Lesson 1

Sensors and Computing Hardware

Sensor:

Device that **measures or detects a property of the environment**, or changes to a property. **A sensor is a device that detects** and **responds to some type of input from the physical environment.** The specific input could be **light, heat, motion, moisture, pressure**, or any one of a great number of other environmental phenomena. The **output is generally a signal that is converted to human-readable** display at the sensor location or transmitted electronically over a network for reading or further processing.

Types:

1. Exteroceptive or Extero : Surroundings - Sensors are used for the observation of the environments.
2. Proprioceptive or Proprio : Internal - Proprioceptive sensors measure values internally to the system.

Exteroceptive Sensors:

Camera:

Essential for **correctly perceiving environment**. **Cameras are a passive**, **light-collecting sensor** that are great at capturing rich, detailed information about a scene. In fact, some groups believe that the camera is the only sensor truly required for self-driving. But **state of the art performance is not yet possible with vision alone.** While talking about cameras, we usually tend to talk about three important comparison metrics.

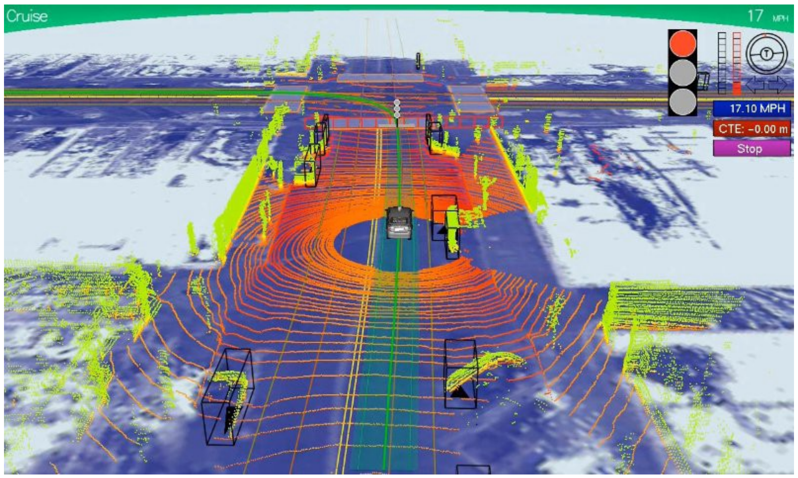
Comparison metrics:

1. Resolution - The resolution is the **number of pixels that create the image.** So it's a way of specifying the **quality of the image.**
2. Field of view (FOV) - The field of view is defined by the h**orizontal and vertical angular extent** that is visible to the camera, and can be varied through **lens selection and zoom.**
3. Dynamic range - The dynamic range of the camera is the difference between the **darkest** and the **lightest tones in an image.** **High dynamic range is critical for self-driving vehicles** due to the highly variable lighting conditions encountered while driving especially at night.

Stereo Camera:

The **combination of two cameras** with overlapping fields of view and **aligned image planes is called the stereo camera**. **Stereo cameras allow depth estimation from synchronized image pairs.**

LIDAR(Light Detecting And Ranging):

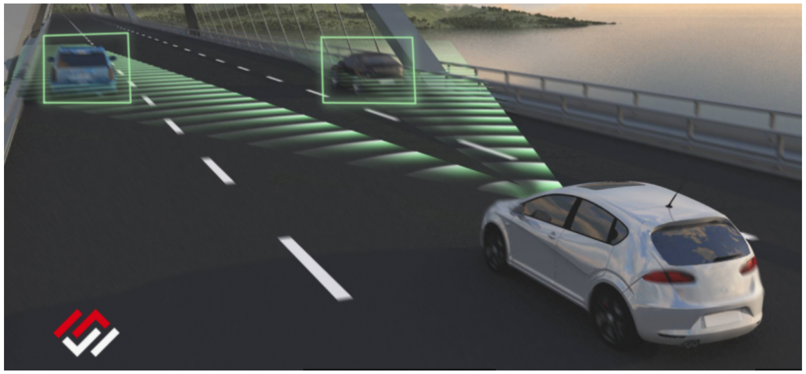


LIDAR sensing involves **shooting light beams into the environment** and **measuring the reflected return.** By measuring the amount of returned light and time of flight of the beam. Both in intensity in range to the reflecting object can be estimated. LIDAR usually include a spinning element with multiple stacked light sources. And output a three dimensional point cloud map, which is great for assessing scene geometry. Because it is an active sensor with it's own light sources, LIDAR are not effected by the environments lighting.

Comparison metrics:

1. **Number of beams** - The number of sources it contains with **8, 16, 32, and 64** being common sizes.
2. **Points per second** - The **faster the point collection**, the more **detailed the 3D point cloud can be**.
3. **Rotation rate** - **The higher this rate, the faster the 3D point clouds are updated.** Detection range is also important, and is dictated by the power output of the light source.
4. **Field of view** **-** It is the **angular extent visible** to the LIDAR sensor.

RADAR (Radio Detection And Ranging):



Radar sensor are Robust Object Detection and Relative Speed Estimation. They are particularly useful in adverse weather as they are mostly unaffected by precipitation.
Works in poor visibility like fog and precipitation!

Comparison metrics:

1. Range.
2. Field Of View (FOV).
3. Position and Speed Accuracy.

Configuration:

1. WFOV, short range.
2. NFOV, long range.

Ultrasonic:
Ultrasonic sensor are **sound navigation and ranging.** Which measure range using **sound waves**. **Sonar are sensors that are short range in inexpensive ranging devices.**
This makes them **good for parking scenarios**, where the **ego-vehicle needs to make movements very close to other cars.** Another great thing about sonar is that they are l**ow-cost.** Moreover, just like RADAR and LIDAR, they are **unaffected by lighting and precipitation conditions**. Sonar is selected based on a few key metrics.

Comparison metrics:

1. Range
2. Field of view

3. Cost

Proprioceptive:
GNSS (Global Navigation Satellite Systems) / IMU(Inertial measurement units):
GNSS receivers are used to measure ego vehicle position, velocity, and **sometimes heading**. The accuracy depends a lot on the **actual positioning methods and the corrections used.**
Apart from these, t**he IMU also measures the angular rotation rate, accelerations of the ego vehicle,** and **the combined measurements can be used to estimate the 3D orientation of the vehicle.** Where heading is the most important for vehicle control.

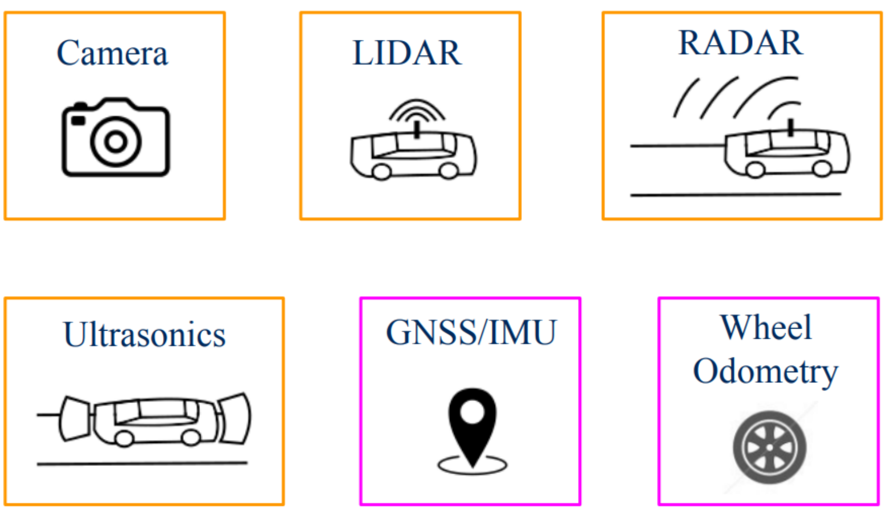
Direct measure of ego vehicle states,

1. Position, velocity (GNSS)
2. Angular rotation rate (IMU)
3. Acceleration (IMU)
4. Heading (IMU, GPS)

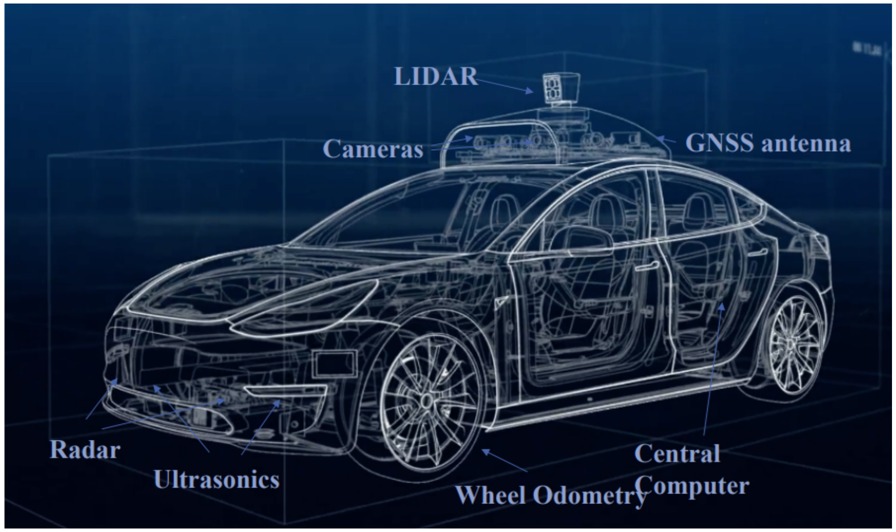
Wheel Odometry:
Tracks wheel velocities and orientation. Uses these to calculate overall speed and orientation of car.

1. Speed Accuracy
2. Position drift

Sensors needed for Perception:



Sensor positions in self driving cars:



Computing Hardware:

The self driving car needs a “self-driving brain”:

1. Takes in all sensor data
2. Computes actions
3. Already existing advanced systems that do self driving car processing (e.g. Drive PX/AGX, Intel & Mobileye EyeQ).

We use **GPU's, FPGA's** and **ASIC's** to do **Image processing, Object Detection** and **Mapping.** and, the hardware should be synchronize different modules and provide a common clock.