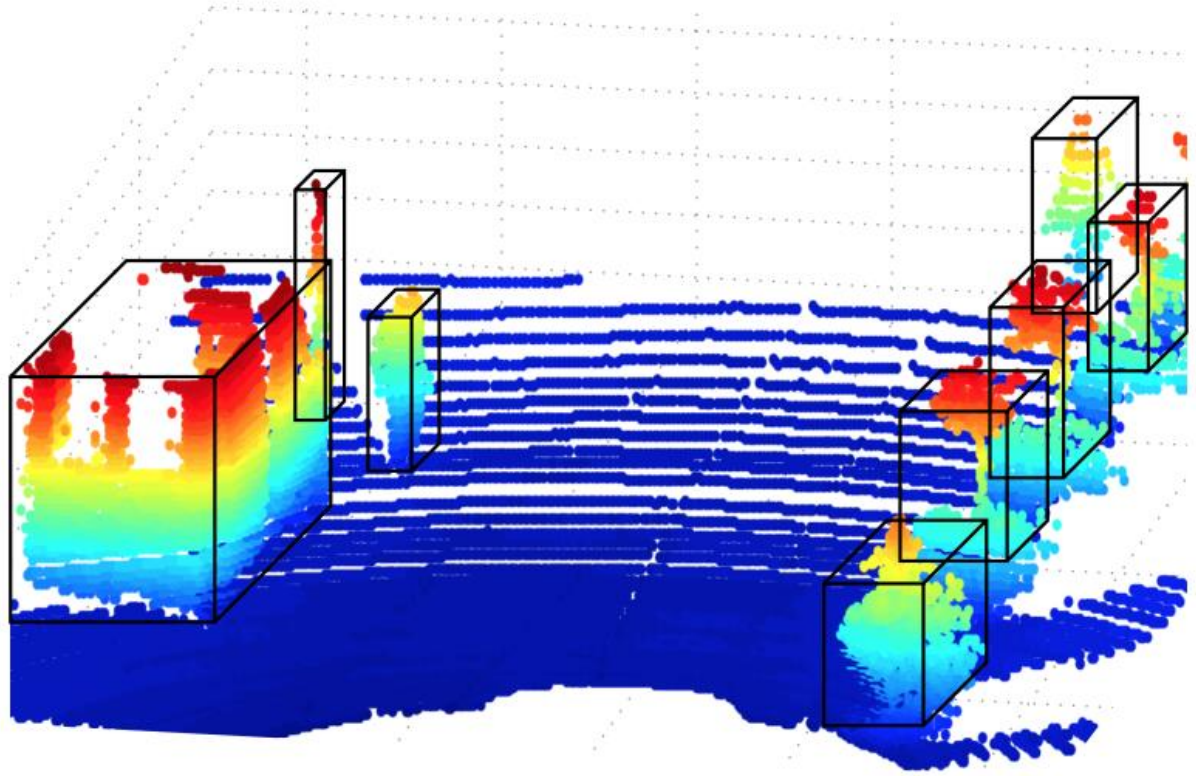


Autonomous Driving: Perception

- Environmental Perception
  - LIDAR
  - Cameras
  - Other approaches
    - RADAR, Ultrasonic sensors
  - Fusion

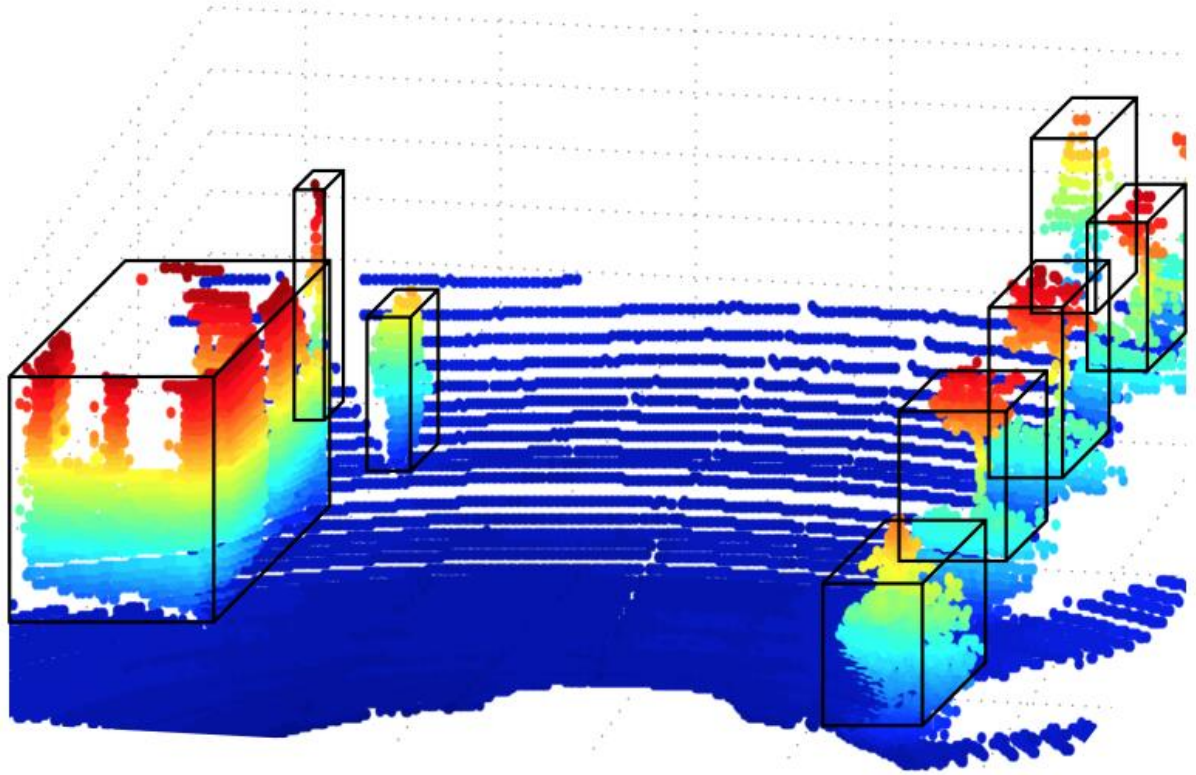
Autonomous Driving: Perception using LIDAR

- Light Detection and Ranging
  - ❿ Illuminate target using pulsed laser lights, and measure reflected pulses using a sensor



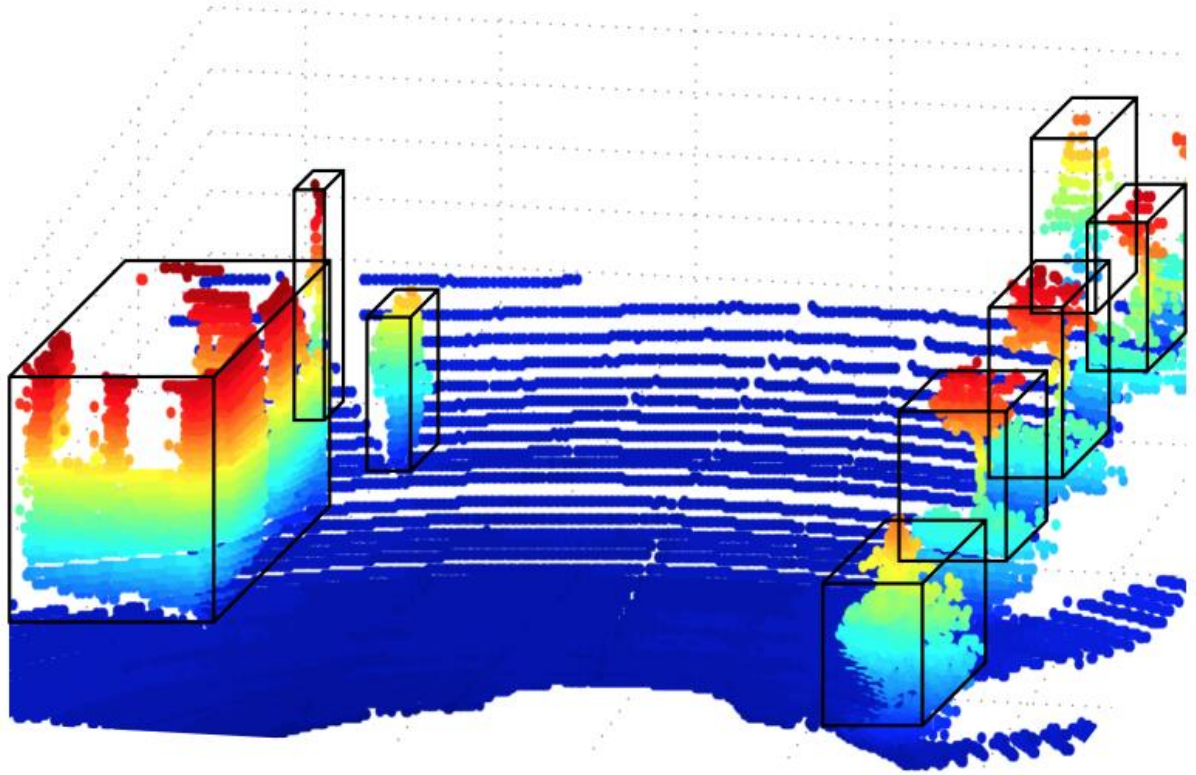
Autonomous Driving: Perception using LIDAR

- LIDAR Challenges
  - Scanning sparsity
  - Missing points
  - Unorganized patterns
  - Knowledge gathering can be difficult



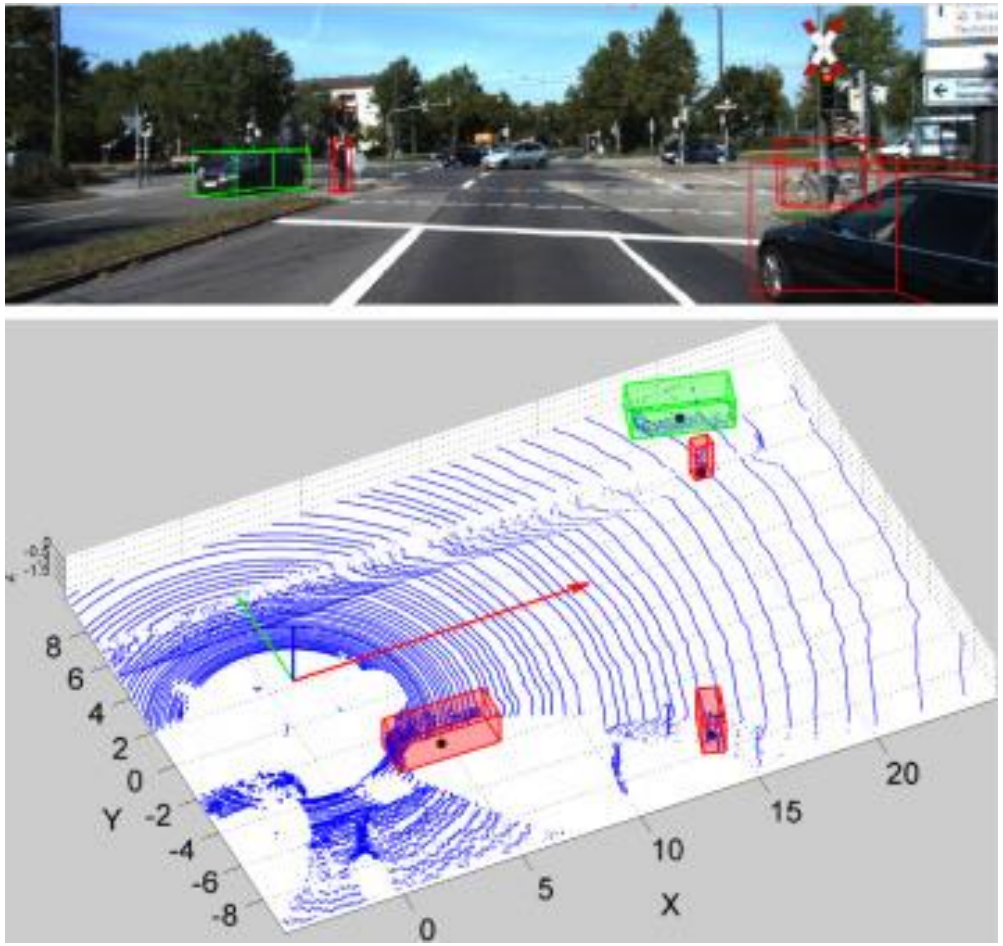
Autonomous Driving: Perception using LIDAR

- Data Representation
  - Point clouds
  - Features: lines, surfaces etc
  - Grid based approaches



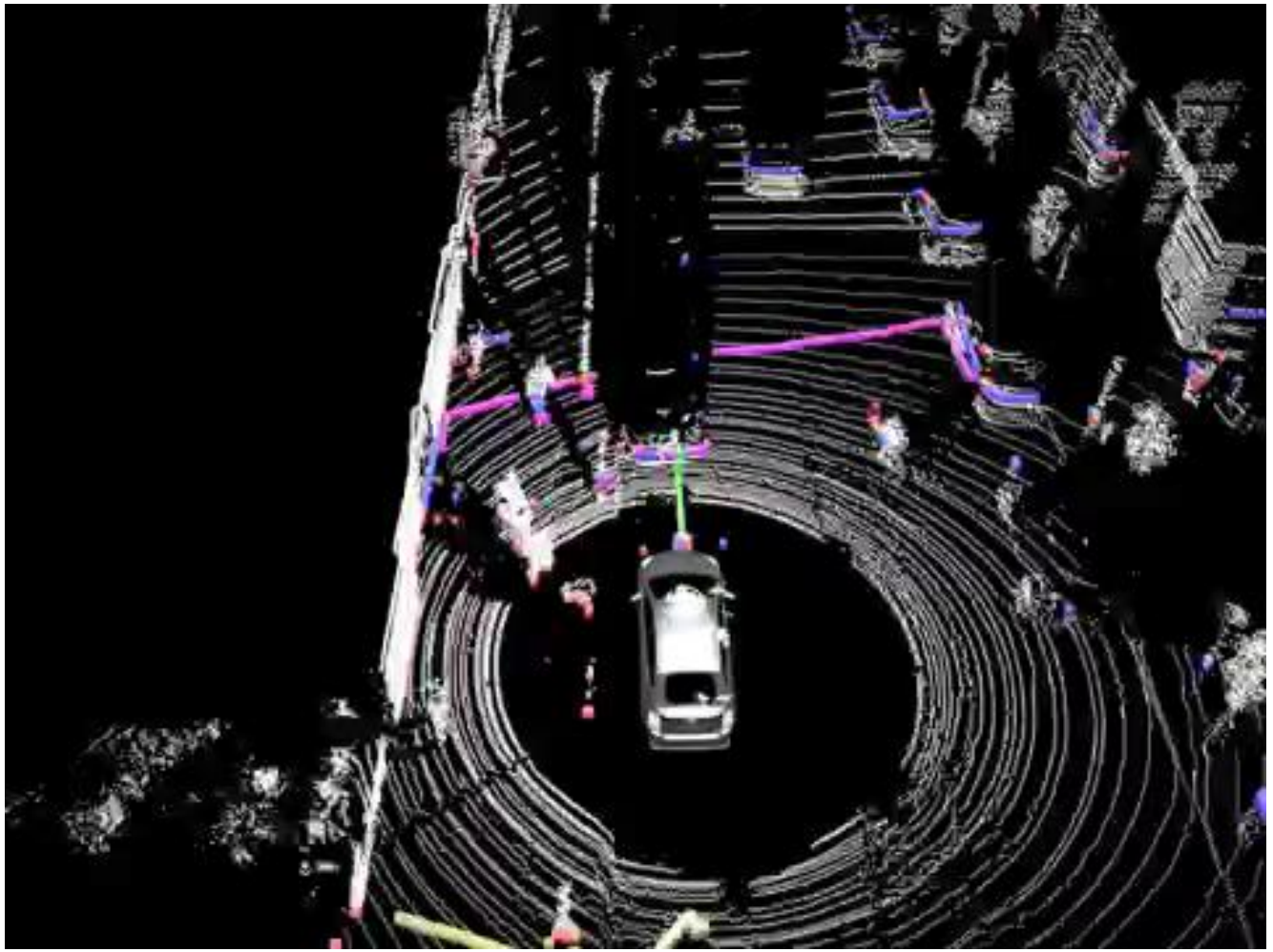
Autonomous Driving: Perception using LIDAR

- Knowledge Extraction
  - 3D point cloud segmentation
    - Edge based
    - Region based
    - Model based
    - Attribute based
    - Graph based
  - Classification



Autonomous Driving: Perception using LIDAR

- LIDAR in practice
  - Velodyne 64HD lidar

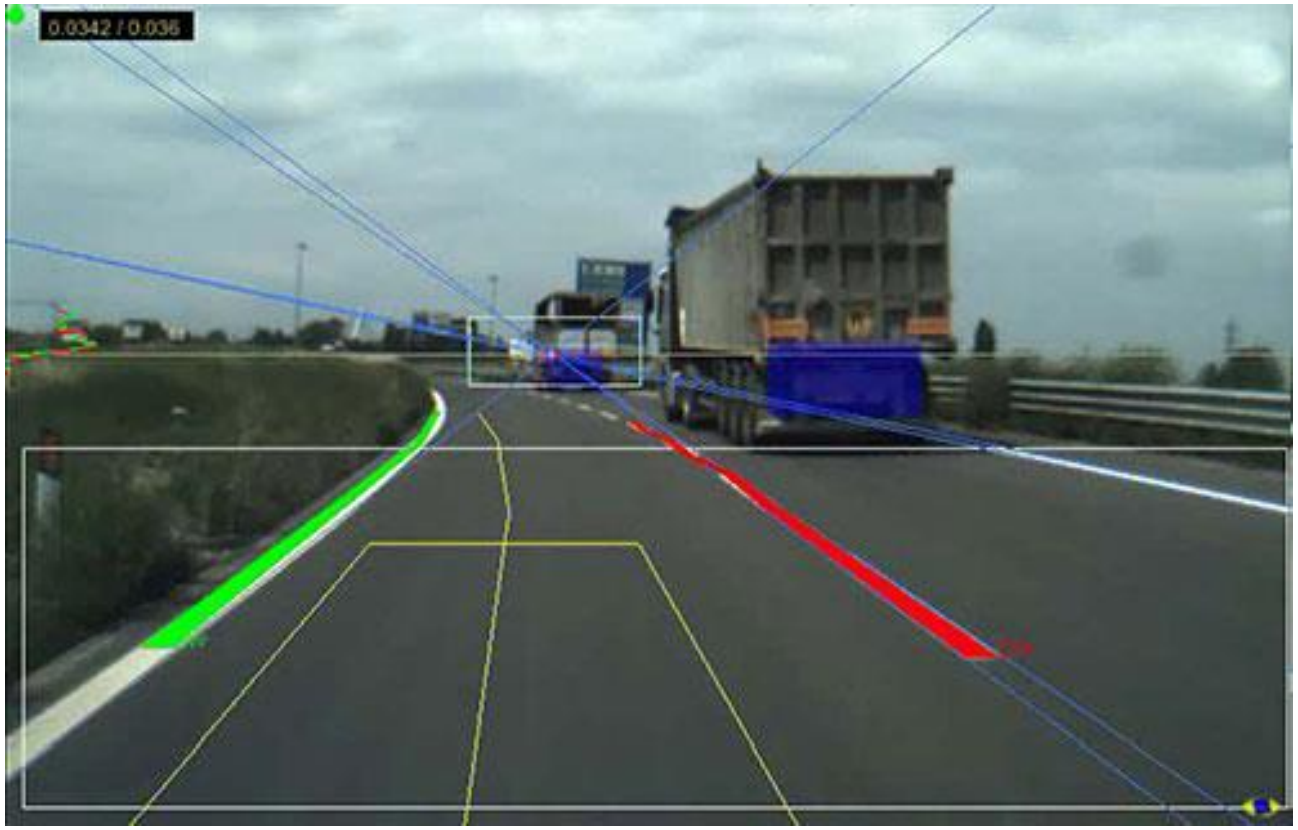


Autonomous Driving: Perception

- Environmental Perception
  - LIDAR
  - Cameras
  - Fusion
  - Other approaches
    - RADAR, Ultrasonic sensors

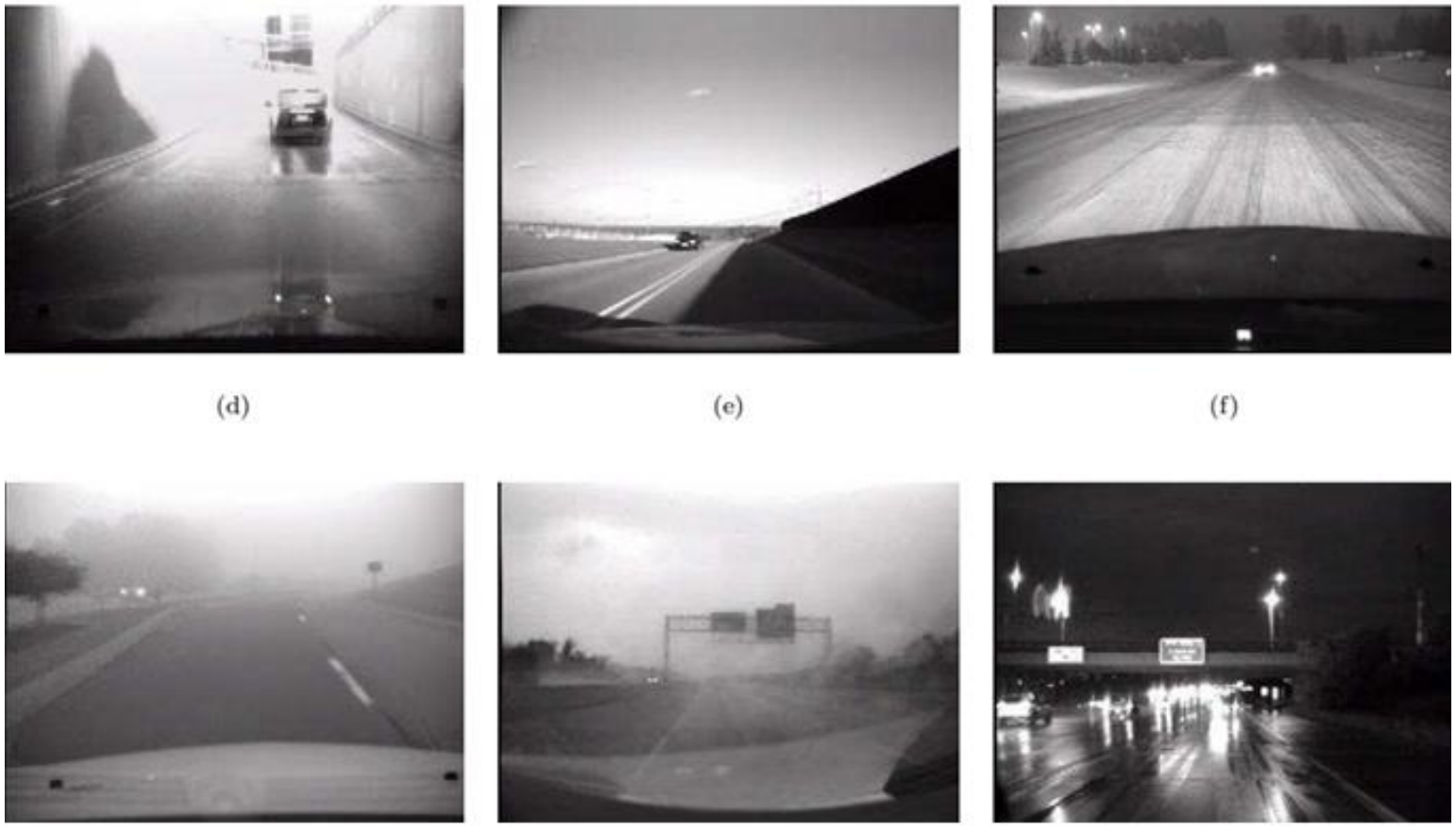
Autonomous Driving: Perception using Cameras

- Camera based vision
  - Road detection
    - Lane marking detection
    - Road surface detection
  - On-road object detection



Autonomous Driving: Perception using Cameras

- Challenges in Lane Detection



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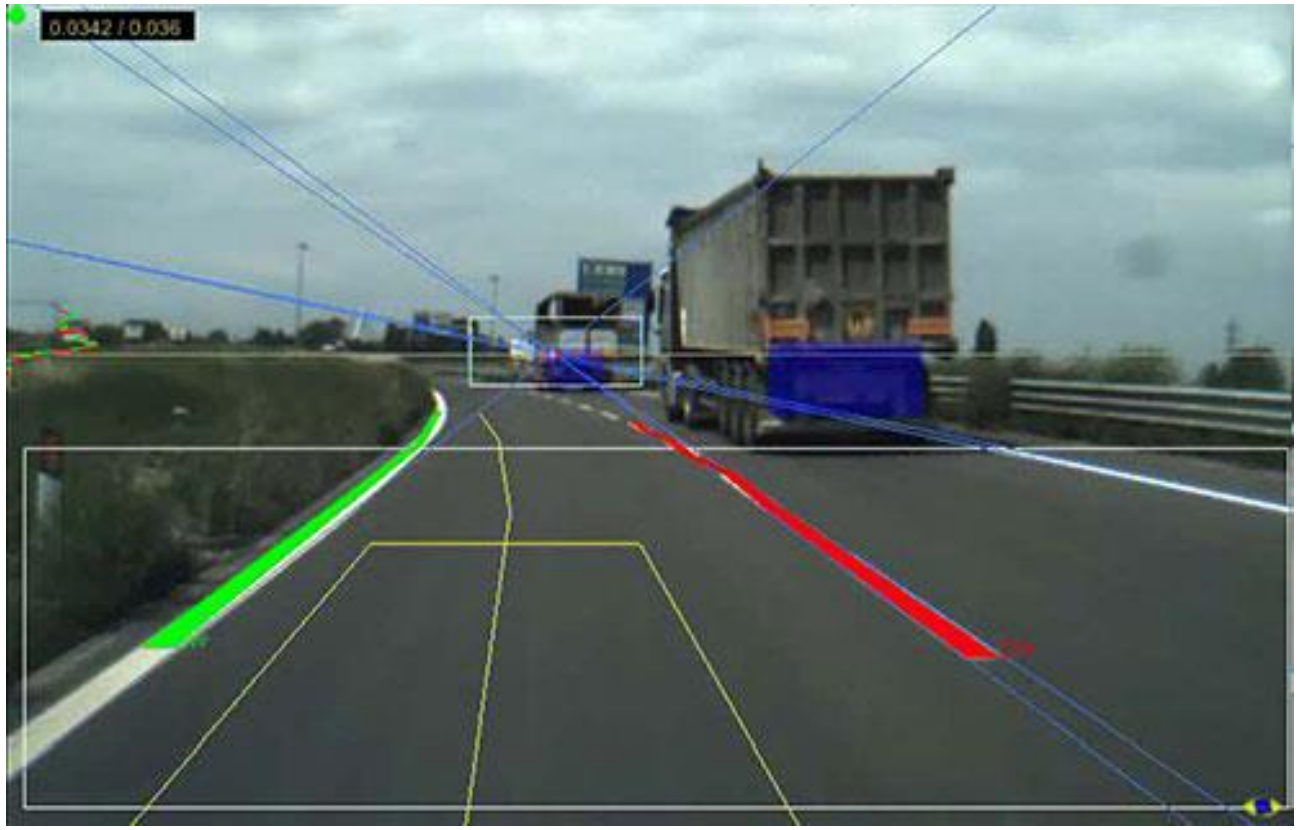

Autonomous Driving: Perception using Cameras

- Approaches to road surface detection
  - Feature-based
  - Deep learning
    - Direct pixel/block labelling
      - High memory and computation requirements
      - Requires annotated data
      - Black box

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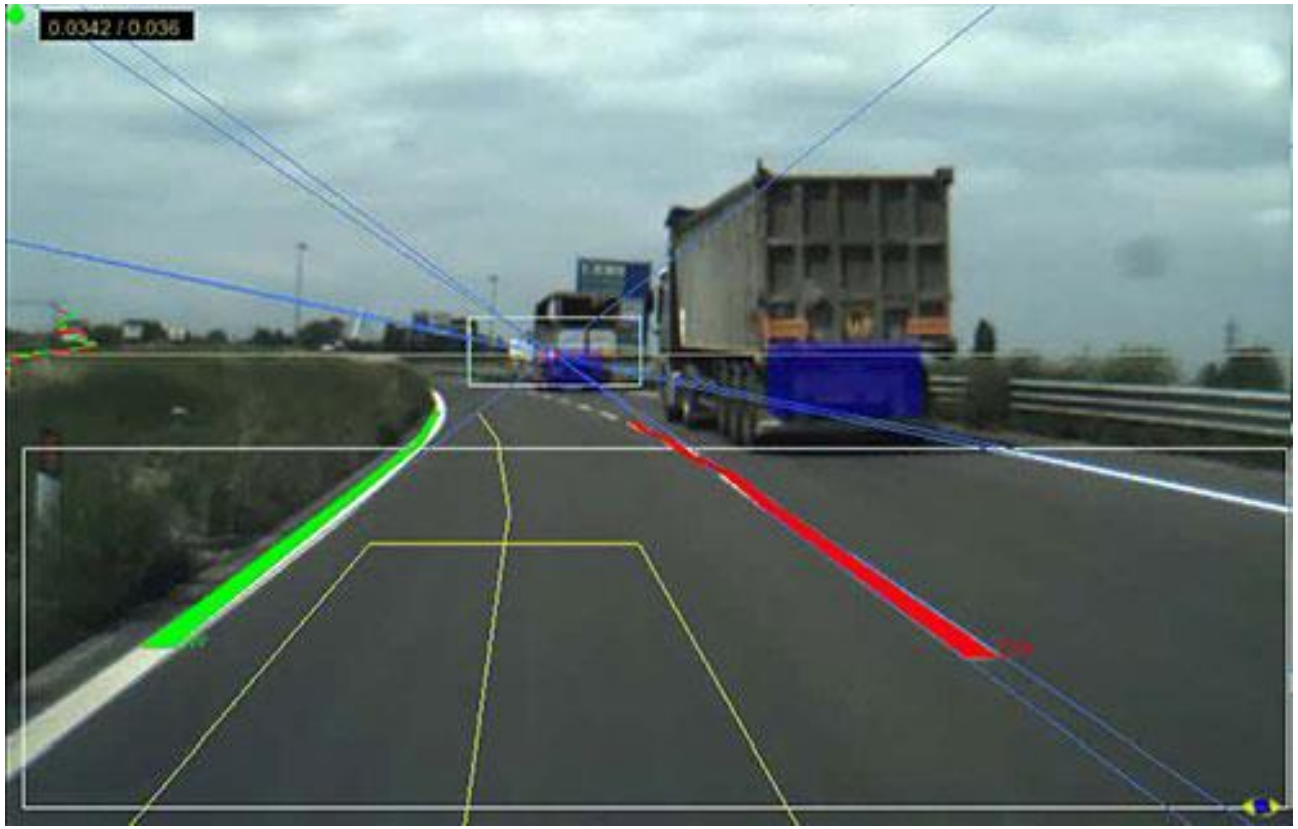
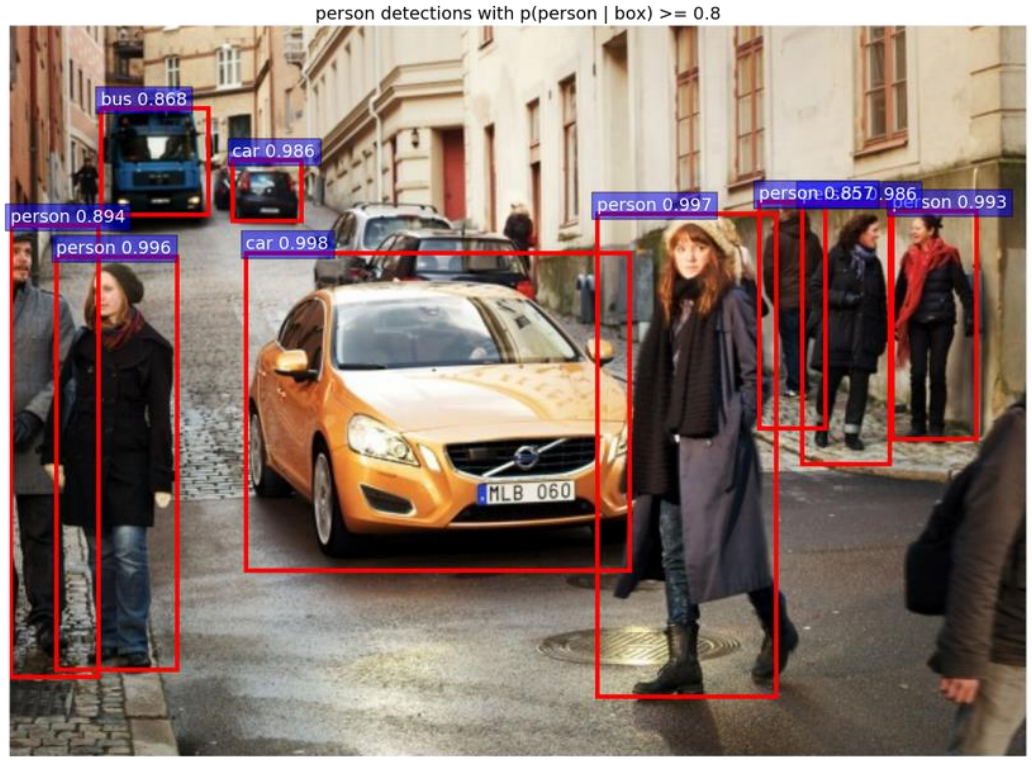


Autonomous Driving: Perception using Cameras

- On-road object detection
  - Pedestrian, cyclists, other cars
- Challenging due to the various types, appearances, shapes, and sizes of the objects

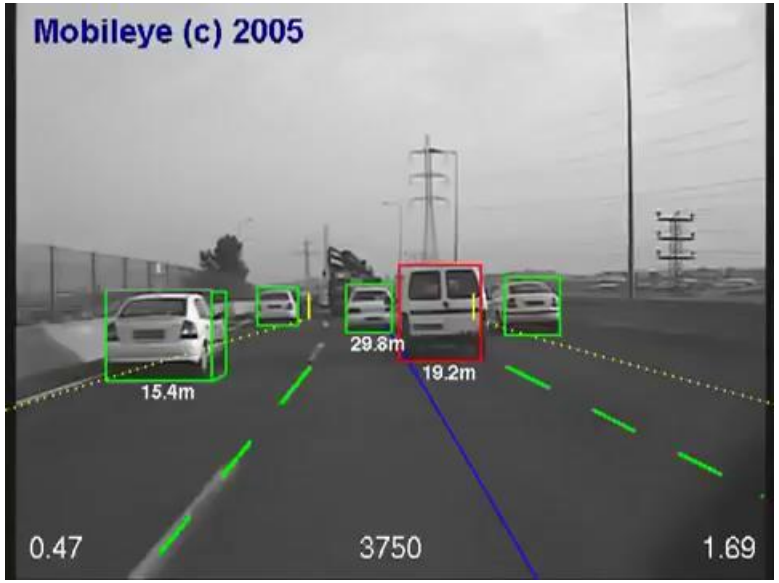
Autonomous Driving: Perception using Cameras

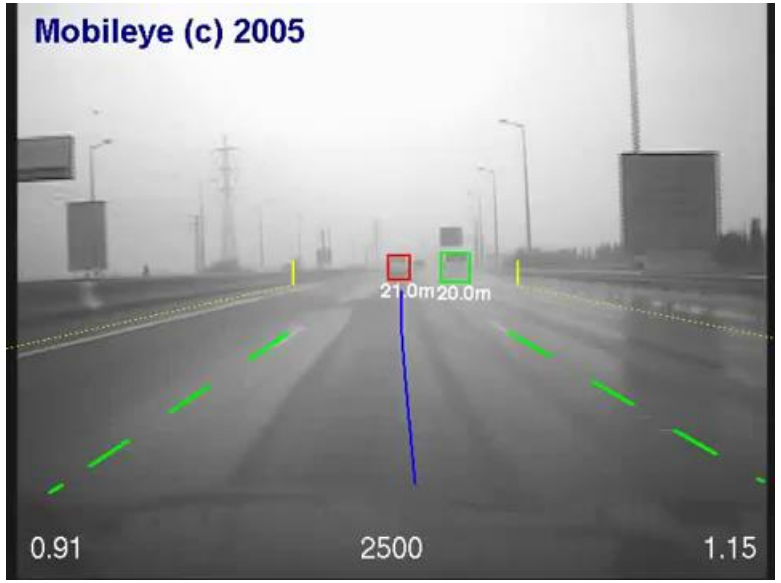
- On-road object detection
  - Pedestrian, cyclists, other cars
- Challenging due to the various types, appearances, shapes, and sizes of the objects
- Deep learning methods are far superior

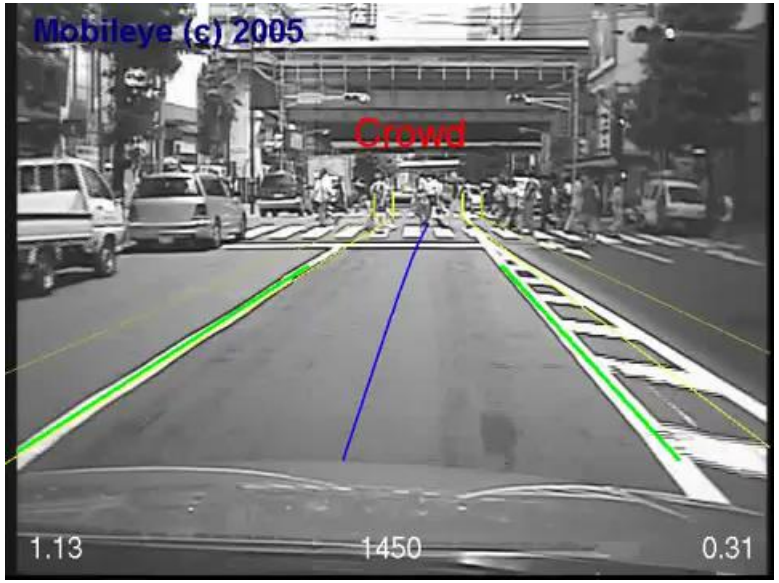


Autonomous Driving: Perception using Cameras

- Mobileye







Autonomous Driving: Perception using Sensor Fusion

- LIDAR
  - 3D measurements
  - Impervious to illumination changes
  - Prone to noise
  - Hard to extract knowledge
- Cameras
  - Provide rich appearance details in 2D
  - Affected by illumination/ weather

Autonomous Driving: Vehicle Localization

- Determining the pose of the ego vehicle and measuring its own motion
- Fusing data
  - Satellite-based navigation system
  - Inertial navigation system
- Map aided localization
  - SLAM

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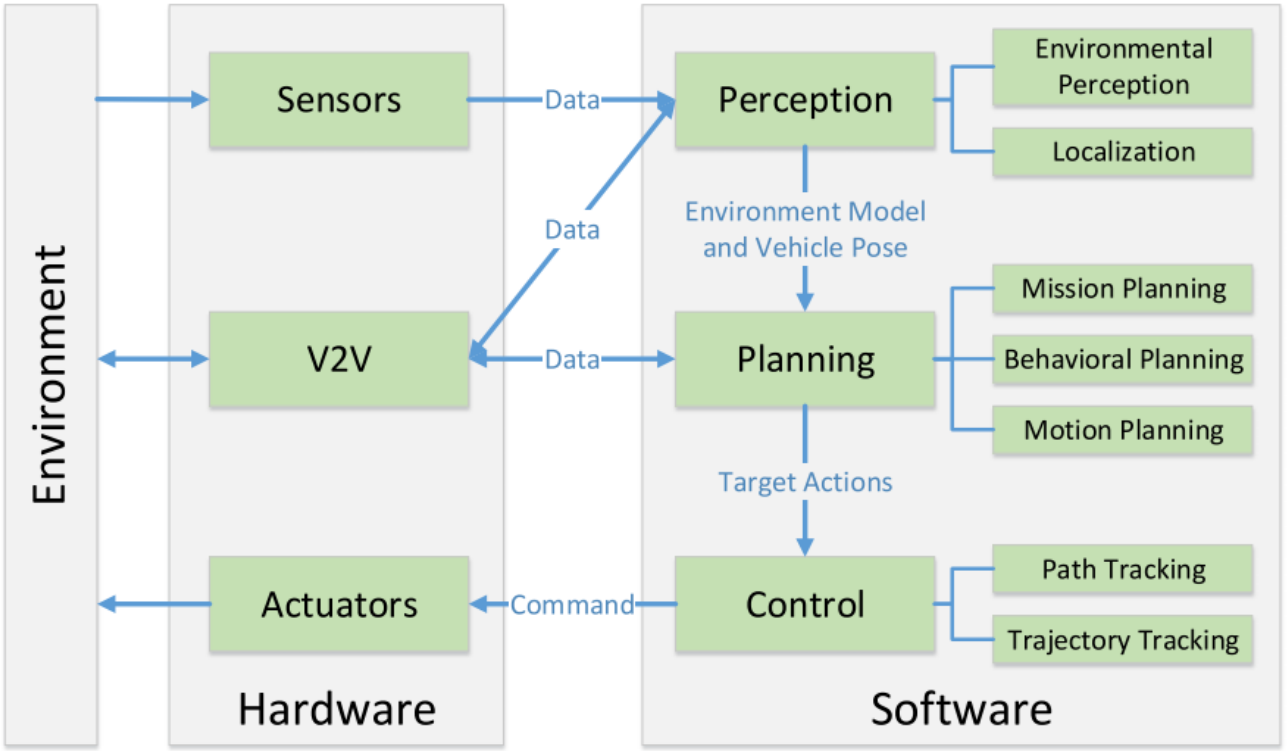

Figure 2. A typical autonomous vehicle system overview, highlighting core competencies.

Autonomous Driving: Planning

- Compare to Pedestrian Techniques:
  - Route Planning: road selection (global)
  - Path Planning: preferred lanes (global)
  - Maneuver-search: high level maneuvers (local)
  - Trajectory planning: Lowest level of planning (local)

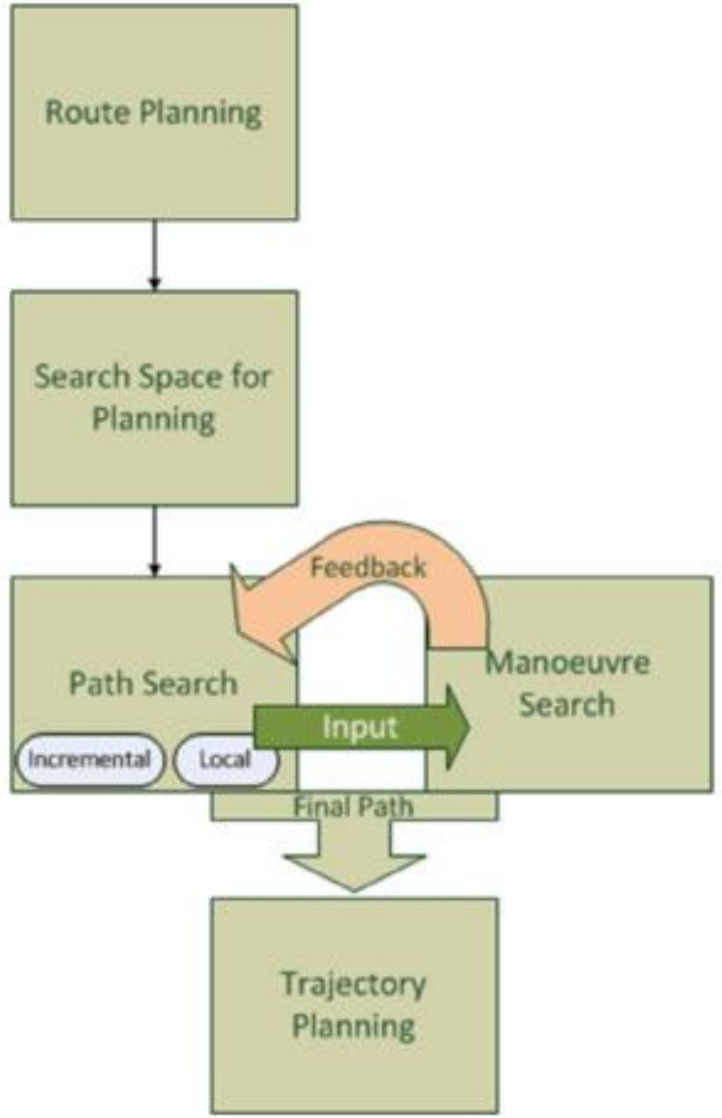

Fig. 2. A flow chart of planning modules.

Autonomous Driving: Planning

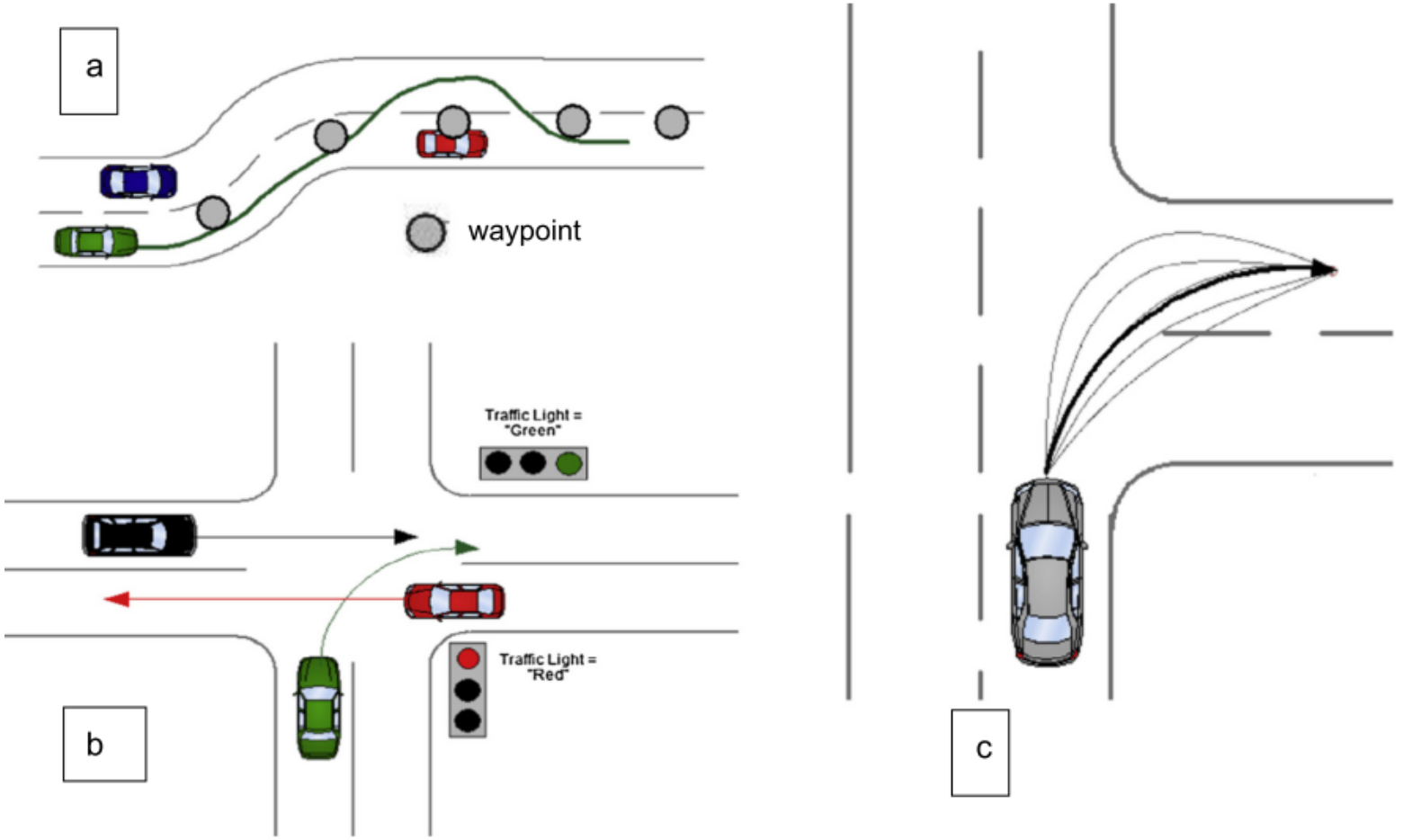

Fig. 3. (a) Path planning, (b) manoeuvre planning and (c) trajectory planning (adapted from Lee and Vasseur (2014)).

Structure

- History of Autonomous Driving
- Main Components
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Autonomous Driving: Control Planning

- Convert plans into actions
  - Provide inputs to the hardware level to generate the desired motion
- Common Approaches
  - Proportional-Integral-Derivative (PID) controller
  - Model Predictive Control (MPC)

Structure

- History of Autonomous Driving
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Autonomous Driving: End-End Approaches

- Nvidia PilotNet
  - Deep learning to directly map video frames to control

Structure

- History of Autonomous Driving
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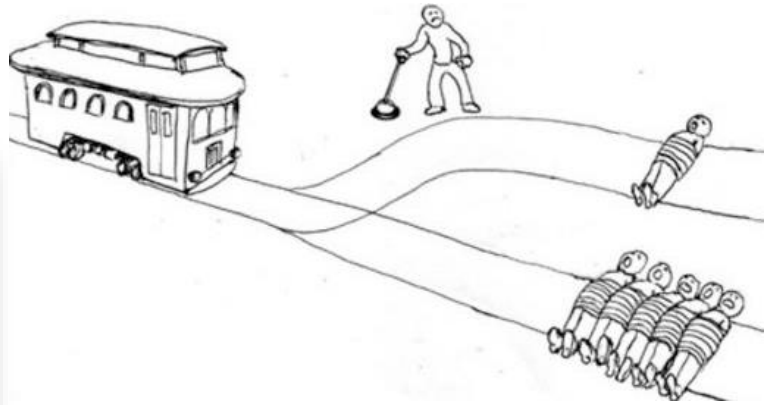
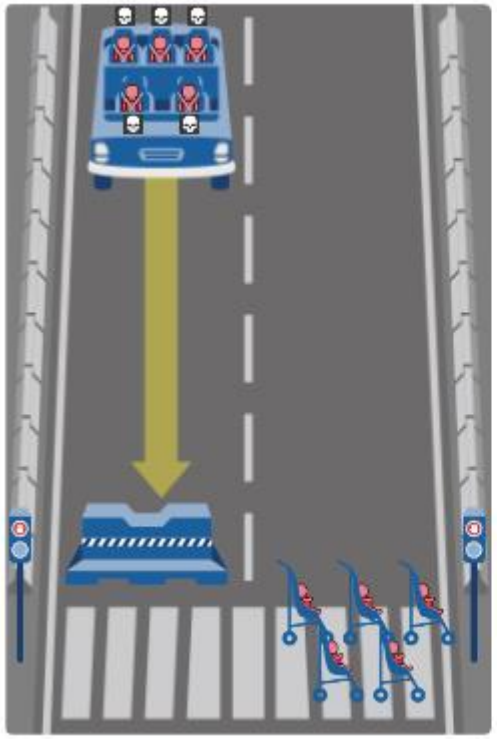
Autonomous Driving: Other Issues

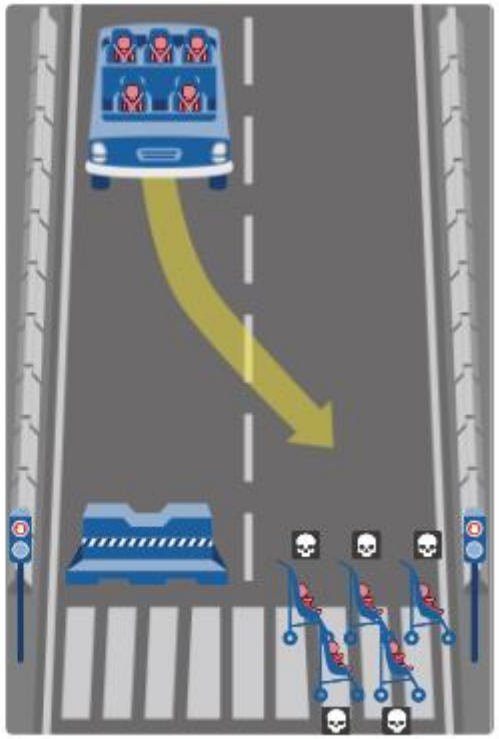
- Other challenges:
  - Communication
  - Coordination
  - Ethical Issues
    - Trolley Problem



Autonomous Driving: Other Issues

- Other challenges:
  - MIT “Moral Machine” [https://goo.gl/RL4pr5]





Autonomous Driving: Other Issues

- Civil Engineering / Ethics
  - Traffic impacts?
    - Pro: Vehicles should respond appropriately to traffic reducing jams
    - Con: Many more vehicles per person possible
  - People may not own cars?
    - Pro: Less emission? Less Traffic?
    - Con: Less access?

Next Lecture

- Modeling a car – kinematics & dynamics
- Motion Planning
- Control
- Modeling interactions with other vehicles
- AutonoVi: simulation platform for autonomous driving

References

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