Autonomous Driving and HD Maps

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Why Autonomous Driving?

• Fewer accidents
  • Road crashes lead to 3000 deaths and 100,000 injured worldwide a day.

• Decreased traffic congestion

• Enhanced human productivity

• Reduced cost of ride sharing

• Fewer parking lots, and no more parking headaches

• Improved mobility for the people who cannot drive
History of Autonomous Driving

1986
CMU Navlab 1

2005
Stanford Stanley
1st in DARPA Grand Challenge

2007
CMU Boss
1st in DARPA Urban Challenge
## Different Levels of Autonomy

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>There are no autonomous features.</td>
</tr>
<tr>
<td>Level 1</td>
<td>These cars can handle one task at a time, like automatic braking.</td>
</tr>
<tr>
<td>Level 2</td>
<td>These cars would have at least two automated functions.</td>
</tr>
<tr>
<td>Level 3</td>
<td>These cars handle “dynamic driving tasks” but might still need intervention.</td>
</tr>
<tr>
<td>Level 4</td>
<td>These cars are officially driverless in certain environments.</td>
</tr>
<tr>
<td>Level 5</td>
<td>These cars can operate entirely on their own without any driver presence.</td>
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</tbody>
</table>
Two Different Approaches

**Somewhere/Full AD**
Tech companies’ approach

Where?

Vehicle?

Who?
Google Baidu...

Full AD features

**Versus**

**Everywhere/Partial AD**
Traditional Automotive Industry

Where?

Vehicle?

Who?
Tesla Volvo...

Partial AD features
Level 4 Players in the US

Google/Waymo

Uber

Zoox

Cruise
Comparison of Level 4 Players in the US

Miles Per Disengagement Comparison

- BMW: 538
- Bosch: 1.5
- GM Cruise: 0.7
- Delphi Automotive Systems: 34.74
- Ford: 41.1
- Delphi Automotive Systems: 11.28
- Google Auto/Waymo: 5128
- Honda: 1244.4
- Nisan: 14
- Mercedes-Benz: 146.39
- Tesla Motors: 1.4
- Tesla Motors: 2
- Tesla Motors: 3
- Volkswagen: 57.5
- Volkswagen: 0

2015 Miles Per Disengagement vs. 2016 Miles Per Disengagement
Level 4 Players in China

Baidu
Commercialization in 3 years, mass production in 5 years.

UiSee
Urban Mobile Box

iDriver+
Autonomous Street Sweeper
Industry Map
How do Autonomous Cars Work?

Sensing → HD Maps → Localization → Perception → Planning → Control
Sensors on an Autonomous Car

GPS (global positioning system) combined with readings from tachometers, altimeters and gyroscopes to provide the most accurate positioning  
Cost: $80-$6,000

Ultrasonic sensors to measure the position of objects very close to the vehicle  
Cost: $15-$20

Odometry sensors to complement and improve GPS information  
Cost: $80-$120

Lidar (light detection and ranging) monitor the vehicle's surroundings (road, vehicles, pedestrians, etc.)  
Cost: $90-8,000

Video cameras monitor the vehicle's surroundings (road, vehicles, pedestrians, etc.) and read traffic lights  
Cost (Mono): $125-$150  
Cost (Stereo): $150-$200

Central computer analyzes all sensor input, applies rules of the road and operates the steering, accelerator and brakes  
Cost: ~50-200% of sensor costs

Radar sensors monitor the vehicle's surroundings (road, vehicles, pedestrians, etc.)  
Cost (Long Range): $125-$150  
Cost (Short Range): $50-$100
Perception

• Dynamic objects
  • Detection
  • Classification
  • Tracking
  • Predication

• Traffic sign & light recognition
Localization: Differential GNSS

- GNSS Constellation
- Carrier phase signal measurements for high precision
- Precisely surveyed base antenna position
- Base Receiver measurement data provided to Rover Receiver
- Baseline limitation < 40km

RTK software resolves the integer ambiguities in the carrier phase measurements.

Errors in satellite clocks are removed and errors in satellite orbits and the atmospheric effects on signal propagation are mitigated because the error sources are common to both receivers.
Localization: LiDAR Reflectivity Map Matching

LiDAR reflectivity map

Correlation of real-time scan and map
Mission & Path Planning

- Traffic rules / logics
- Obstacle avoidance
- Safety metrics
- Vehicle dynamics
Control

- Vehicle dynamic models
- Control algorithms
  - Traditional PID control
  - Dynamic perfect control
  - Neural network control

Inputs
- Position
- Orientation
- Velocity

Control Algorithm

Outputs
- Throttle
- Brake
- Steering
- Gear

CAN bus
High-Definition (HD) Maps

- Road network layer
  - Traffic sign, lights, poles
  - Lane markers
  - Logics
- Perception layer
  - Static features
  - Grounds
- Localization layer
  - Reflectivity
  - Geometry
HD Map Generation Pipeline

Data collection → 3D reconstruction → Feature extraction → Labeling → Road network layer

3D reconstruction

Ground detection

Reflectivity statistics

Perception layer

Localization layer
Efficient 3D Representation Using Octree
Road Network Representation

- Lane section $A_{left}$
- Lane section $B_{left}$
- Lane section $A_{right}$
- Lane section $B_{right}$

<table>
<thead>
<tr>
<th>Road</th>
<th>Predecessor</th>
<th>Successor</th>
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<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>ambiguous</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>5</td>
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Challenges and Potential Improvements

• Construction zones:
  • Additional radio signals to guide traffic, and
  • Construction plans filed in advance and available to autonomous cars.

• Traffic lights:
  • Radio signals to indicate state, or at least
  • Clear visibility to car’s cameras, regardless of the sun’s position.

• School bus, ambulance, and other emergency service vehicles:
  • Additional radio signals to indicate state.
Thank you!

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