Lecture 2 | Functional Design & Sensors

Secure Autonomous Systems

CSCI 6907/3907 88

Fall 2022

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https://bit.ly/secureauto-fall22

TA

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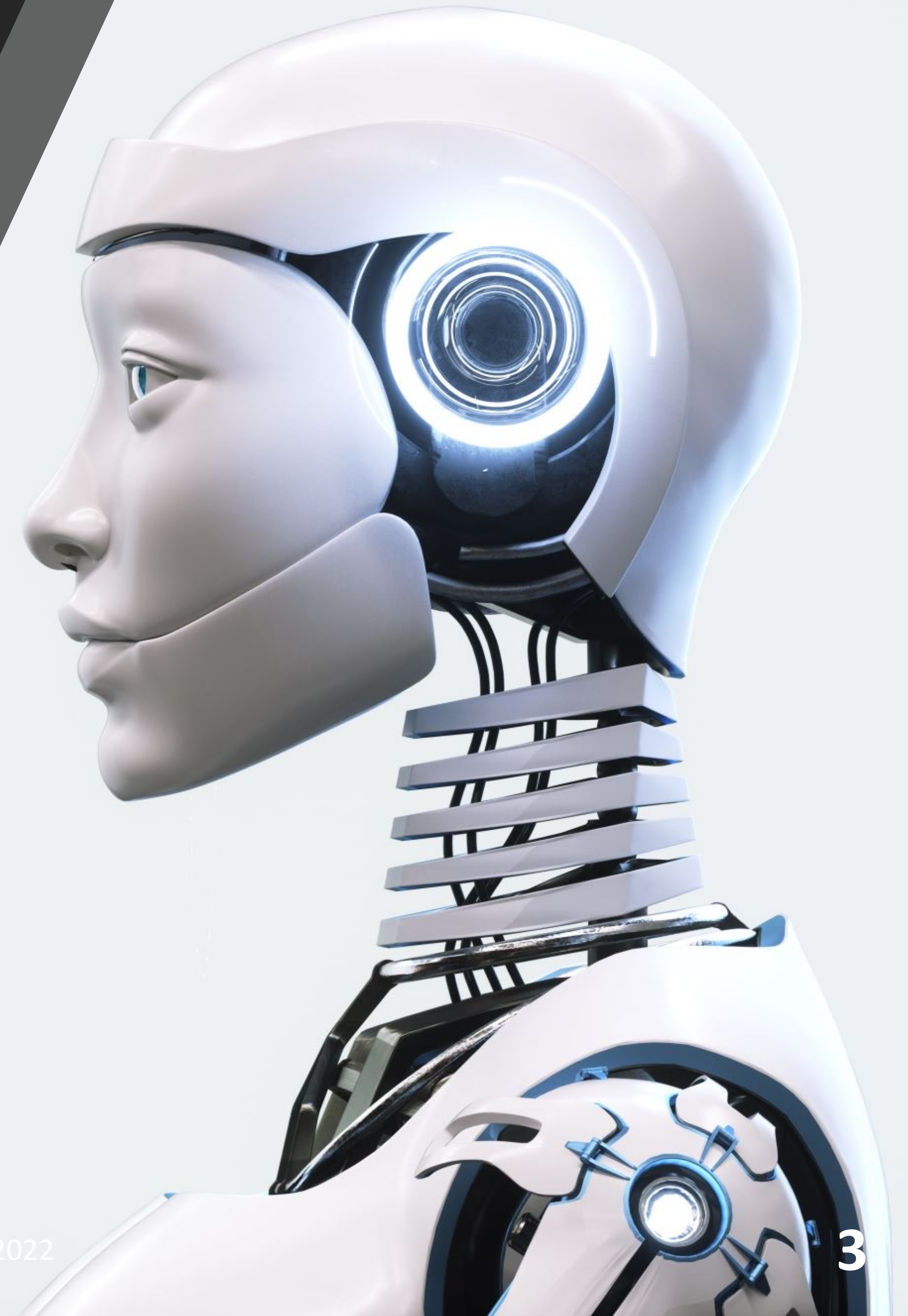
Note: contact via **Blackboard** first

Autonomy | A Definition

Autonomy is the **ability to perform given tasks** based on the **system's perception** without **human intervention**



Aspects of Autonomy

- Perception
- Compute
- Actuation
- Planning
- Sensing
- Motion

Functional Architecture

- specification of
  - **intended functions** and
  - **necessary interactions**

to achieve **desired behaviors**

Some Common Definitions

OEM → original equipment manufacturers [integrators]

ECU → electronic control units

CAN, Flexray → communication buses/standards

AUTOSAR → software technology platforms

Automotive Standards and Definitions

SAE J3016 Standards

- Dynamic Driving Task (DDT)
- Driving Automation System
- Operational Design Domains (ODD)
- DDT fall-back
- DDT fall-back-ready user
- DDT feature

Dynamic Driving Task [DDT]

- Real-time **operational** and **tactical** functions to operate a vehicle

- Driving a car on fixed trajectory
- Actuator control
- Keeping vehicle in lanes
- Maintaining distance from other vehicles

Driving Automation System

- Hardware+Software capable of some or all of DDT

- Design-specific functionality, **features**
- Automated parking, lane keep assistance

Operational Design Domains [ODD]

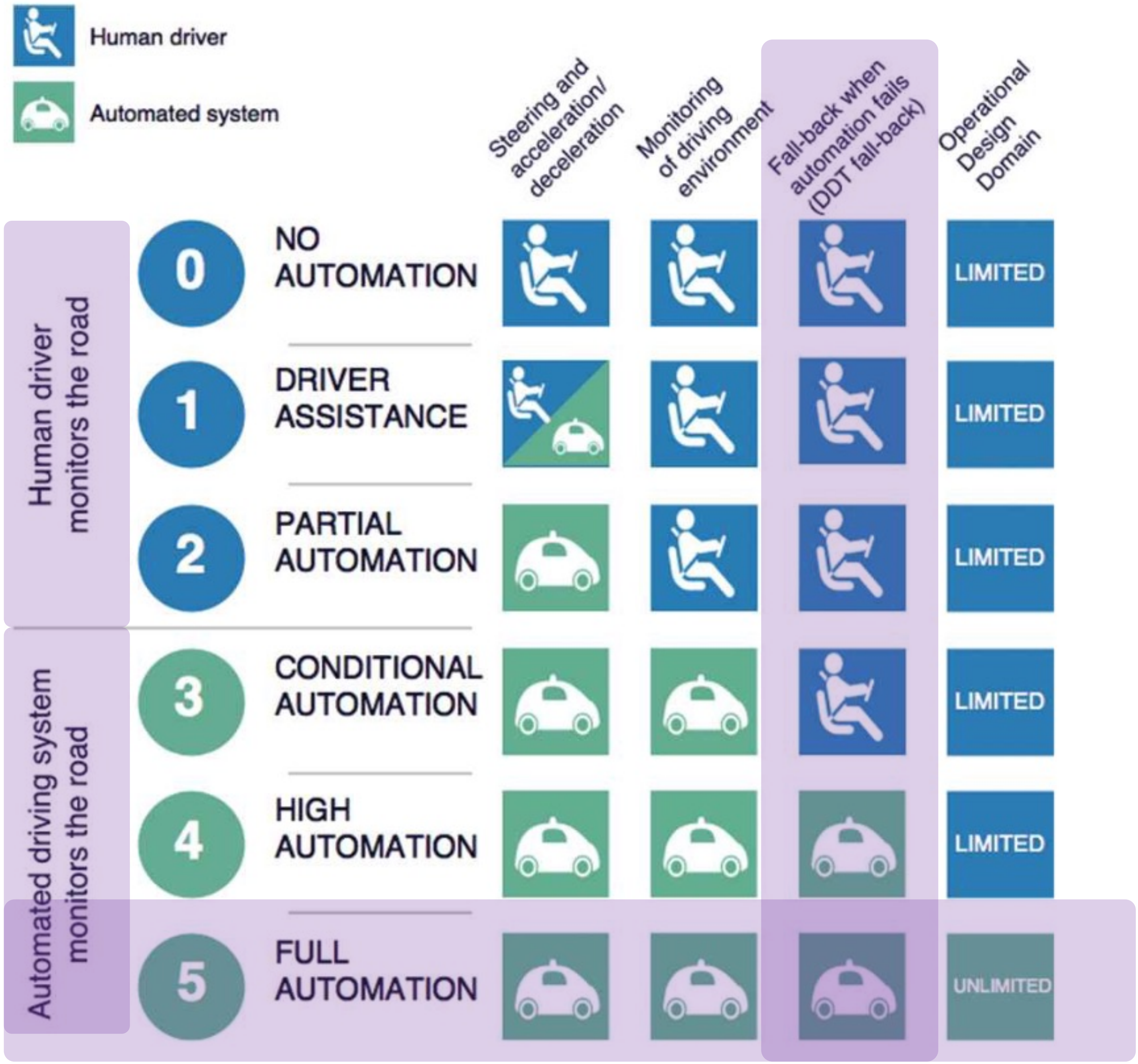
- **Specific conditions** under which driving automation system is to function

- **Design phase** requirements
- E.g., Woårk in sunny weather in city grid

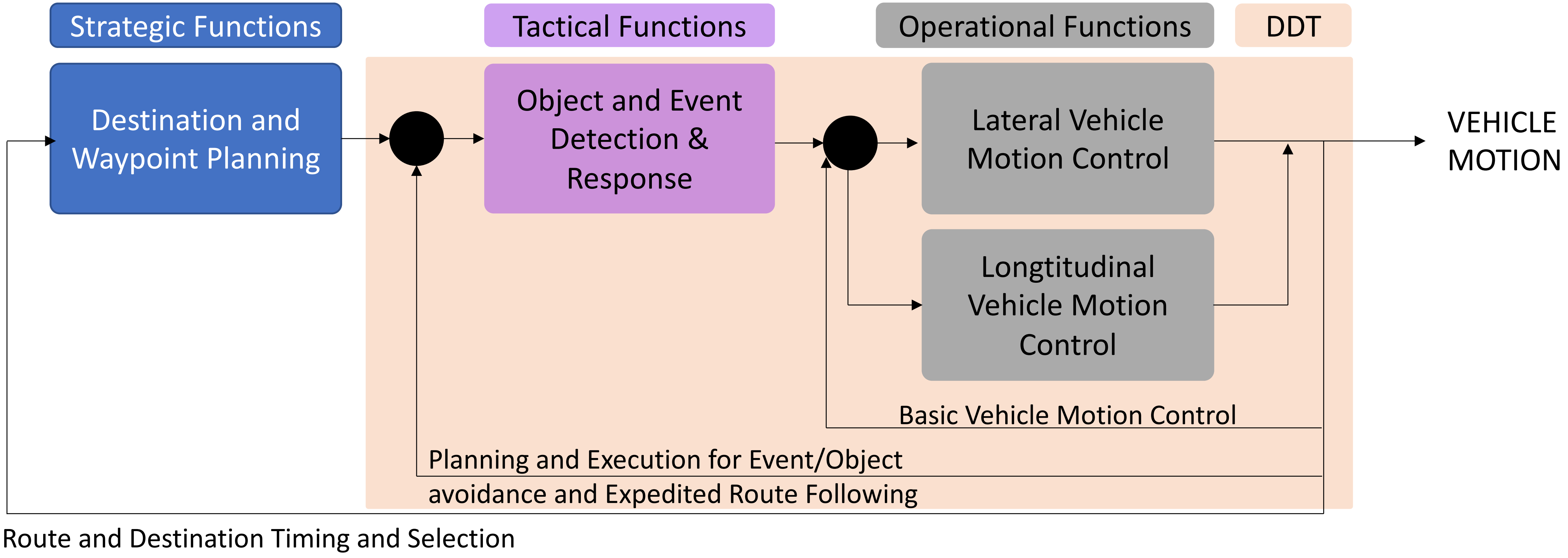
Some more definitions

- DDT fall-back
- DDT fall-back-ready-user
- DDT feature

SAE Classification

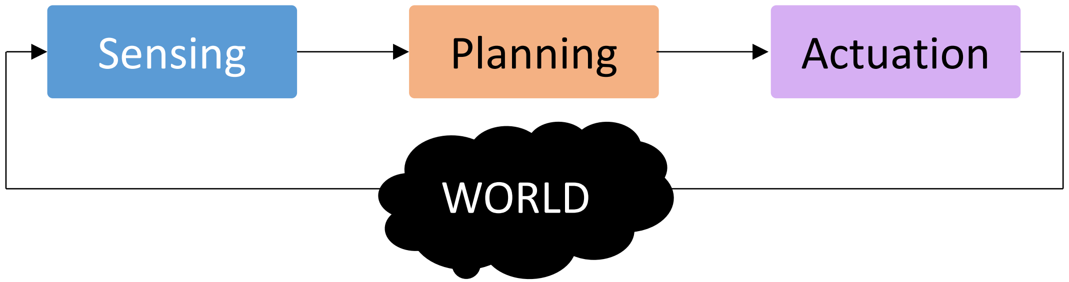


Functional Components



Software Design

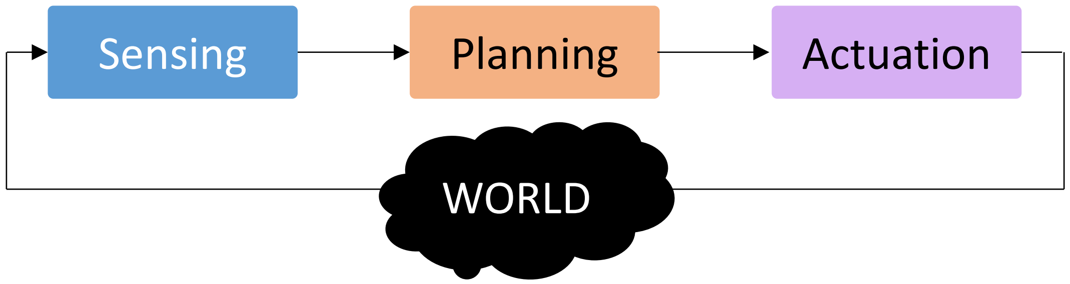
- Analogous to real-time systems design



Planning

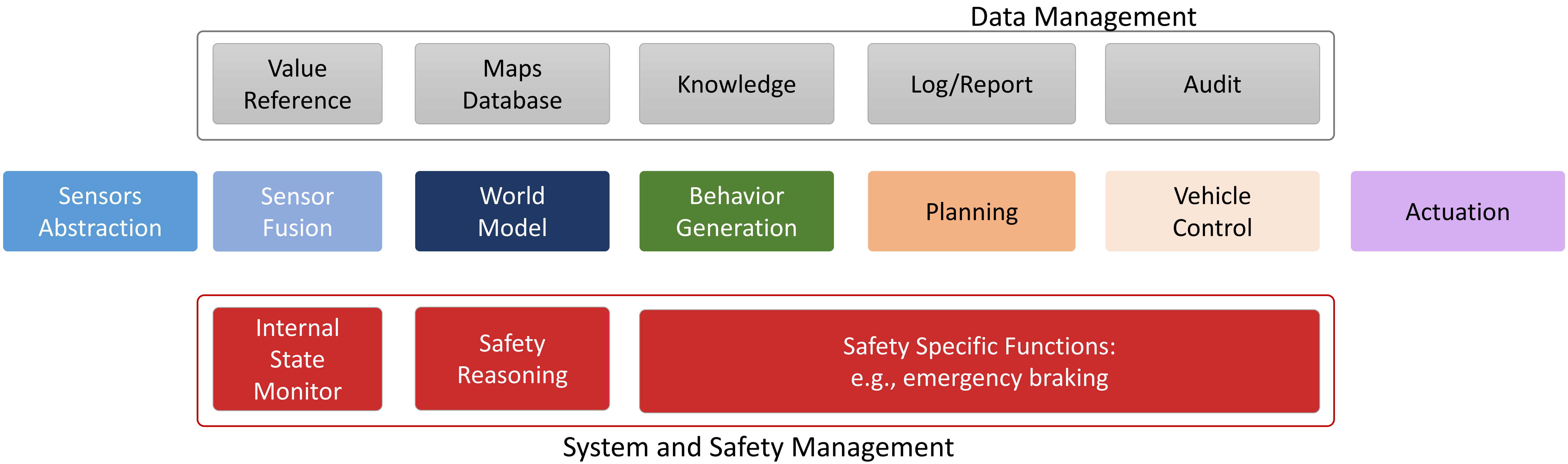
- system maintains an **internal state representation**
  - position itself in environment
  - plan next actions
- Must be up-to-date and accurately reflect environment
  - requires **a lot of information**!
- With increasing complexity of operational environment
  - complexity of internal representation also increases
  - More time to plan next steps
  - New plans may be obsolete **before** they're deployed!

Sensing, Planning, Actuation
Functional Decomposition

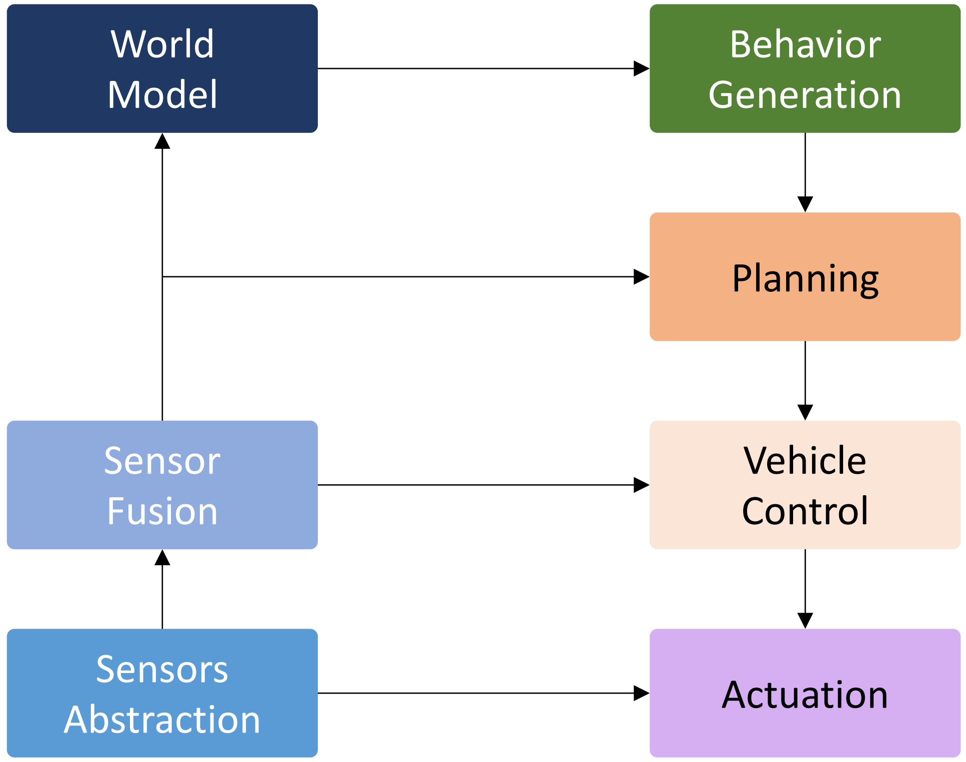


Sensors Abstraction	Sensor Fusion	World Model	Behavior Generation	Planning	Vehicle Control	Actuation
RADAR LIDAR Cameras GPS V2X Internal St	Object Det Global Pos Local Pos Vehicle State	Internal Model External Model Data Sinks Bird's Eye View	HMI Route i/p Global Routing Behavior Gen. Behavior Select	Path Planning Monitoring Lane Keeping Lane Change Collision Avoid HMI Driver Alert	Lateral Longitudinal Trajectory Intention Comm.	Steering Brake Throttle Transmission

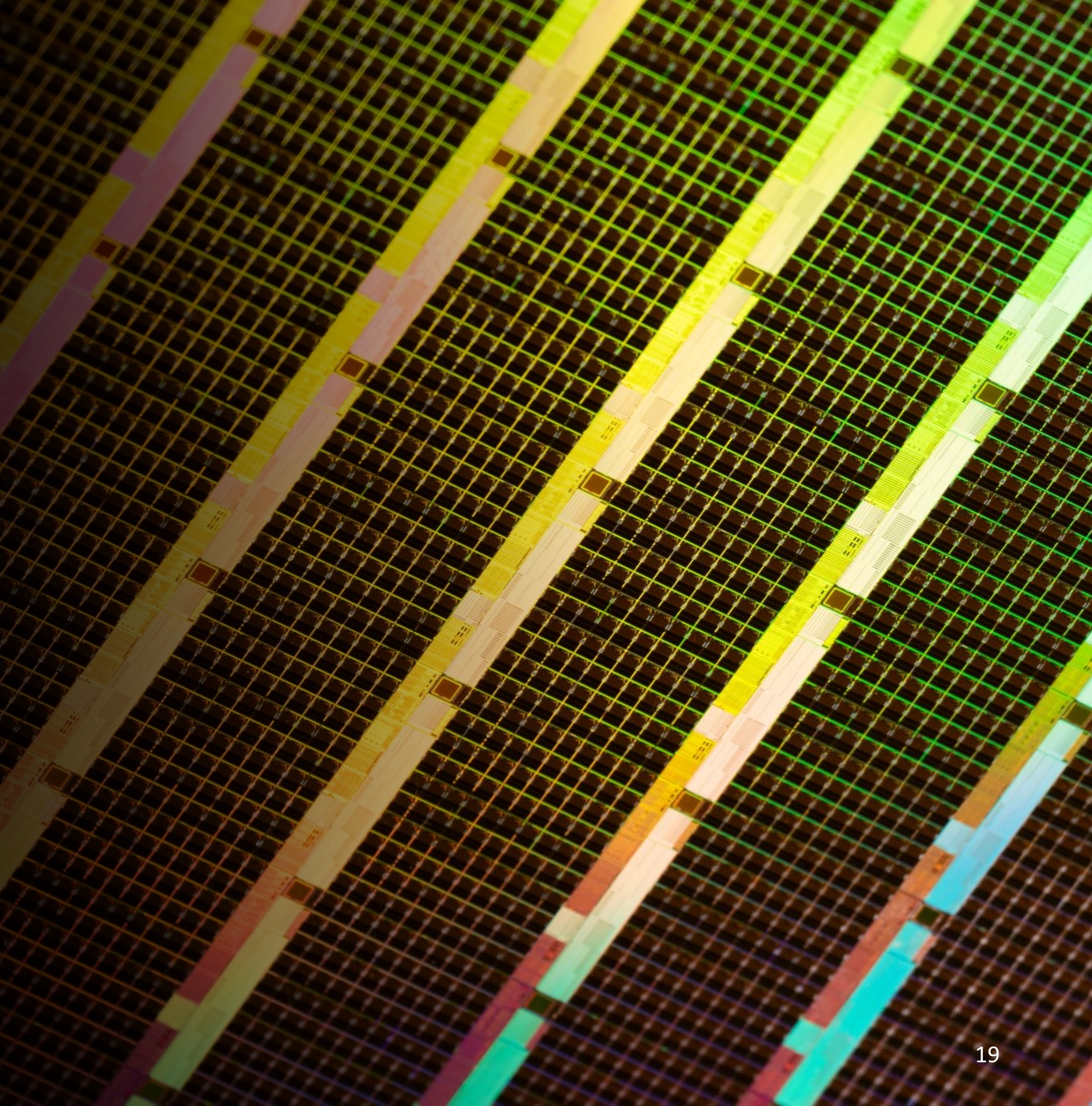
Orthogonal Classes



Functional Architecture



Sensors and Sensor Abstractions



Sensors

“perception”

Interface to the external world

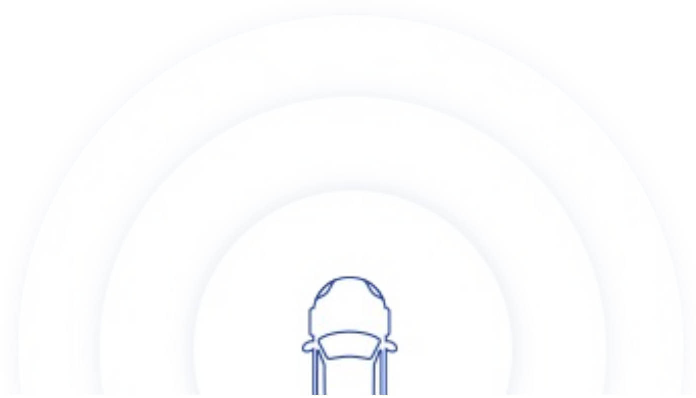
Sensor “plan” will balance
- Function
- Range
- Cost

Common Sensor Types

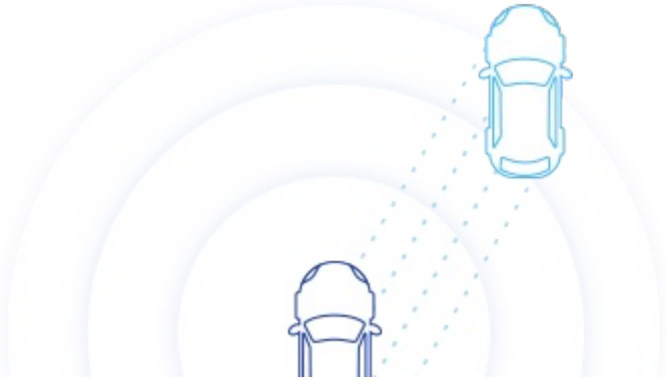
- **LiDAR/Millimeter Rada**
- **GPS**
- **Cameras:** lane, road, traffic light, stop line, surroundings
- **Stereo Vision**
- **Sonic**

LiDAR

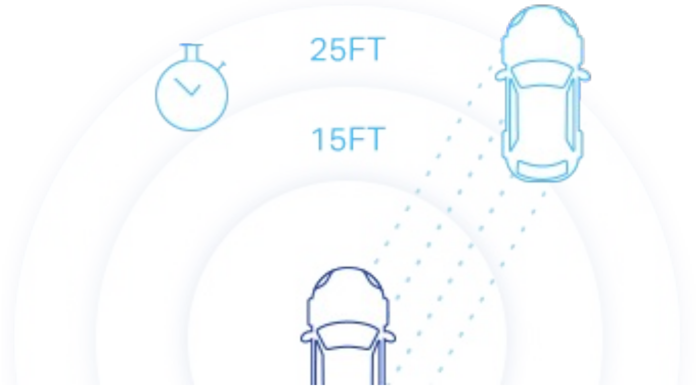
- **Li**ght **D**etection **A**nd **R**anging
- Laser scanning/3D scanning
- Uses eye-safe laser beams ➔ create 3D representation of environment



A typical lidar sensor emits pulsed light waves into the surrounding environment



These pulses bounce off surrounding objects and return to the sensor



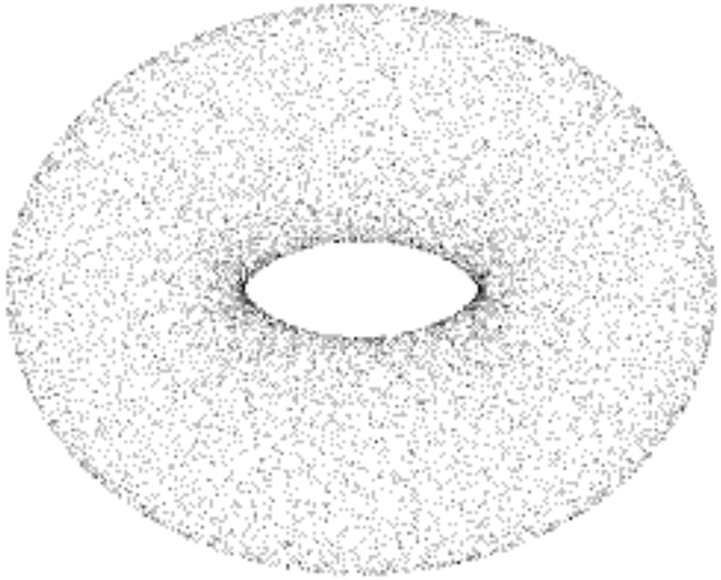
The sensor uses the time it took for each pulse to return to the sensor to calculate the distance it traveled

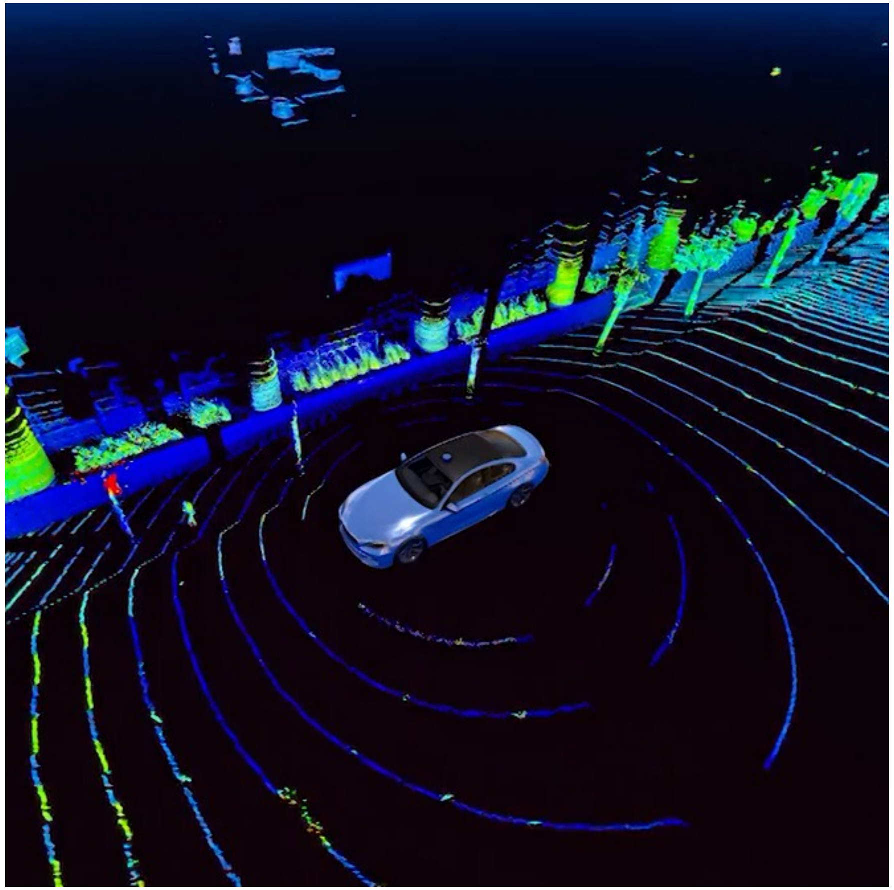
LiDAR Output

Point clouds In 3D

Range: **70-100** m

View: **360 degrees**





Millimeter Wave Radar [mmWave]

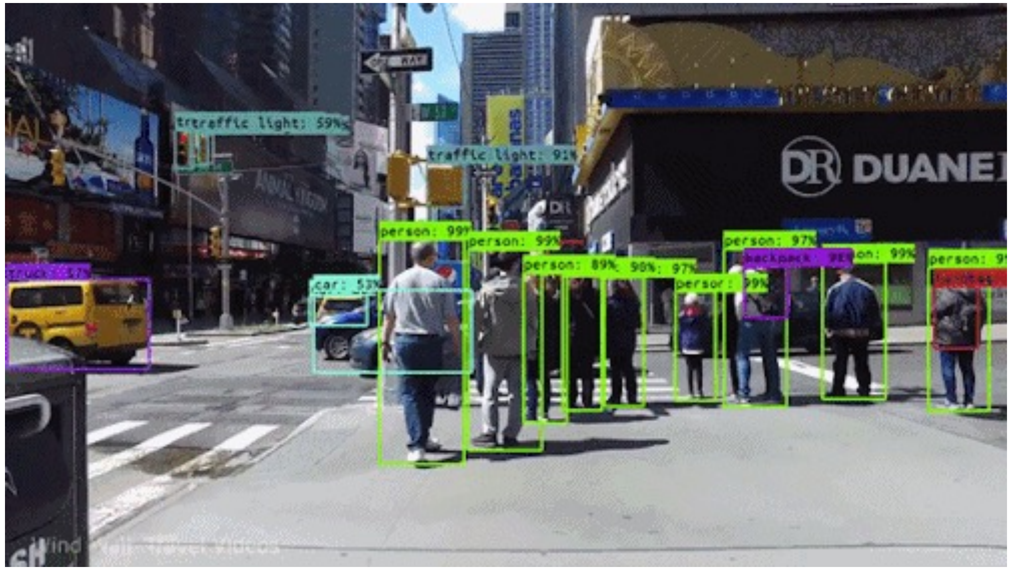
- Radar technology
- short-wavelength electromagnetic waves
- Measures reflected radar signals

- **High accuracy**
- 76-81 GHz ➔ detect movements in a **fraction of a millimeter**!
- Limited distance [< 80m]

- Also, used for in-cabin monitoring of drivers

Cameras

- Accurate way to create visual representations
- Front, left, right, rear cameras
  - to create **a 360-degree view**
- Main focus ➔ **object detection**

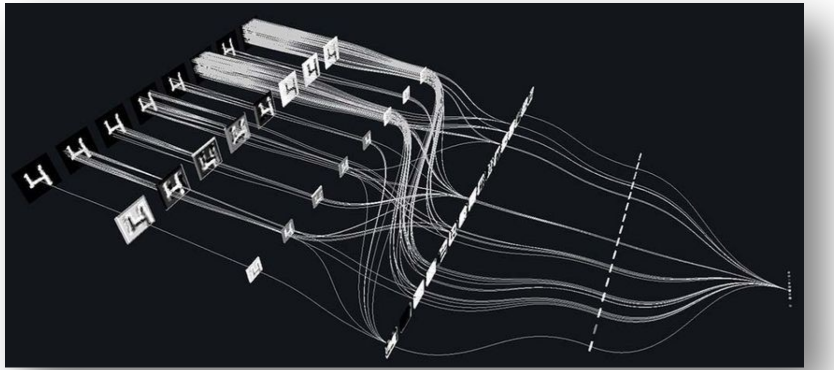


Cameras | Computer Vision

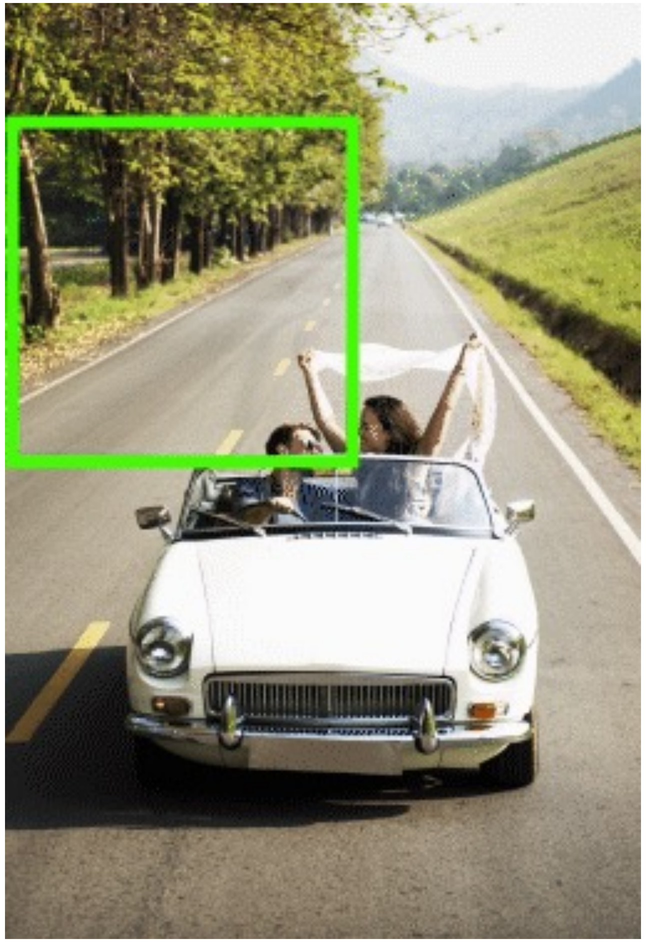
- Computer Vision algorithms for object detection
  1. Image classification → determine objects in an image are
  2. Image localizations → providing specific locations of image [bounding box]

Cameras | Image Classification

- Convolutional Neural Networks (CNNs)
  - **trained** to recognize objects like cars, pedestrians, etc.
  - performs **convolution operations at runtime**
    - to classify images from camera



- CNNs limited to single objects taking up entire image
- **Sliding Windows**!



References

- SAE J3016 Standard:

https://sibin.github.io/teaching/csci6907_88-gwu/secure_autonomous/fall_2022/other_docs/J3016_201609.pdf

- A better explanation of the standard and its components:

https://www.atlantis-press.com/journals/jase/125934832/view

- Velodyne LiDAR Video:

https://sibin.github.io/teaching/ csci6907_88-gwu/secure_autonomous/fall_2022/What-is-Lidar-video.mp4

- mmWave

https://www.ti.com/lit/wp/spyy005a/spyy005a.pdf?ts=1641417836995&ref_url=https%253A%252F%252Fwww.google.com%252F