CSE 352: Self-Driving Cars

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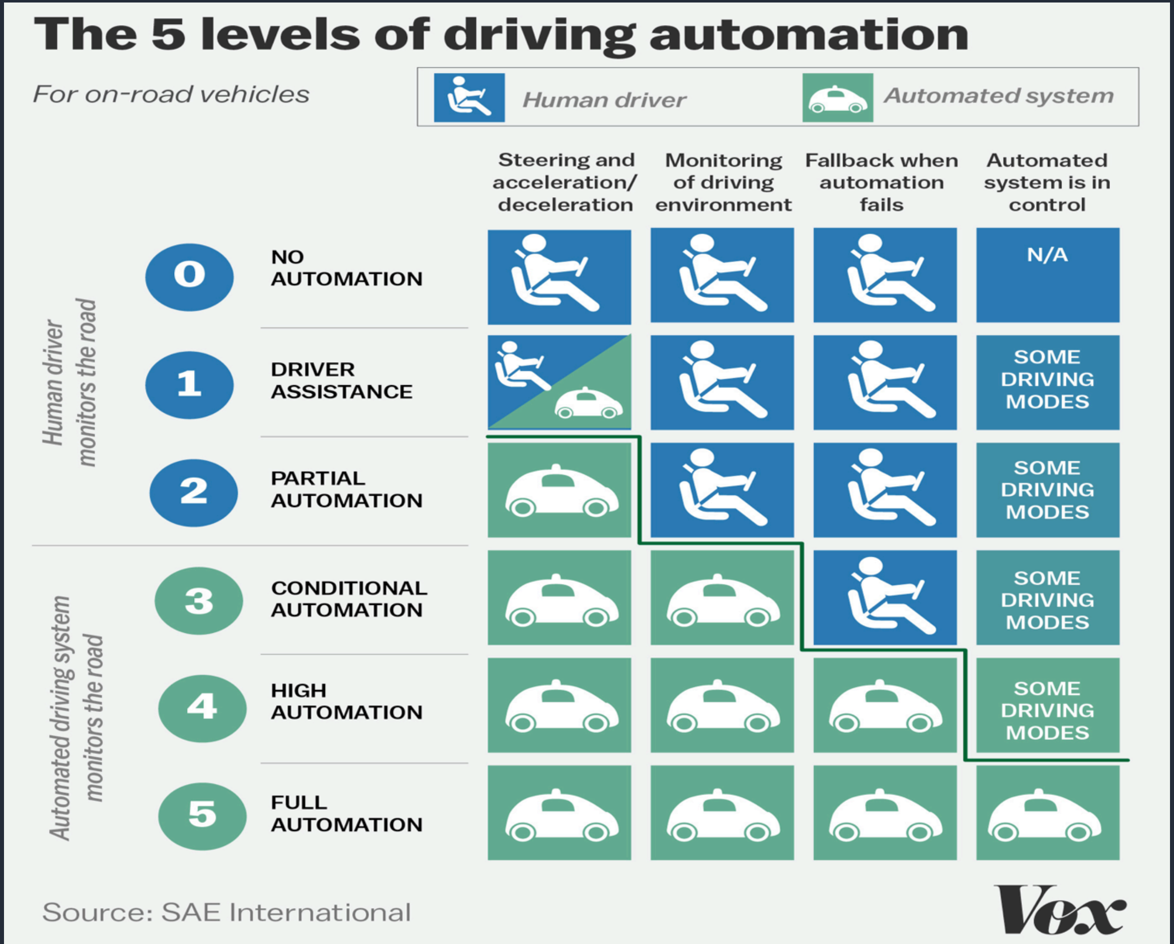
Self-Driving car History

Self-driven cars experiments started at the early 20th century around 1920. The early experiment manage to have the cars drive on testing roads with no traffic or any other interference.

Autonomous cars started to show real progress by the 21st century. Many automobile companies were interested and worked on prototypes of the self driving cars, such companies as Mercedes-Benz, Tesla, Nissan, Volvo.

Tesla is one of today’s leading companies in autonomous car production.


The 5 levels of driving automation
For on-road vehicles
Human driver
Automated system
Steering and acceleration/ deceleration
Monitoring of driving environment
Fallback when automation fails
Automated system is in control
Human driver monitors the road
Automated driving system monitors the road
0 NO AUTOMATION
N/A
1 DRIVER ASSISTANCE
SOME DRIVING MODES
2 PARTIAL AUTOMATION
SOME DRIVING MODES
3 CONDITIONAL AUTOMATION
SOME DRIVING MODES
4 HIGH AUTOMATION
SOME DRIVING MODES
5 FULL AUTOMATION
Source: SAE International
Vox

Tesla 2014

In October 2014, Tesla Motors announced its first version of AutoPilot on Model S.

Its system is capable of lane control with autonomous steering, braking and speed limit adjustment based on signals image recognition.

The system provided autonomous parking and was able to to receive software updates to improve skills over time.

Tesla 2015

In March 2015, Tesla Motors announced that it will introduce it Autopilot technology by mid 2015 through a software update for the cars equipped with the systems that allow autonomous driving.

On the same month, Tesla has been testing the autopilot system on the highway between San Francisco and Seattle with a driver but letting the car to drive the car almost unassisted.

A Tesla spokesman said there is "nothing in our autopilot system that is in conflict with current regulations." "We are not getting rid of the pilot. This is about releasing the driver from tedious tasks so they can focus and provide better input."

In mid October 2015, Tesla Motors rolled out version 7 of their software in the U.S. that included Autopilot capability.

Tesla 2016

On January 9, 2016, Tesla rolled out version 7.1 as an over-the-air update, adding a new "summon" feature that allows cars to self-park at parking locations without the driver in the car.

At this levels the car can act autonomously but requires the full attention of the driver, who must be prepared to take control at a moment's notice.

Tesla's autonomous driving features are ahead of production cars, and can be classified as is somewhere between level 2 (hands off) and level 3 (eyes off) under the NHTSA five levels of vehicle automation.

In urban driving the system will not read traffic signals or obey stop signs. The system also does not detect pedestrians or cyclists

Tesla’s first fatal accident in AutoPilot mode.

In Williston, Florida on 7 May 2016 while a Tesla Model S electric car was engaged in Autopilot mode. The driver was killed in a crash with a large 18-wheel tractor-trailer.

On 28 June 2016 the National Highway Traffic Safety Administration (NHTSA) opened a formal investigation into the accident working with the Florida Highway Patrol. According to the NHTSA, preliminary reports indicate the crash occurred when the tractor-trailer made a left turn in front of the Tesla at an intersection on a non-controlled access highway, and the car failed to apply the brakes. The car continued to travel after passing under the truck’s trailer.

The NHTSA's preliminary evaluation was opened to examine the design and performance of any automated driving systems in use at the time of the crash, which involves a population of an estimated 25,000 Model S cars.

Tesla 2016

Starting October 2016, all Tesla cars are built with the necessary hardware to allow full self-driving capability at a safety level (SAE Level 5 Full Automation).

The hardware includes eight surround cameras and twelve ultrasonic sensors, in addition to the forward-facing radar with enhanced processing capabilities.

The system will operate in "shadow mode" (processing without taking action) and send data back to Tesla to improve its abilities until the software is ready for deployment via over-the-air upgrades.

Full autonomy is only likely after millions of miles of testing, and approval by authorities. Tesla Motors says it expects to enable full self-driving by the end of 2017.

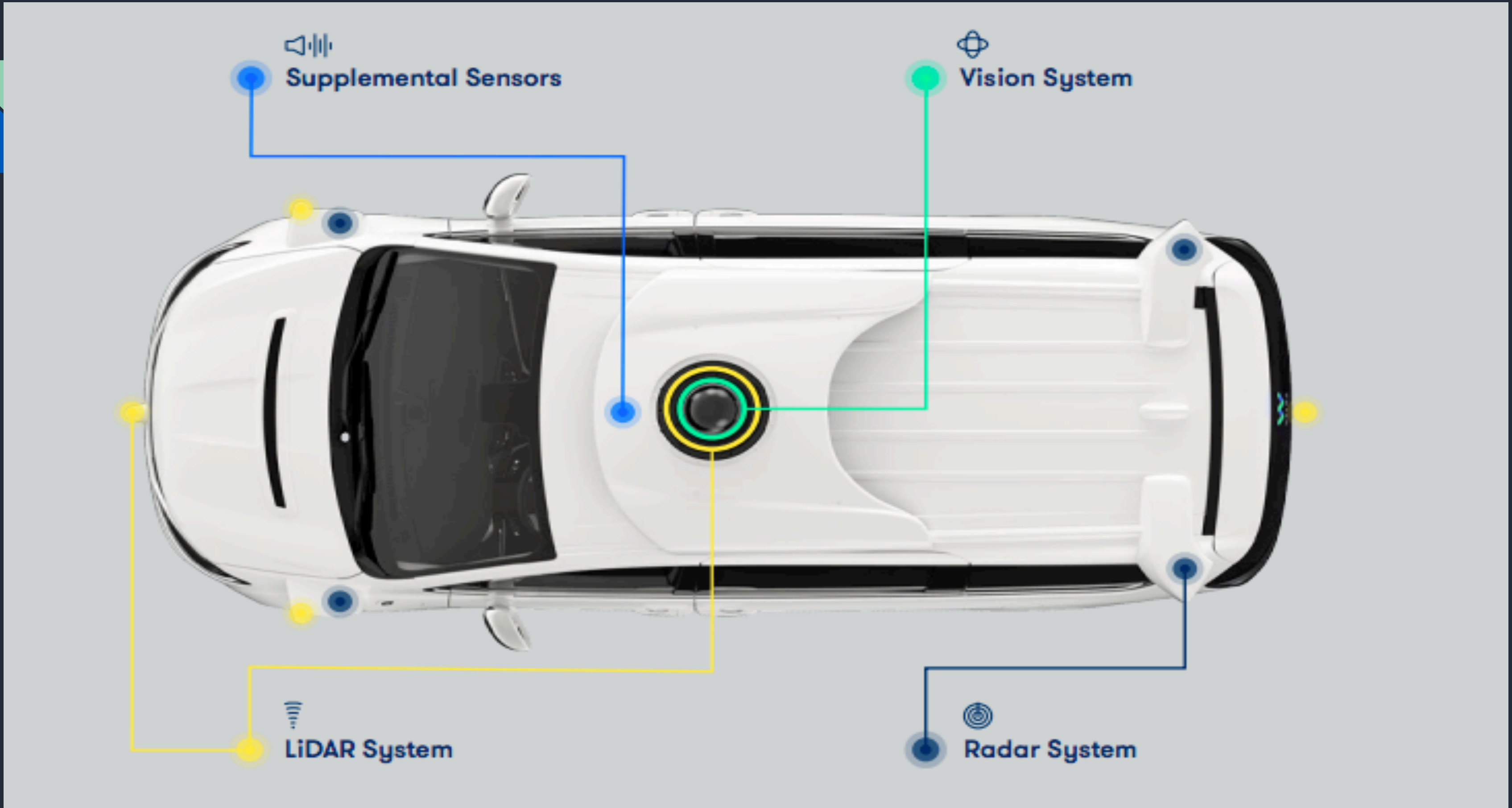
Videos of Tesla

- Self-driving Tesla (Video)
- Crash prediction Tesla (Video)

Technologies

Technologies that make self driving cars possible:

- Sensors
- Connectivity
- Software and control algorithms



Source: https://storage.googleapis.com/sdc-prod/v1/safety-report/waymo-safety-report-2017-10.pdf

Sensor technology

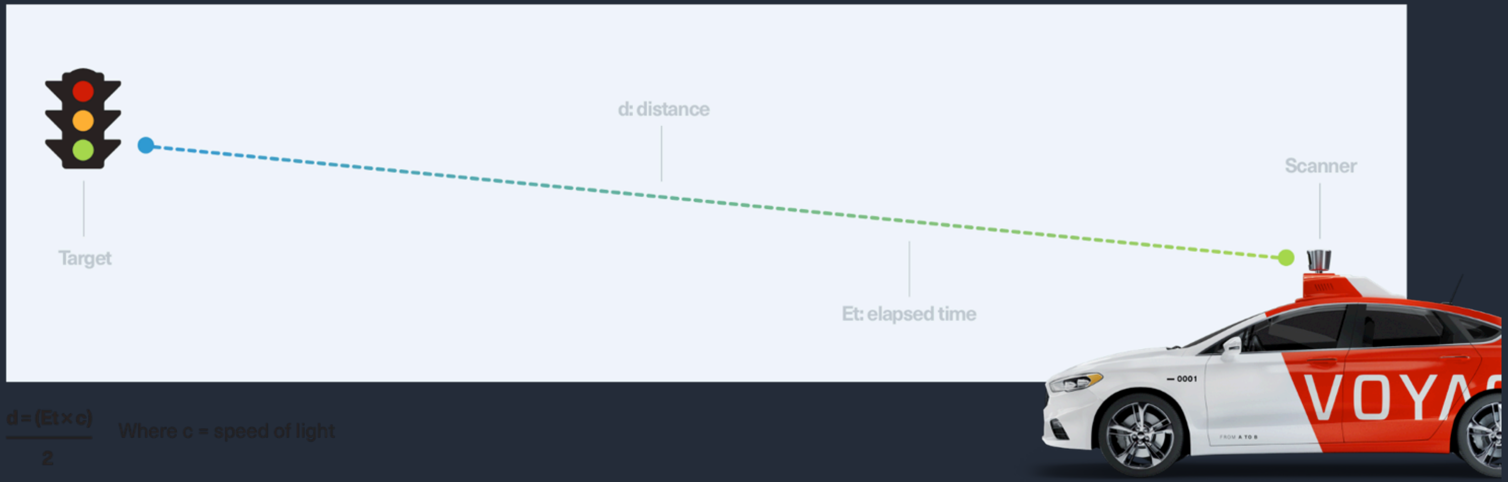
Sensors are essentially the “eyes” of the car. Sensors are used to capture data about their surroundings (pedestrians, other vehicles, bicycles, sidewalks).

Popular sensor technology used in self driving cars: LIDAR (Light detection and ranging).

- Companies that are using LIDAR
  - Google
  - Uber
  - Baidu

How do LIDAR sensors work?

- LIDAR has 360 degree view with depth perception that is very accurate
- LIDAR sensors continually fire beams of laser light (millions per second) and measures how long it takes to come back
- Able to deduce the exact measurements of objects within the sensor’s field of vision (60 meters)



$$d = \frac{(Et \times c)}{2}$$ Where c = speed of light

Vision System

Forward Cameras

Wide, Narrow, Main Cameras

Side Cameras

Camera monitor rear blind spots on both sides of the car

Backward Cameras

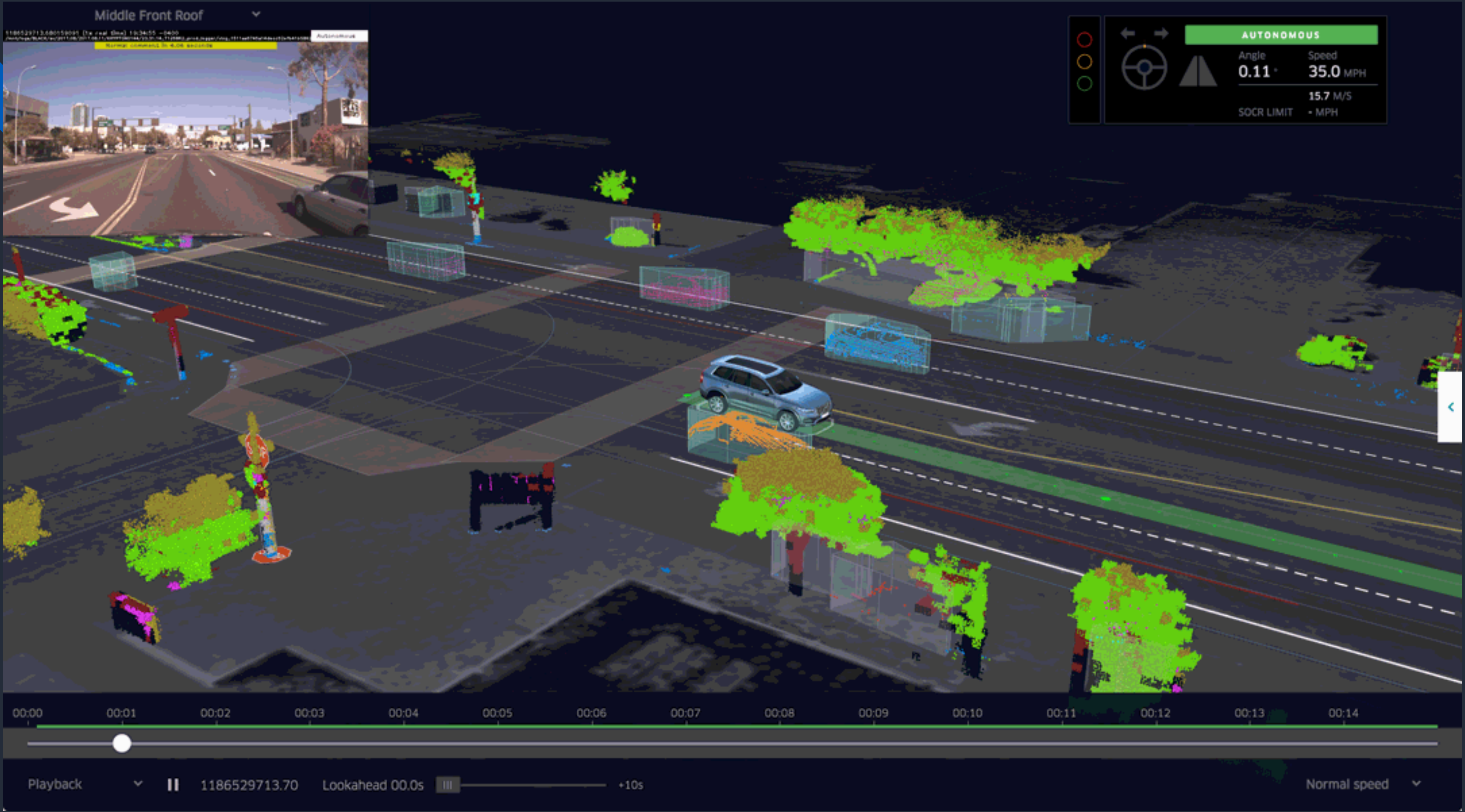
Parking

Radar System

Detect travel around objects like rain drops, making radar effective in rain, fog, and snow, day or night. Some self driving car's radar system has a continuous 360-degree view, so it can track the speed of road users in front, behind and to both sides of the vehicle.

Supplement Sensor system

detection system that can hear police and emergency vehicle. GPS to understand physics locations



Middle Front Roof
AUTONOMOUS
Angle
0.11
Speed
35.0 MPH
15.7 M/S
SOCR LIMIT
- MPH
00:00
00:01
00:02
00:03
00:04
00:05
00:06
00:07
00:08
00:09
00:10
00:11
00:12
00:13
00:14
Playback
1186529713.70
Lookahead 00.0s
+10s
Normal speed

Connectivity

Connectivity means that the smart car will be able to communicate with other vehicles / devices and platforms in order to send and receive information.

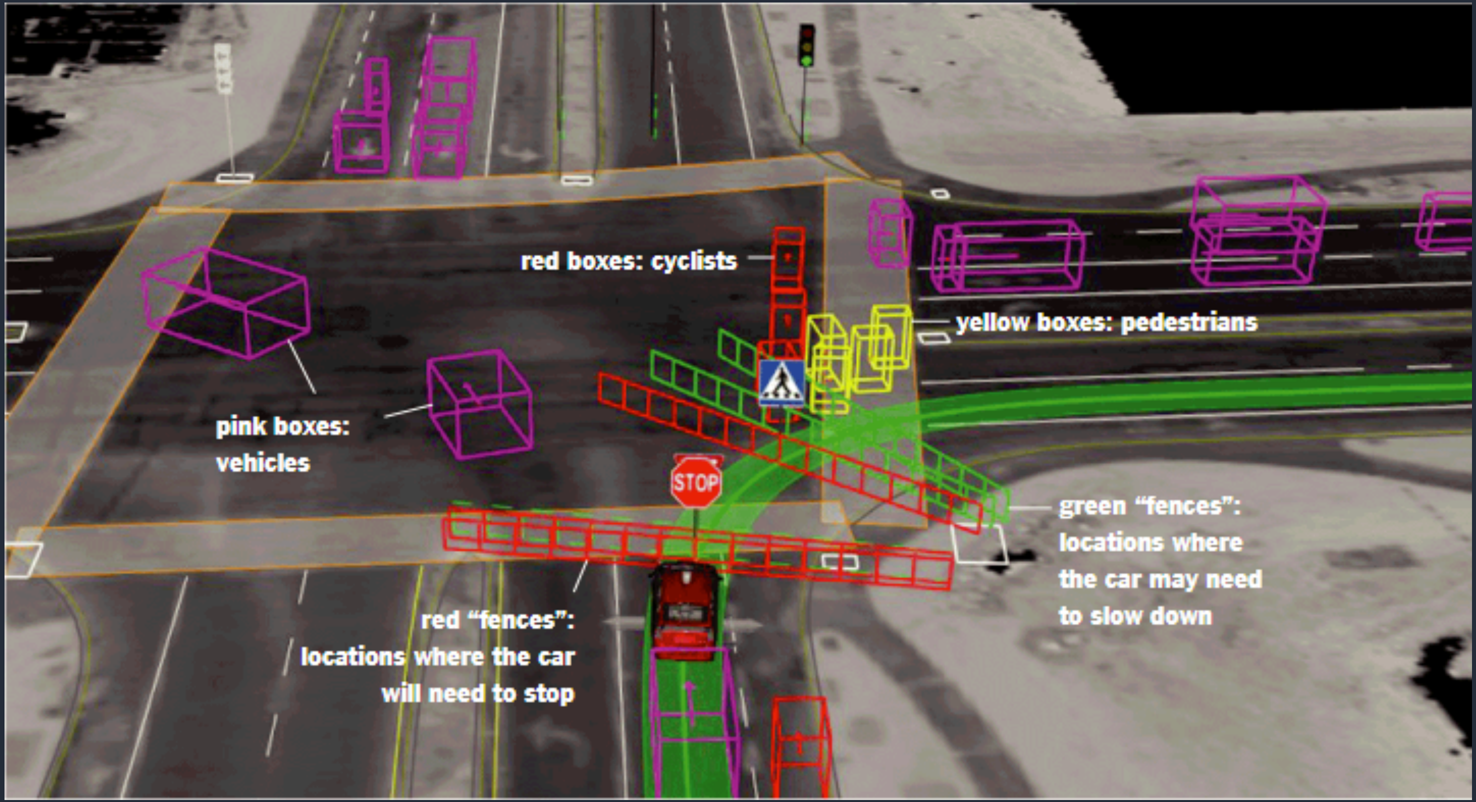
- Traffic and GPS data for navigation
- Weather and surface conditions
- Sending back data on map and performance errors so manufacturers can fine tune the systems
- Self driving cars that are able to communicate with each other makes for a much safer experience overall

The data from connectivity, along with sensor data are estimated to produce up to 2 gigabytes of data per second.

Software and Control Algorithms

With all of that data being captured, software is needed to make decisions such as where to steer, what speed to drive, and when to stop.

- Image data (road signs, traffic lights, pedestrians) are used to train AI in both recognition and decision making
- Machine learning and pattern analysis algorithms are used to categorize the objects based on how likely they are to behave and build classifiers to predict how to react to them
- The algorithms must know how to handle a multitude of driving situations, no matter how simple or complex


red boxes: cyclists
yellow boxes: pedestrians
pink boxes: vehicles
STOP
green “fences”: locations where the car may need to slow down
red “fences”: locations where the car will need to stop

Pattern analysis - Scene labeling

Testing

- Base Vehicle Testing
- Hardware Testing
- Software Testing

Hardware Testing

- Component Testing

- Integrated testing
- Whole vichie testing

Self-Driving Software Testing

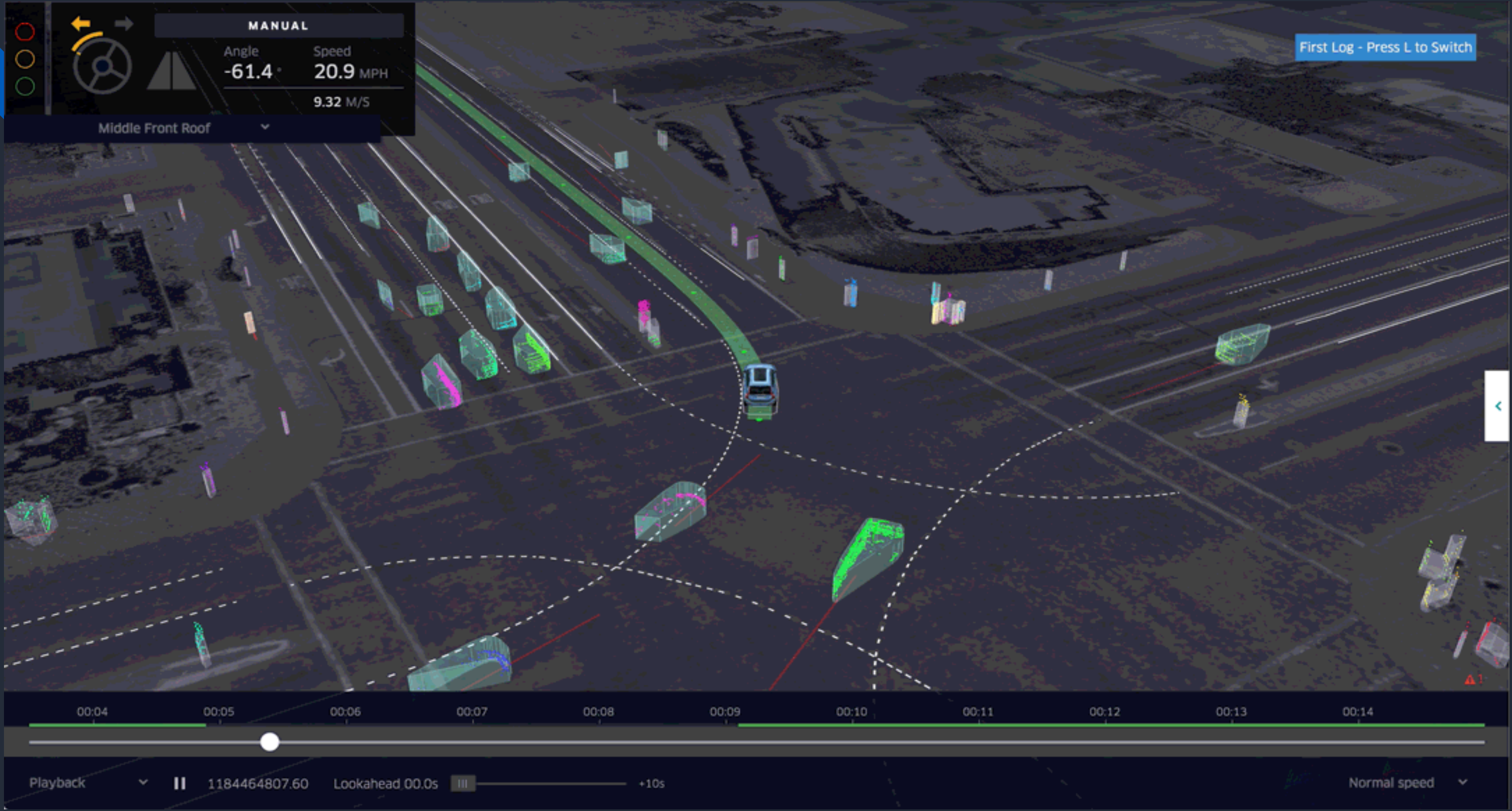
How Simulation works

Step 1: Collect Detailed Vision of the World

Step 2: Predict possible situations

Step 3: Create test scenes

Step 4: Iterate through tests



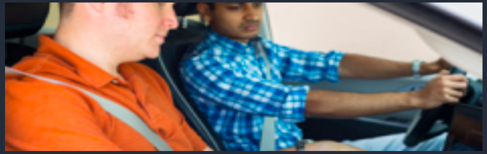
MANUAL
Angle
-61.4
Speed
20.9 MPH
9.32 M/S
Middle Front Roof
First Log - Press L to Switch
00:04
00:05
00:06
00:07
00:08
00:09
00:10
00:11
00:12
00:13
00:14
Playback
1184464807.60
Lookahead 00.0s
+10s
Normal speed

- Closed-Course Testing

    Compare software with human driver

- Real-World Driving

    Estimate performance on real road



Safety Area

- Behavioral Safety
- Functional Safety
- Crash Safety
- Non-Collision Safety:
- Operational Safety

Safety Testing

Behavioral Competency Testing

demonstrate competency in a variety of reasonably foreseeable traffic situations, i.e high speed merge, lane Changes, respond to Emergency Vehicles

Testing Crash Avoidance Capabilities

Avoiding or mitigating those kinds of crashes, therefore, is an important goal for our vehicle development.

Safety Facts

- 2010 Safety Stats:
  - 32,999 killed
  - 3.9 million injured
  - $277 billion in damages
- Existing autonomy reduces crashes by one-third
- 90% of crashes due to human error

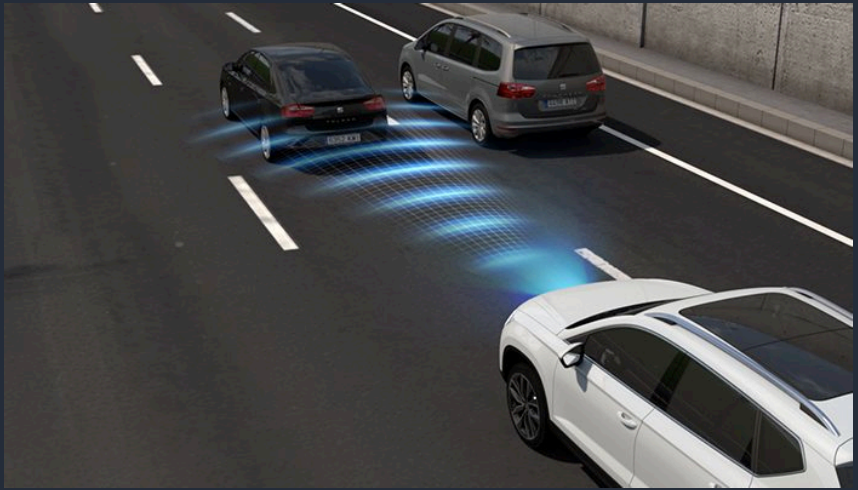
Future Implications

- Vehicle Safety
- Road Congestion
- Ride Sharing
- Environmental Benefits

Congestion

- Reduction in crashes
  - Fewer delays
  - Higher reliability
- Connected Vehicles
  - Inter-vehicle reservations
  - 2-3 times quicker than traffic signals
- More A.V.s, less congestion

- Potential for more congestion



Car company Seat uses A.V. technology called “Traffic Jam Assist” (http://www.seat.com/car-terms/t/traffic-jam-assist.html)

Ride Sharing and Car Ownership

- Increase in cabs: no drivers to pay
- Multiple parties can ride in one car
  - Decrease in total distance driven
- Ride-sharing is cheaper than car ownership
  - Car ownership drops up to 43%
  - Only 1.2 cars per household

Environment

- Historically, fuel economy gets better with time
- A.V. algorithms can use “eco-driving”
- Coordinated driving saves fuel
- Reduced idle time from traffic
- Fewer physical safety systems leads to reduced weight

Laws

- There are no federal laws pertaining to self driving cars
- California requires a supervising driver
- Plans to remove driver 2018
- Companies keep data about traffic usage private for personal interest
  - Ex:San Francisco requested traffic data from Uber and Lyft, but didn't receive them
- laws often require state police to test driving and insane amount of insurance

Ethics

-Should there be a driver behind the wheel?

-What jobs could this replace?

-Who takes responsibility in an accident?

-How do you deal with traffic?

-privacy?

-Drivers cause accidents through human error

-Cabs drivers, Uber drivers, and other drivers could lose their jobs

-There is potential to increase the magnitude of traffic

-The car records a person’s daily schedule

Work cited

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