School of Mechanical Engineering
FACULTY OF ENGINEERING

UNIVERSITY OF LEEDS

MECH5170M
Connected and Autonomous Vehicles Systems

Perception and Sensors

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Outline

- Perception
- LIDAR
- Camera
- Ultrasonic

Perception

Human Driver Perception

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Main senses used during driving:

1. Vision
2. Vestibular (acceleration, deceleration)
3. Hearing

Number	**Sense**	**Absolute threshold (obsolete system of signal detection used)**
1	Hearing	Ticking of a watch 6 m away, in an otherwise silent environment
2	Vision	Stars at night; candlelight 48 km (30 mi) away on a dark and clear night
3	Vestibular	Tilt of less than 30 seconds (3 degrees) of a clock's minute hand
4	Smell	A drop of perfume in a volume of the size of three rooms
5	Touch	A wing of a fly falling on the cheek from a height of 7.6 cm (3 inches)
6	Taste	A teaspoon of sugar in 7.5 liters of water

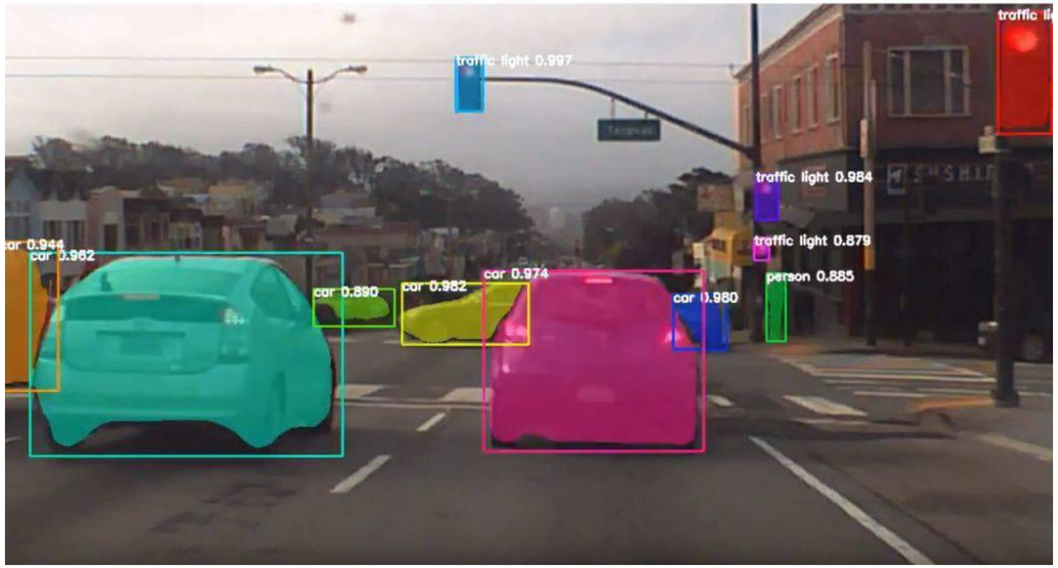
*[Galanter, E. (1962). "Direct measurement of utility and subjective probability". American Journal of Psychology. **75** (2): 208–220.]*

Autonomous vehicle control

Perception system requirements

- Perception System for Autonomous Vehicles
  - Standalone
  - Reliable
  - Inexpensive
  - Object Detection and Classification
  - Full-Range

Perception: How Self-Driving Cars 'See' the World



Functional Requirements

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- Conduct full-range perception
- Perceive in real-time
- Use multiple sensors
- Detect and identify objects
- Classify objects
- Estimate vehicle motion
- Be self-contained

Performance Requirements

Detect objects up to 150 m

Unify sensor data up to 50 m

Acquire sensor data at up to 20 Hz

Detect object size with an accuracy of up to 90%

Detect object distance with an accuracy of up to 95%

Detect object velocity with an accuracy of up to 90%

Classify objects with an accuracy of up to 80%

Estimate vehicle motion with an accuracy of up to 90%

Functional Architecture

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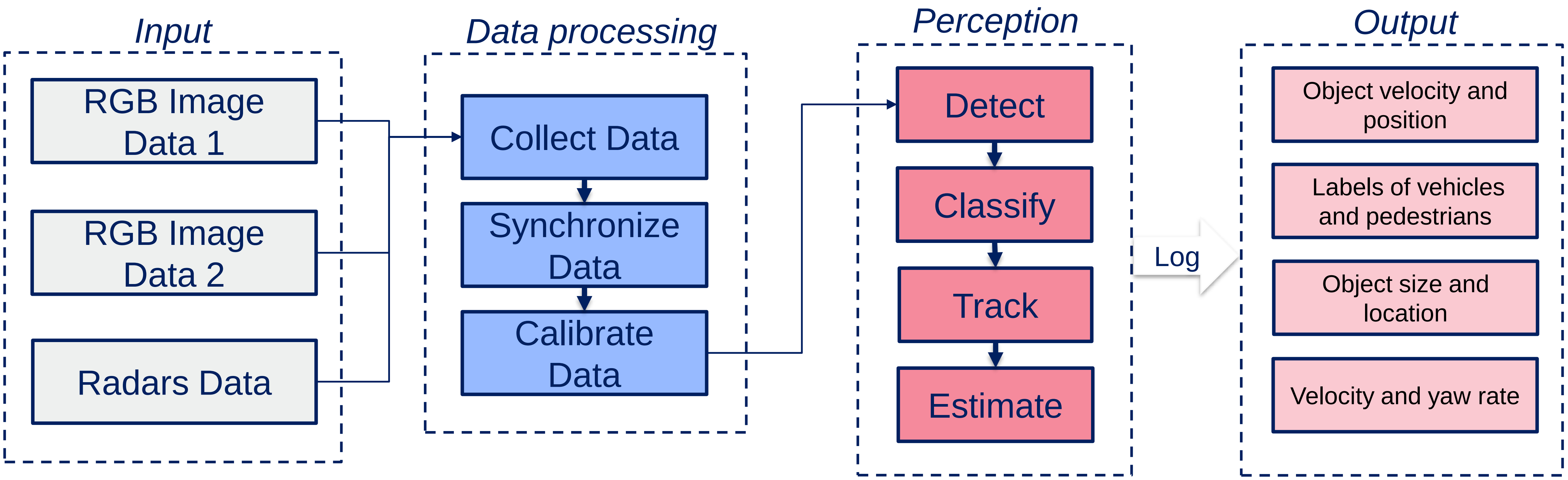


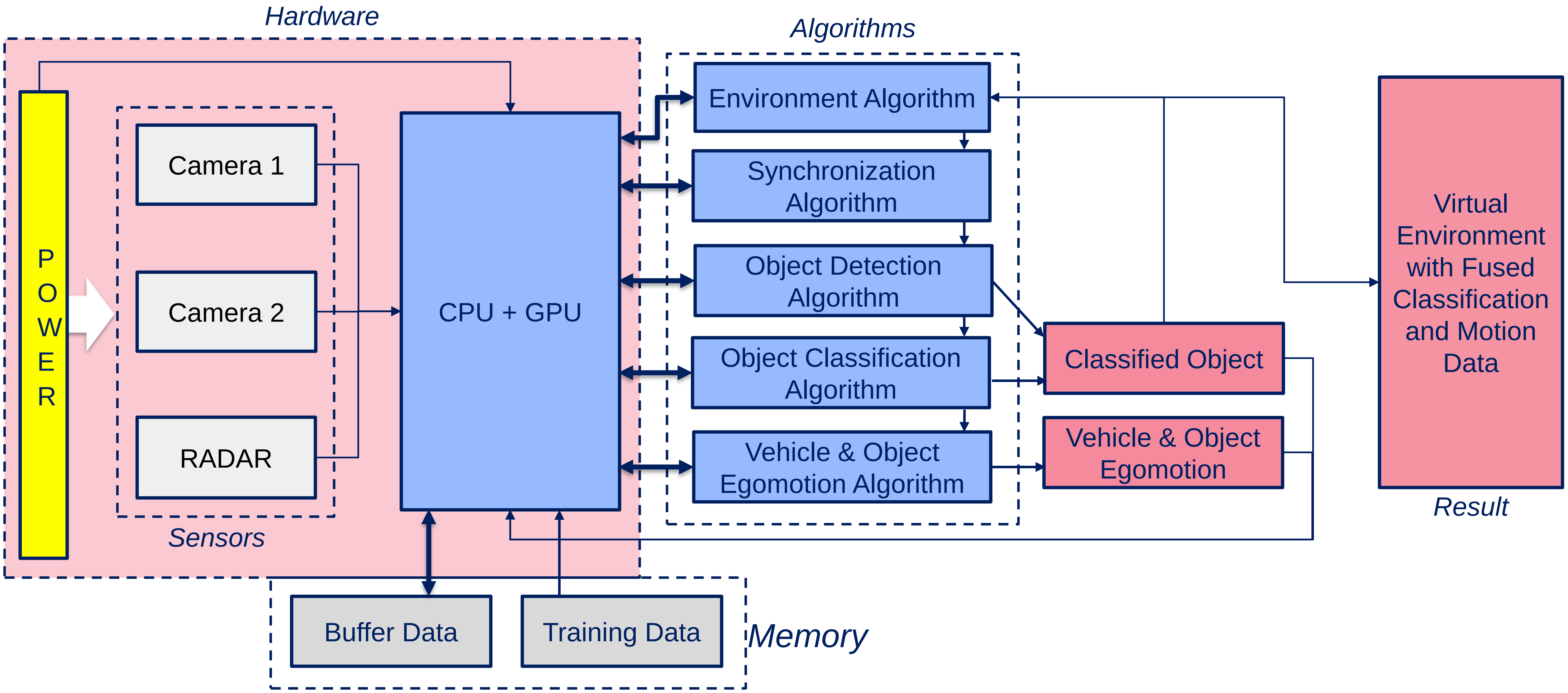
Camera, Radar, Lidar, Ultrasound

Different cameras
Different sizes

Python – Development
C, C++ - Embedded

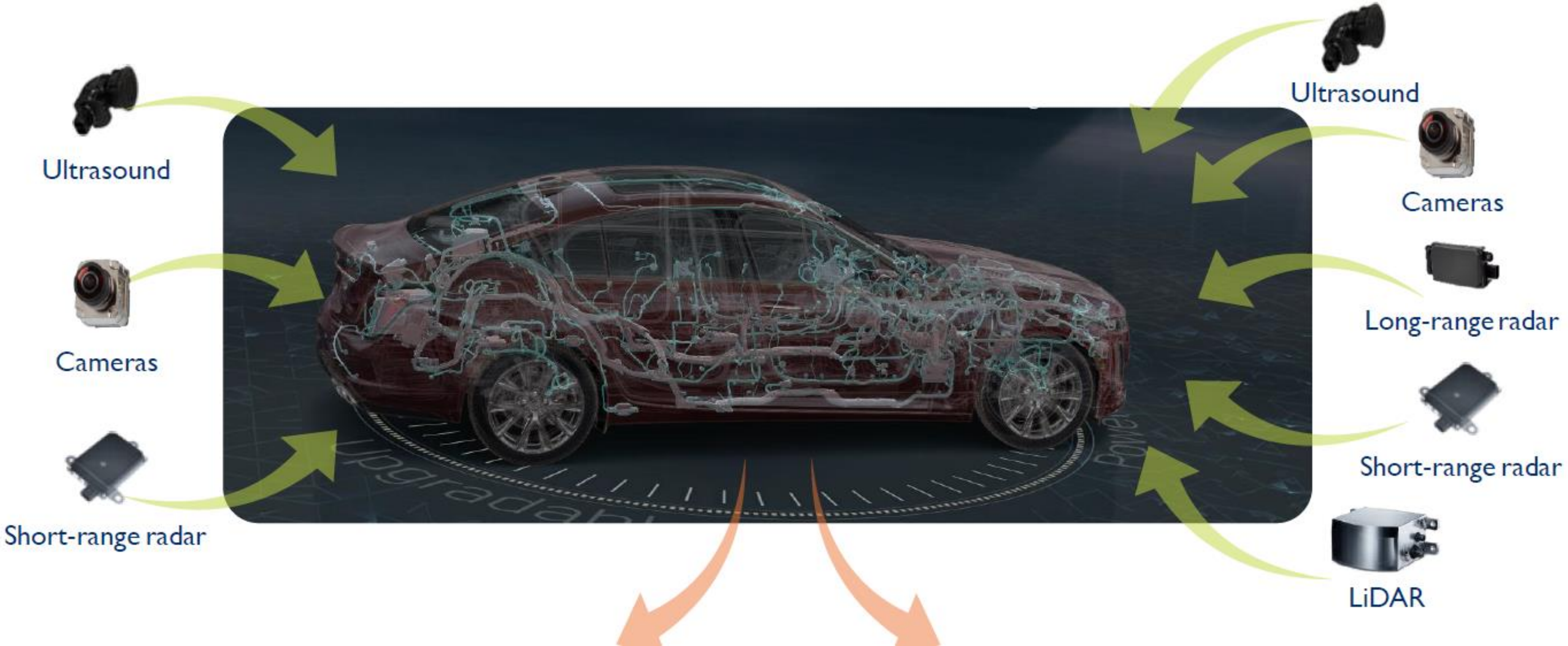
Example of output data

Cyber-physical Architecture



Type of sensors

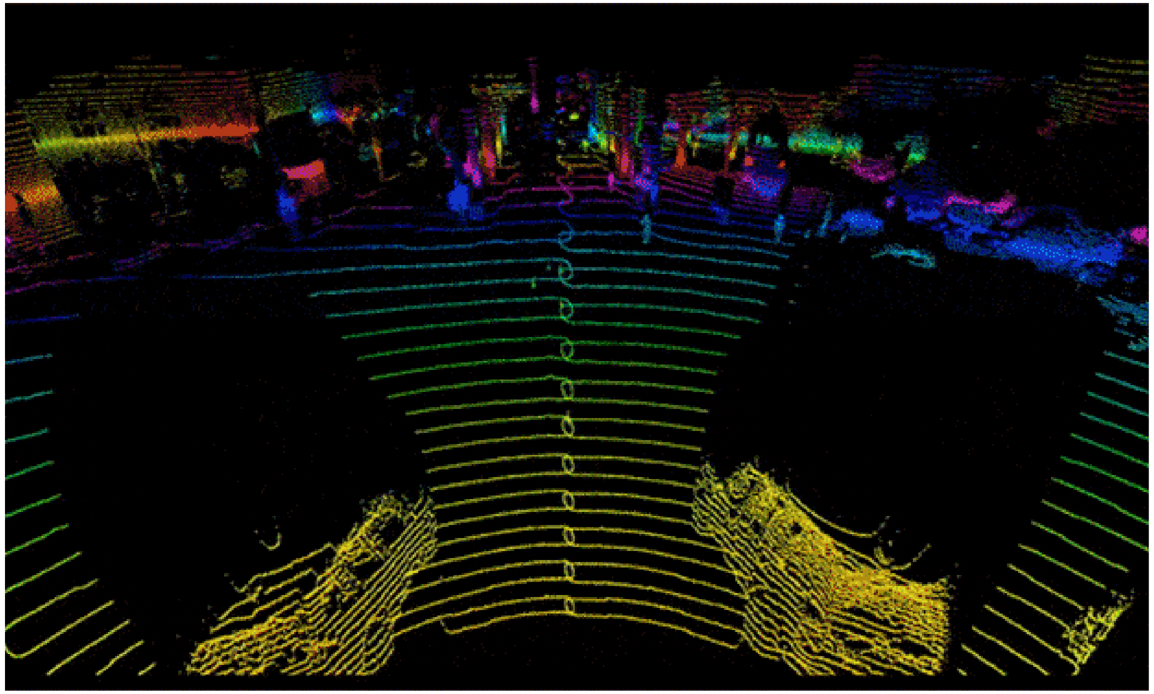
- GPS (Global Positioning System)
- IMU (Inertial Measurement Unit)
- LIDAR (light detection and ranging)
- Video Cameras
- Radar Sensors
- Ultrasonic



LIDAR

LIDAR

- High accuracy – distance data
- High output rate
- Output point cloud
- Cost: Expensive
- Fragile



Lidar - Operation Principle

LIDAR determines the distance of an object or a surface with the formula:

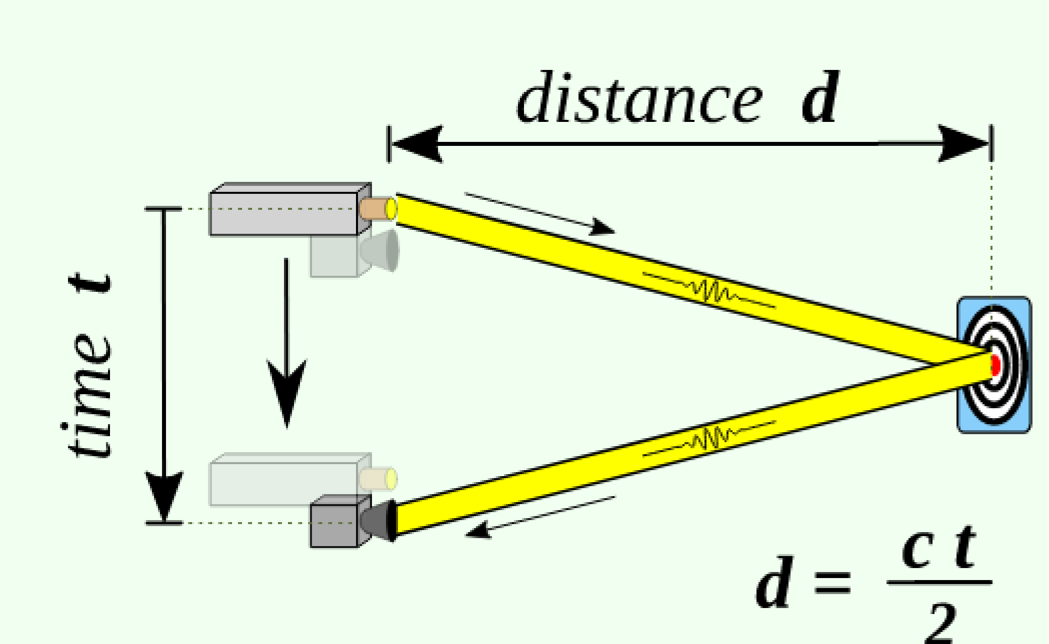
$$d = \frac{c \cdot t}{2}$$

where:

c is the speed of light,

d is the distance between the detector and the object or surface being detected,

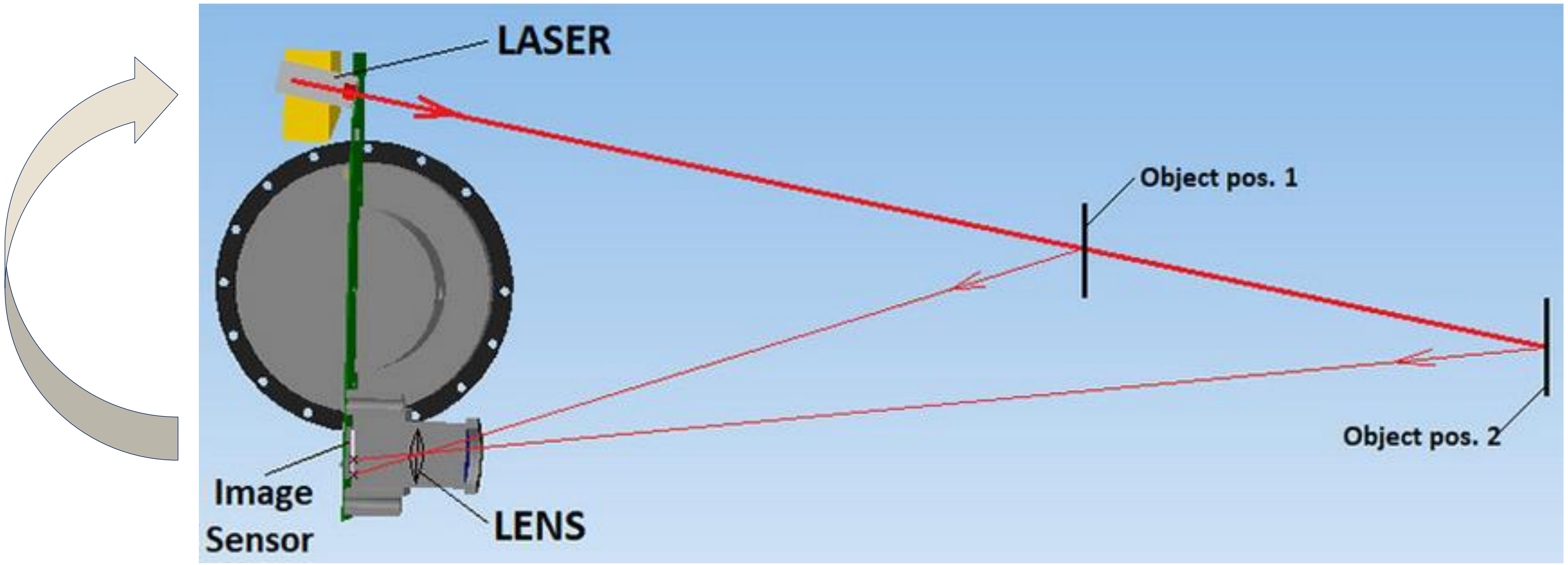
t is the time spent for the laser light to travel to the object and back to the detector.



[wikimedia]

2D LIDAR system

- Mechanical rotation
- Low frequency (few Hz only)

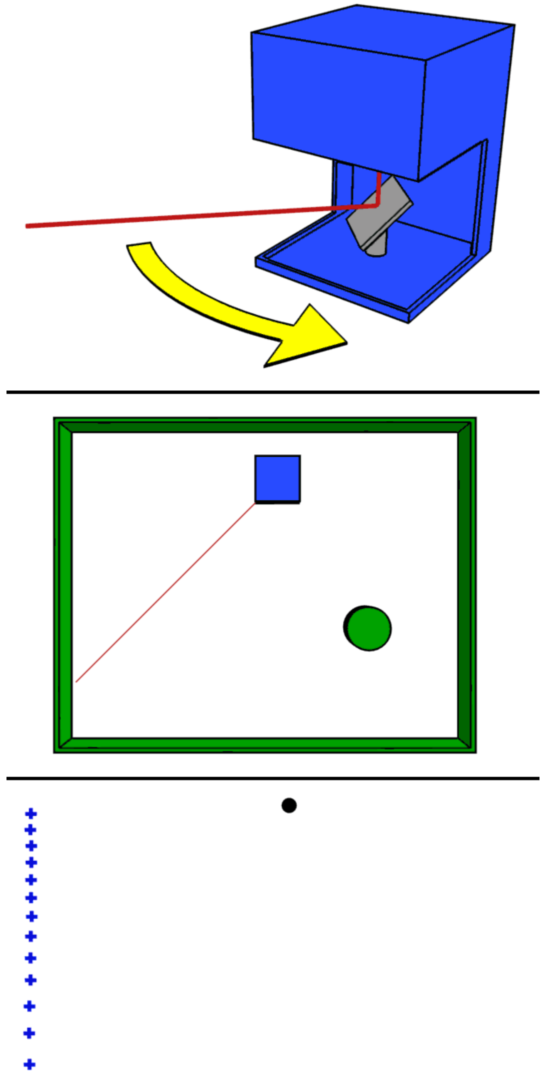


LIDAR

Types:

- Planar
- Multi beam
- Image like
- Solid state

- Laser allows the vehicle to generate a detailed 3D map of its environment.
- The car then takes these generated maps and combines them with high-resolution maps of the world.



[wikimedia]

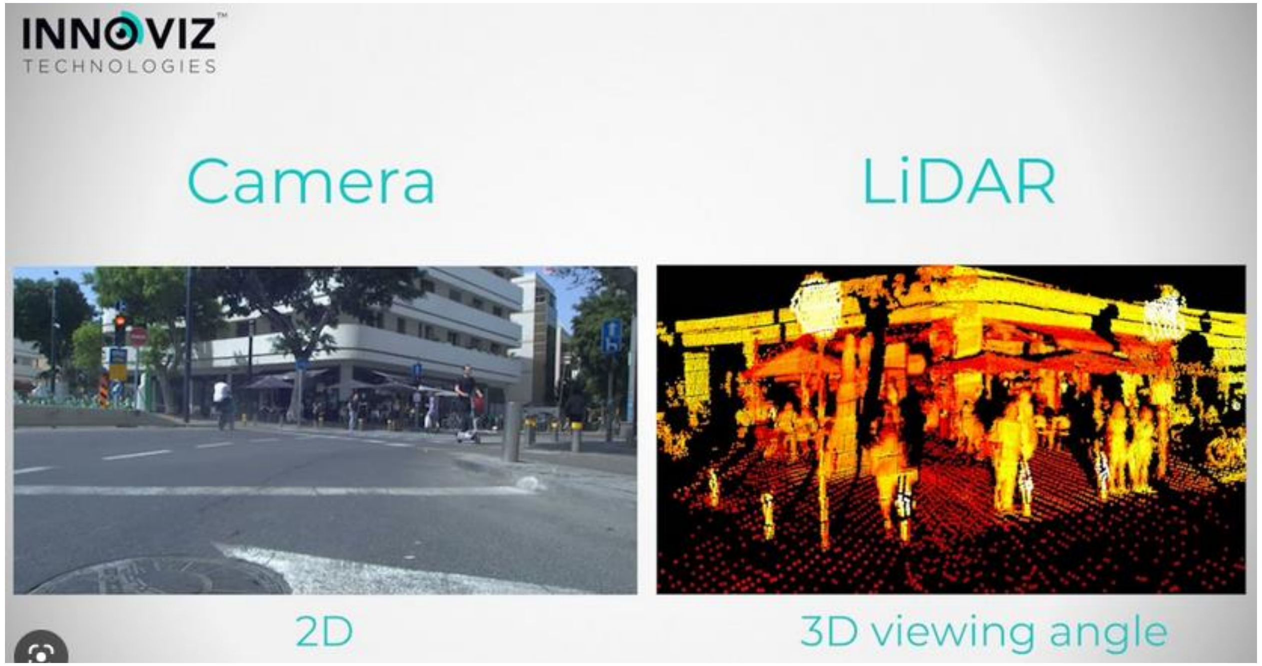
LIDAR vs. No-LIDAR

LIDAR:

- LIDAR was very expensive (£70K) in 2000 now about £2-5k
- LIDAR has other latency problems (data transfer issues)
- High volume of data (cloud points to process)

Camera:

- 2D image
- Night vision problems



Camera Vision

Number of cameras per car

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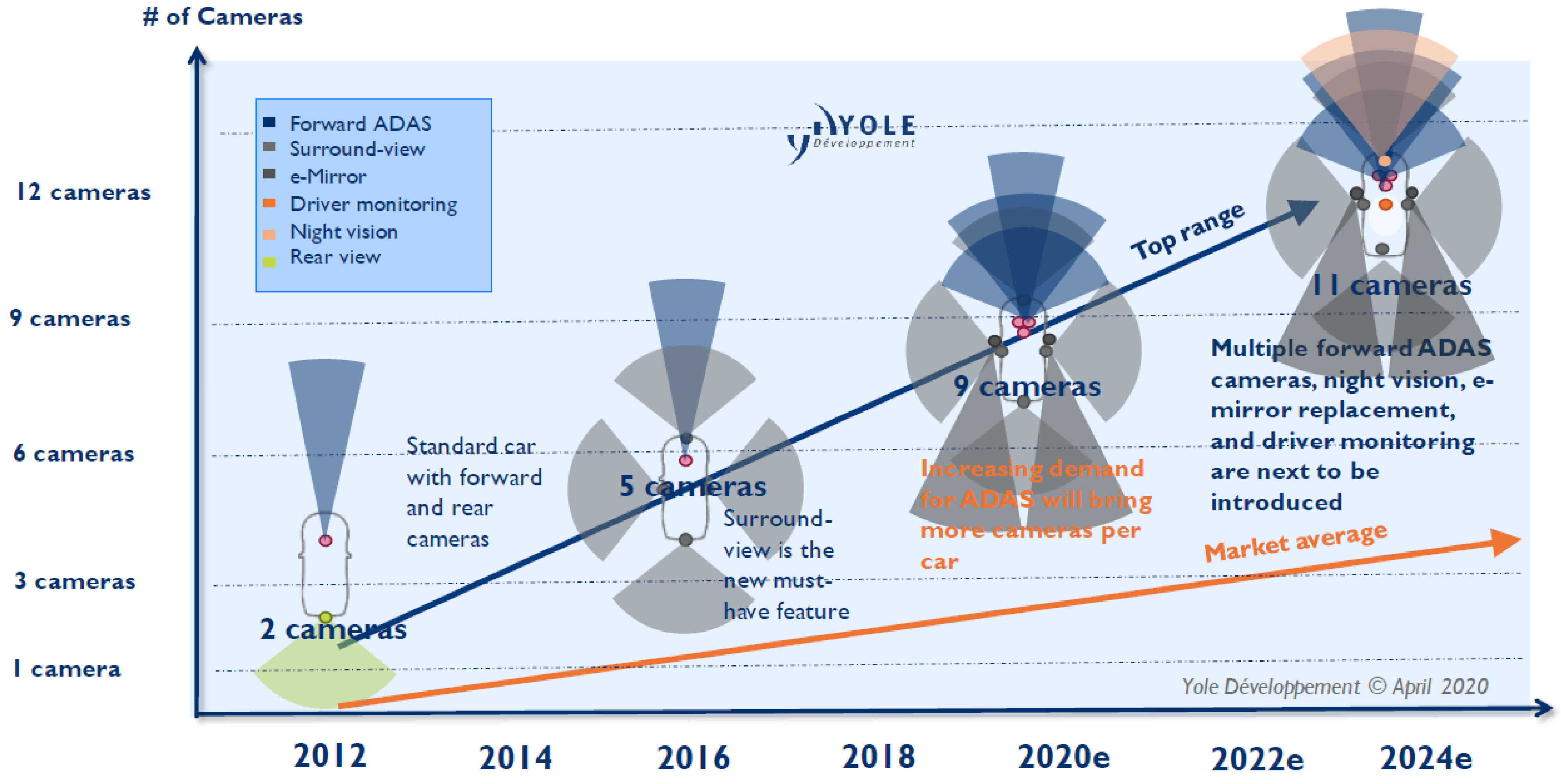


Cameras

- High output rate
- Lots of data
- Versatile
- Cheap
- Computationally expensive
- Huge variety to choose from

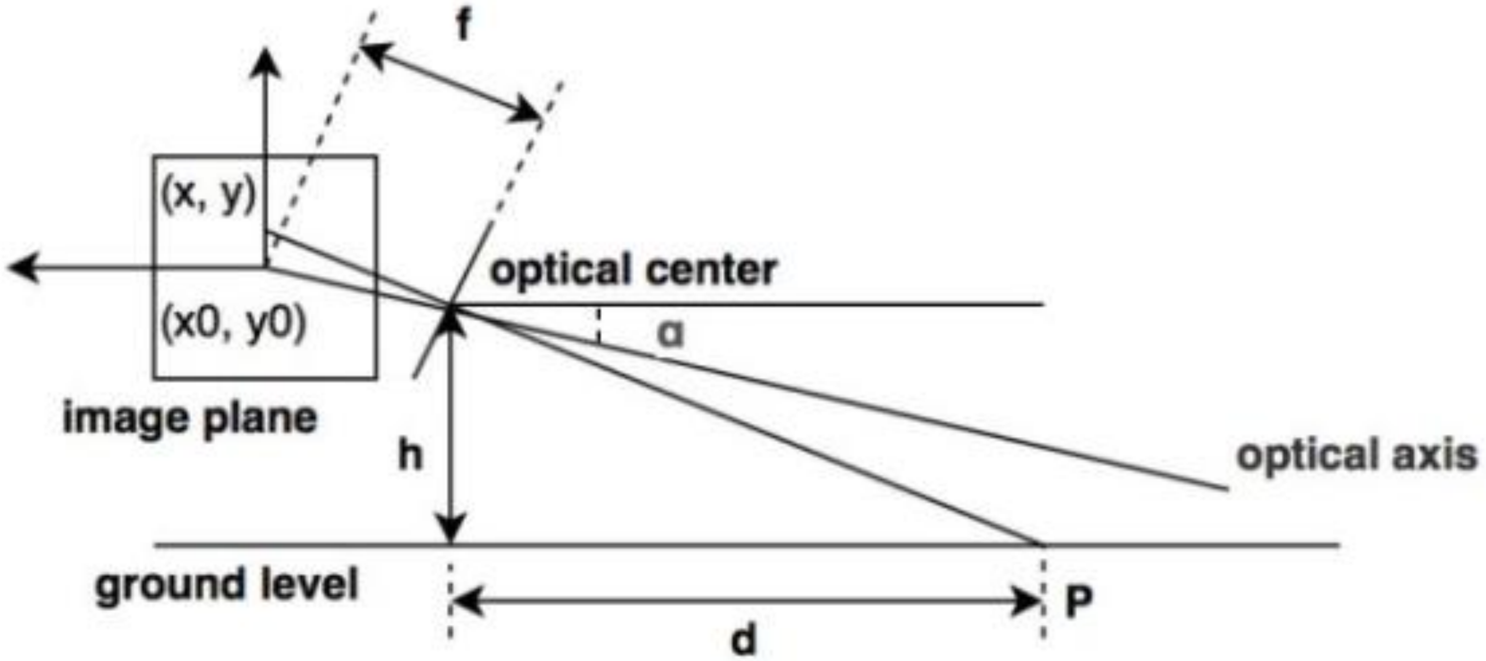
Types:

- Monocular
- Stereo

Monocular vision

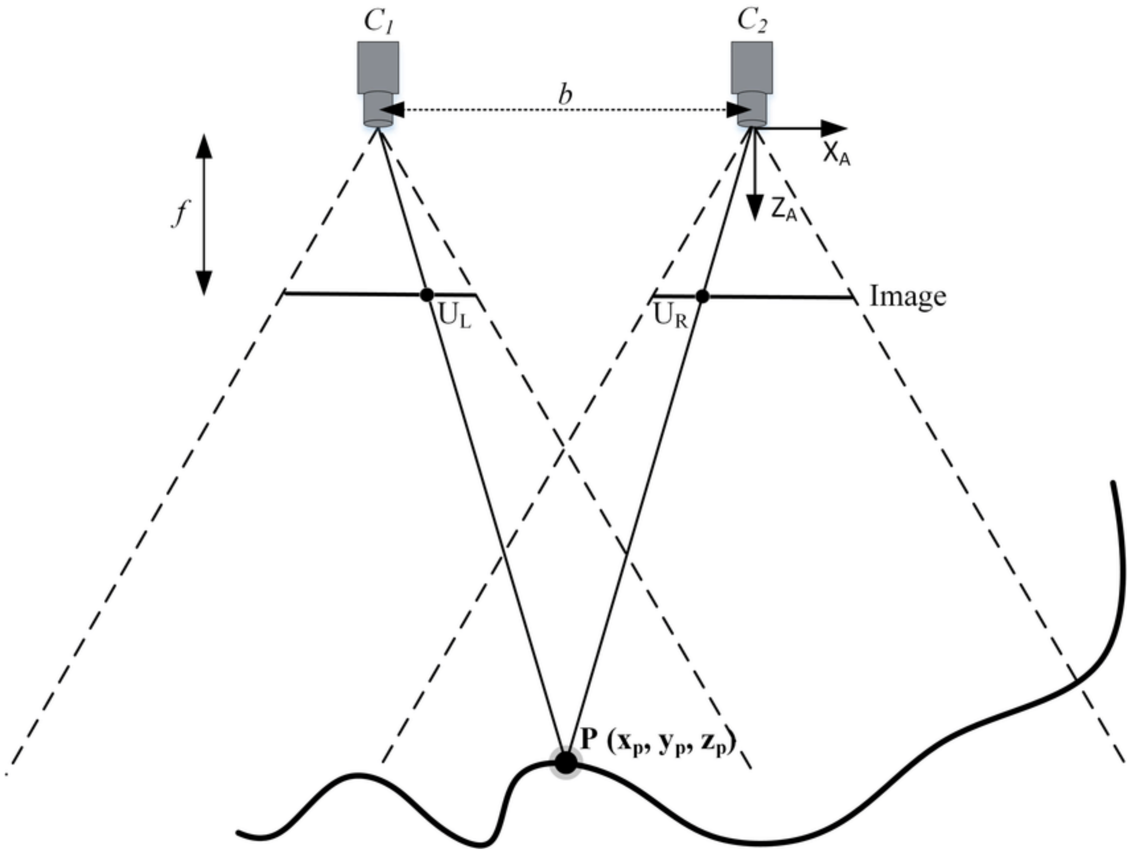
- Distance possible to estimate
- Very low accuracy

$$d = h/\tan(\partial + \arctan(\frac{y - y_0}{f}))$$



Stereo vision

- Better distance estimation
- Could points possible to obtain
- Less accurate than LIDAR
- Contain processing unit



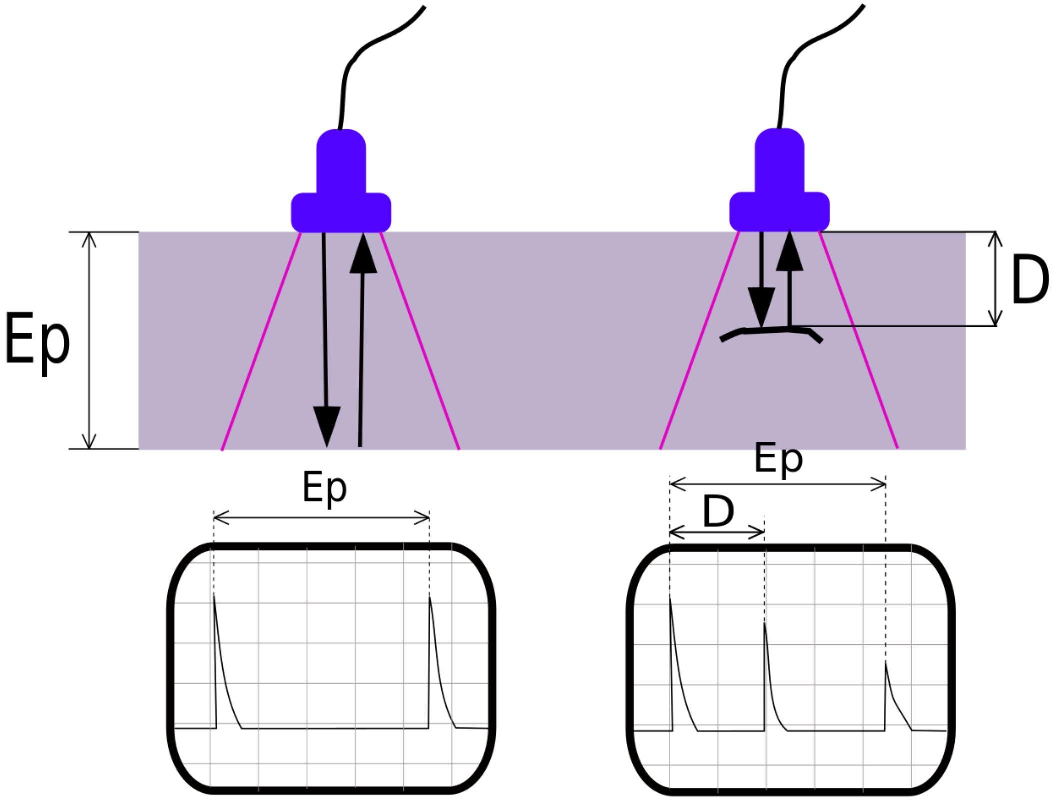
Intel® RealSense™ Depth Camera D455 Features (£400)

- Intel® RealSense™ Vision Processor D4
- Up to 1280x720 active stereo depth resolution
- Up to 1280x800 RGB resolution
- Diagonal Field of View over 90°
- Dual global shutter sensors for up to 90 FPS depth streaming
- RGB global shutter sensor for up to 90 FPS
- Range 0.4m to over 10m (Varies with lighting conditions)
- Includes Inertial Measurement Unit (IMU) for 6 degrees of freedom (6DoF) data

Ultrasonic sensors
IMU / GPS

Ultrasonic sensors

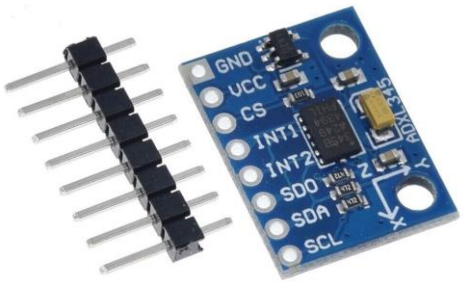
- Small range - distance <5m
- Can detect obstacles
- Speed of sound limitation
- Sound frequency >20kHz
- Quite low measurement frequency



[instrumentationtools.com]

IMU and GPS

- Huge variety!
- Estimate location in 3D space
- From £5 to £1000
- Quality varies greatly

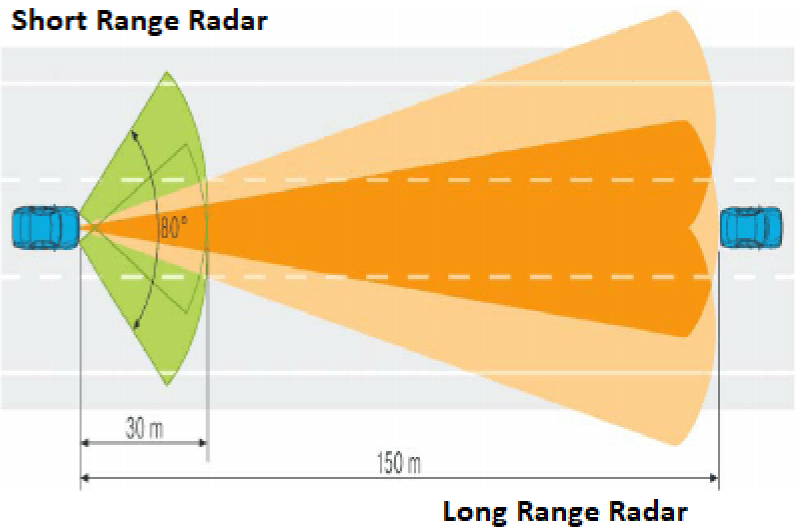


Radars

Detect the speed and range of objects in the vicinity of the car.

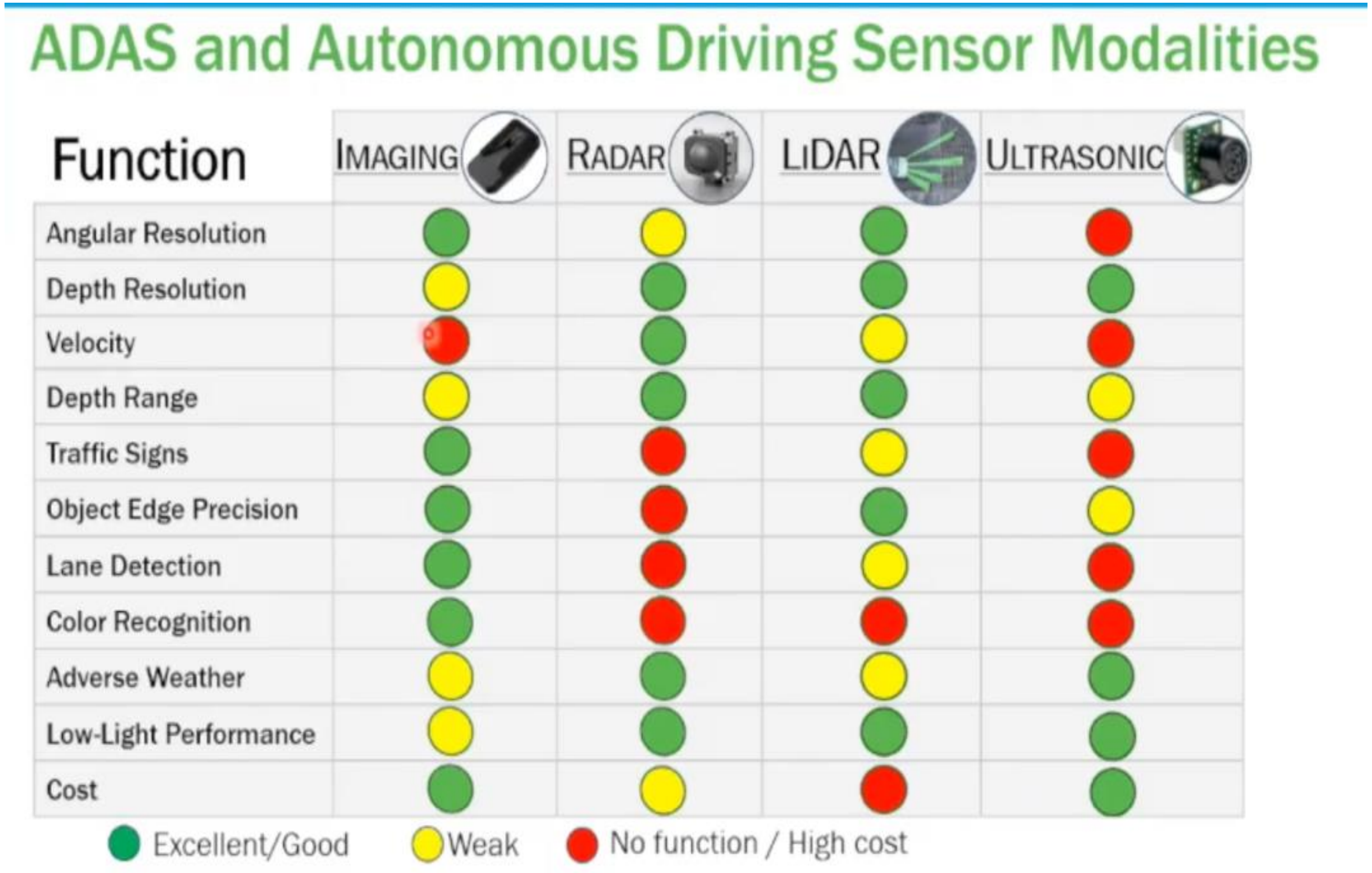
The transmitter sends out radio waves that hit an object and bounce back to the receiver, determining the objects' distance, speed and direction.

Short-range radars (SRR)
Use the 24 GHz frequency and are used for short range applications like blind-spot detection, parking aid or obstacle detection and collision avoidance.



Long-range radars (LRR)
Use the 77 GHz band (from 76-81GHz) provide better accuracy and better resolution.
Range up to 200m

Sensors functionalities



Conclusions

Multiple sensors are required to increase resolution and accuracy of environment perception:

- GPS (Global Positioning System) – Low frequency updates
- IMU (Inertial Measurement Unit) – high frequency, local data
- LIDAR (light detection and ranging) – good depth perception, expensive
- Video Cameras – low depth perception, poor night vision
- Ultrasonic – low range, low frequency, not affected by bad weather, except snow

ANY QUESTIONS ???