Passion for Technology

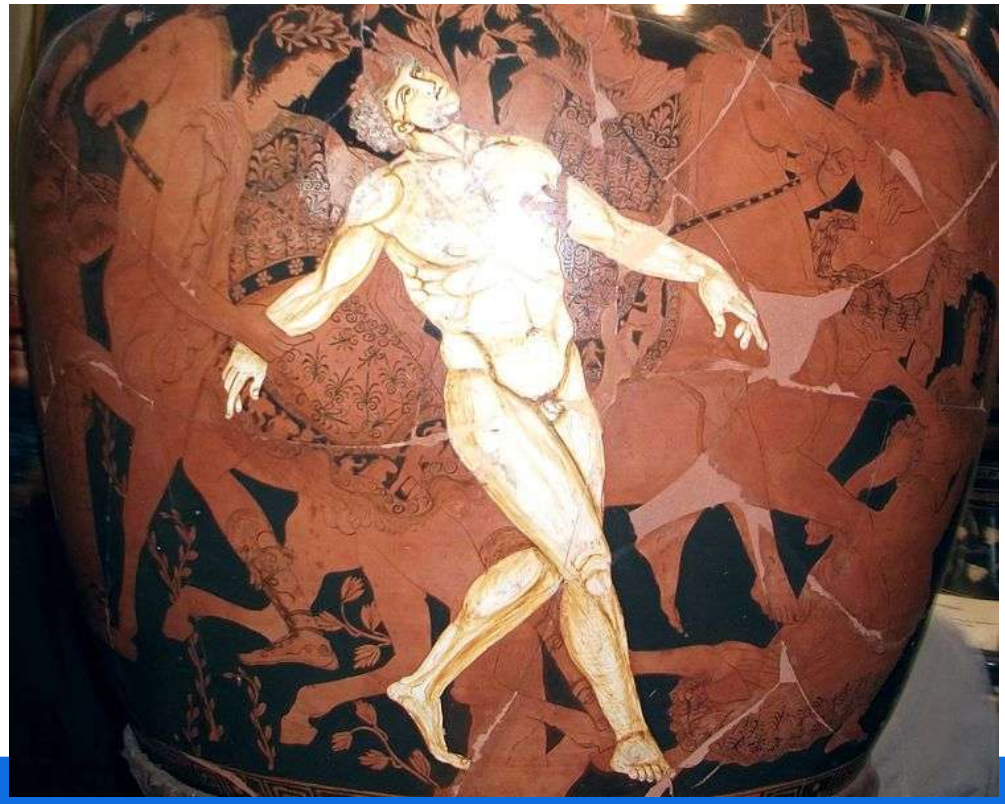
Application of machine learning in autonomous vehicles

Paweł Czapiewski 05.03.2024

Agenda

1. History of the autonomous vehicles
2. Current status of self-driving cars
3. Algorithm of finding the environment and obstacles
4. Algorithm for localization in space
5. Algorithm for movement planning
6. Algorithms for generating a steering angle and an acceleration value
7. Example of autonomous driving open-source projects

Talos

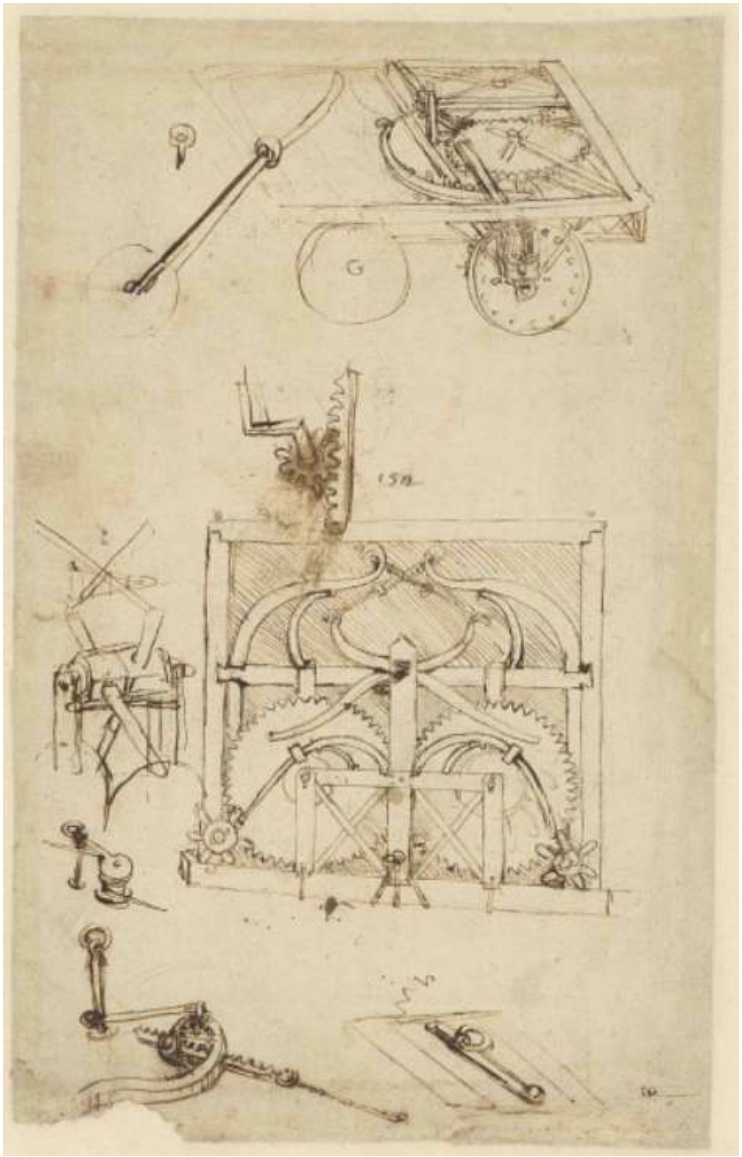


Source: https://en.wikipedia.org/wiki/Talos

Al-Jazari

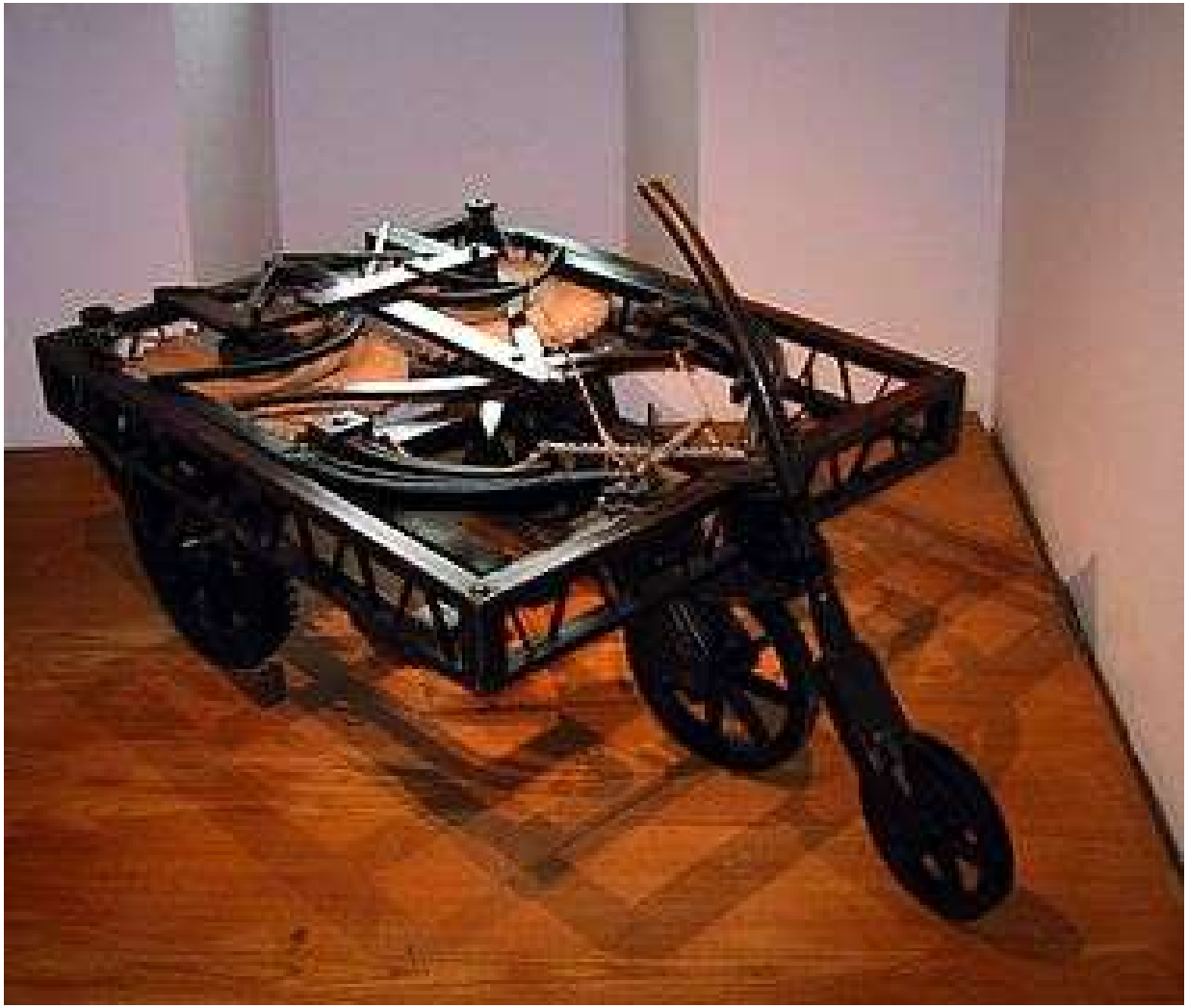
Source: https://en.wikipedia.org/wiki/Ismail_al-Jazari#/media/File:Al-jazari_elephant_clock.png

Leonard da Vinci



Source: https://www.researchgate.net/publication/338412717_How_Autonomous_Vehicles_Will_Profoundly_Change_The_World/figures?lo=1

Leonardo's self-propelled cart

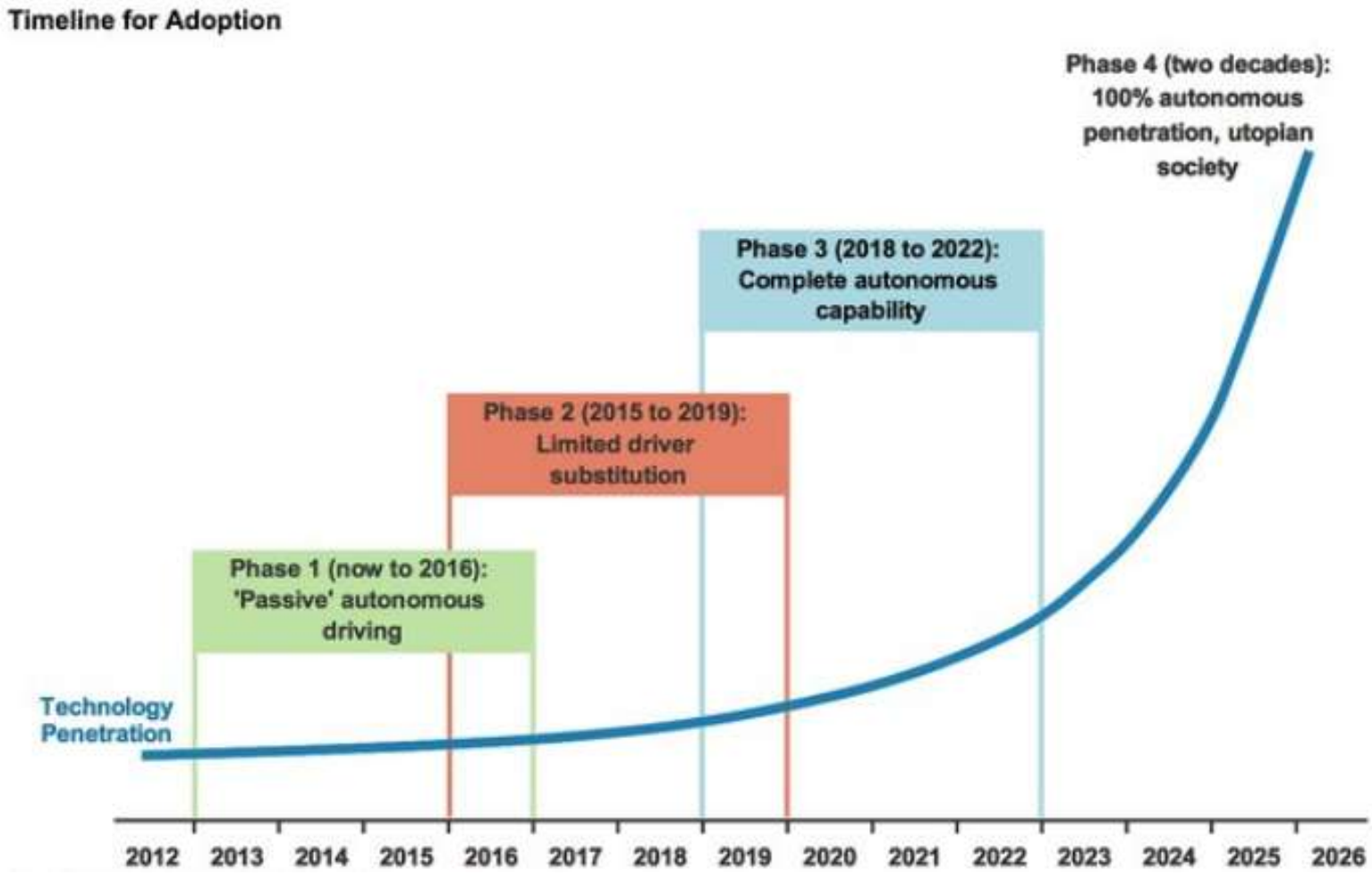


Source: https://en.wikipedia.org/wiki/Leonardo%27s_self-propelled_cart

How Autonomous Vehicles Will Profoundly Change The World

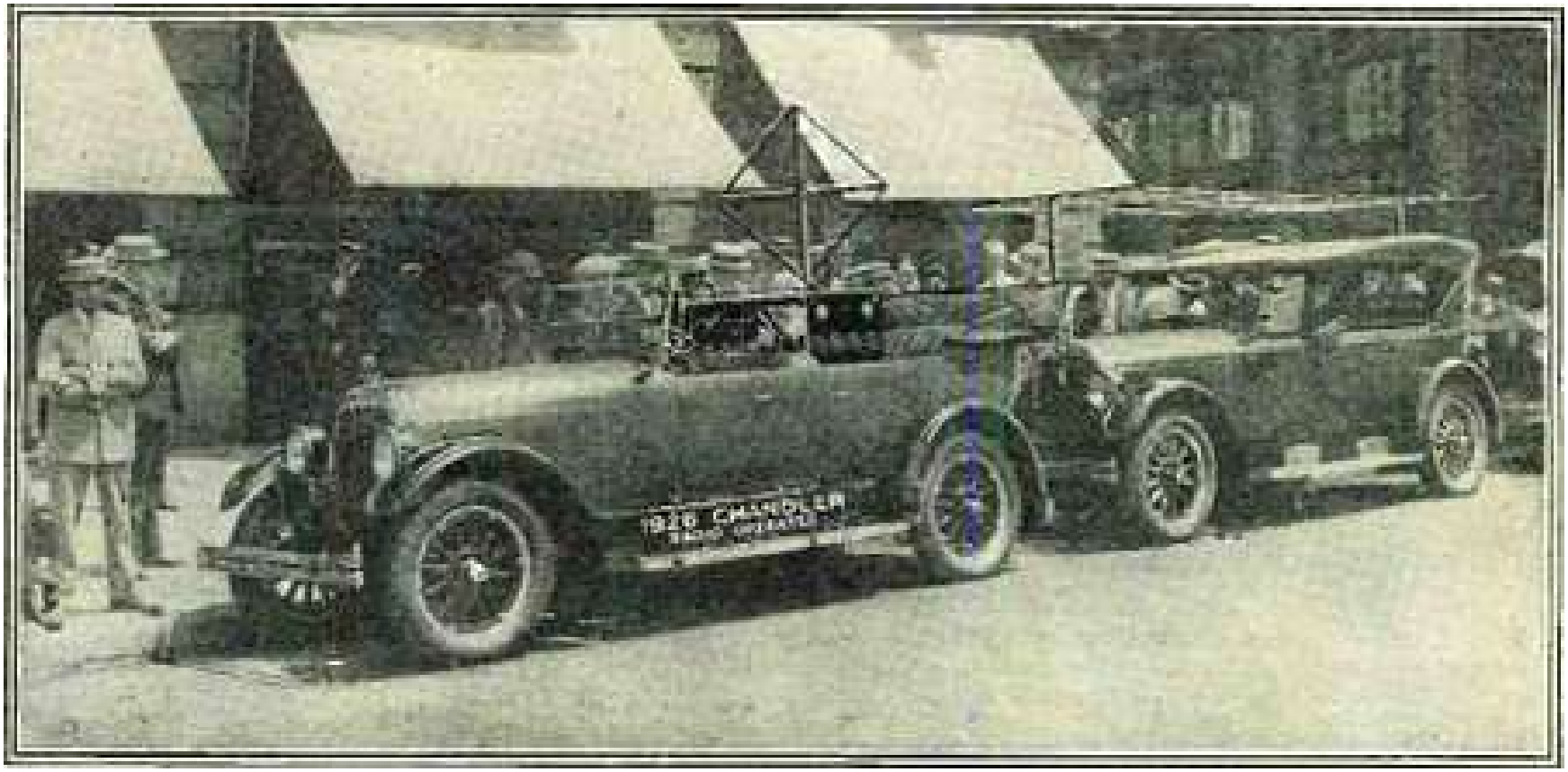
Source: https://www.researchgate.net/publication/338412717_How_Autonomous_Vehicles_Will_Profoundly_Change_The_World/figures?lo=1

How Autonomous Vehicles Will Profoundly Change The World



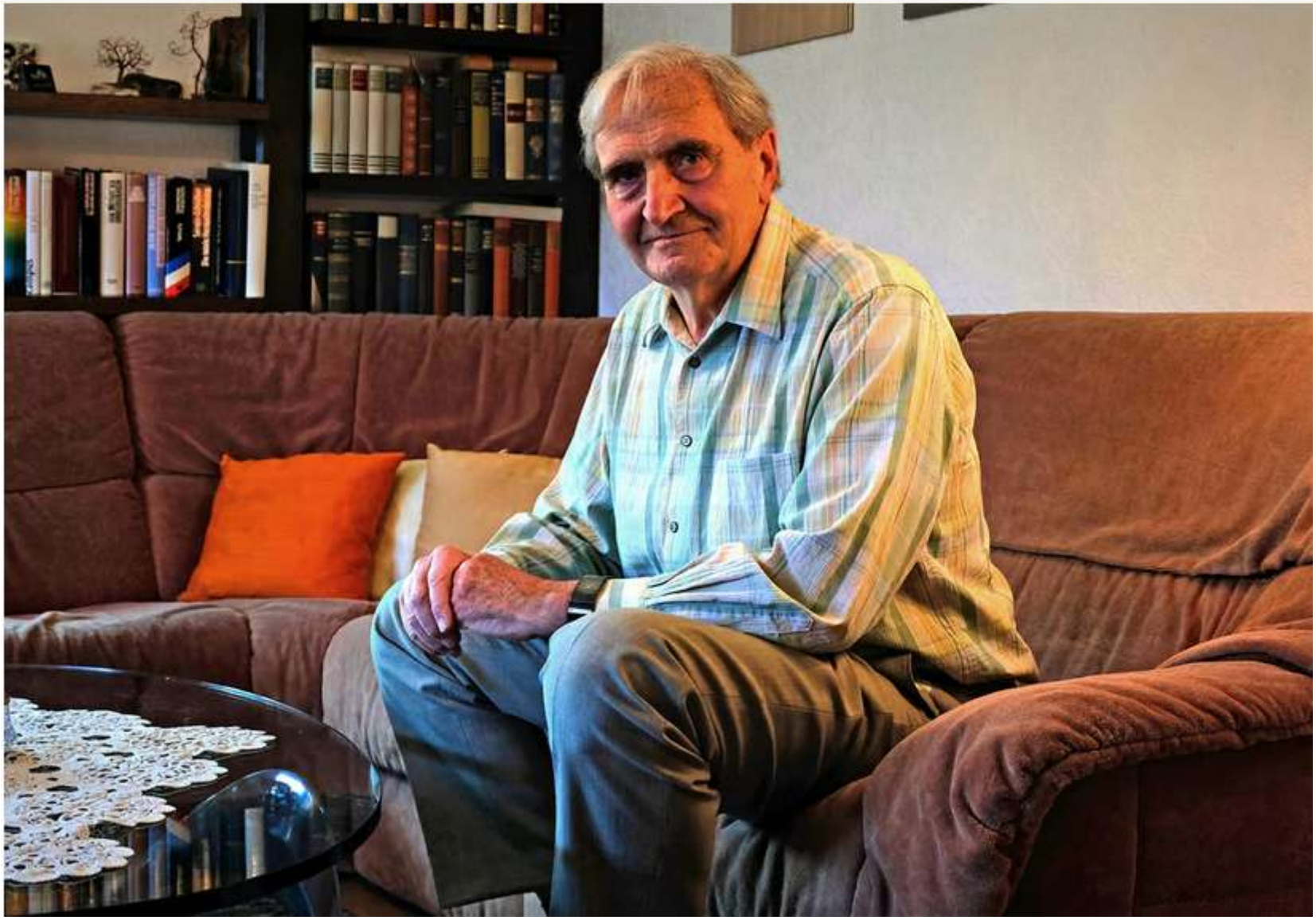
Source: https://www.researchgate.net/publication/338412717_How_Autonomous_Vehicles_Will_Profoundly_Change_The_World/figures?lo=1

Houdina Radio Control



Source: https://en.wikipedia.org/wiki/Houdina_Radio_Control

Ernst Dickmann



Source: https://www.politico.eu/article/delf-driving-car-born-1986-ernst-dickmanns-mercedes/

‘VaMoRs’ and ‘VaMP’ vehicles by Ernst Dickmann

Source: https://www.researchgate.net/publication/338412717_How_Autonomous_Vehicles_Will_Profoundly_Change_The_World/figures?lo=1

How Autonomous Vehicles Will Profoundly Change The World

The computing system used in Ernst Dickmann's VaMoRs van (1987).

The nVidia PX computing system for autonomous vehicles (2015).

Source: https://en.wikipedia.org/wiki/DARPA_Grand_Challenge#/media/File:UrbanChallenge_StandfordRacingandVictorTango.JPG x

Darpa Challenge

Source: https://en.wikipedia.org/wiki/DARPA_Grand_Challenge#/media/File:UrbanChallenge_StandfordRacingandVictorTango.JPG

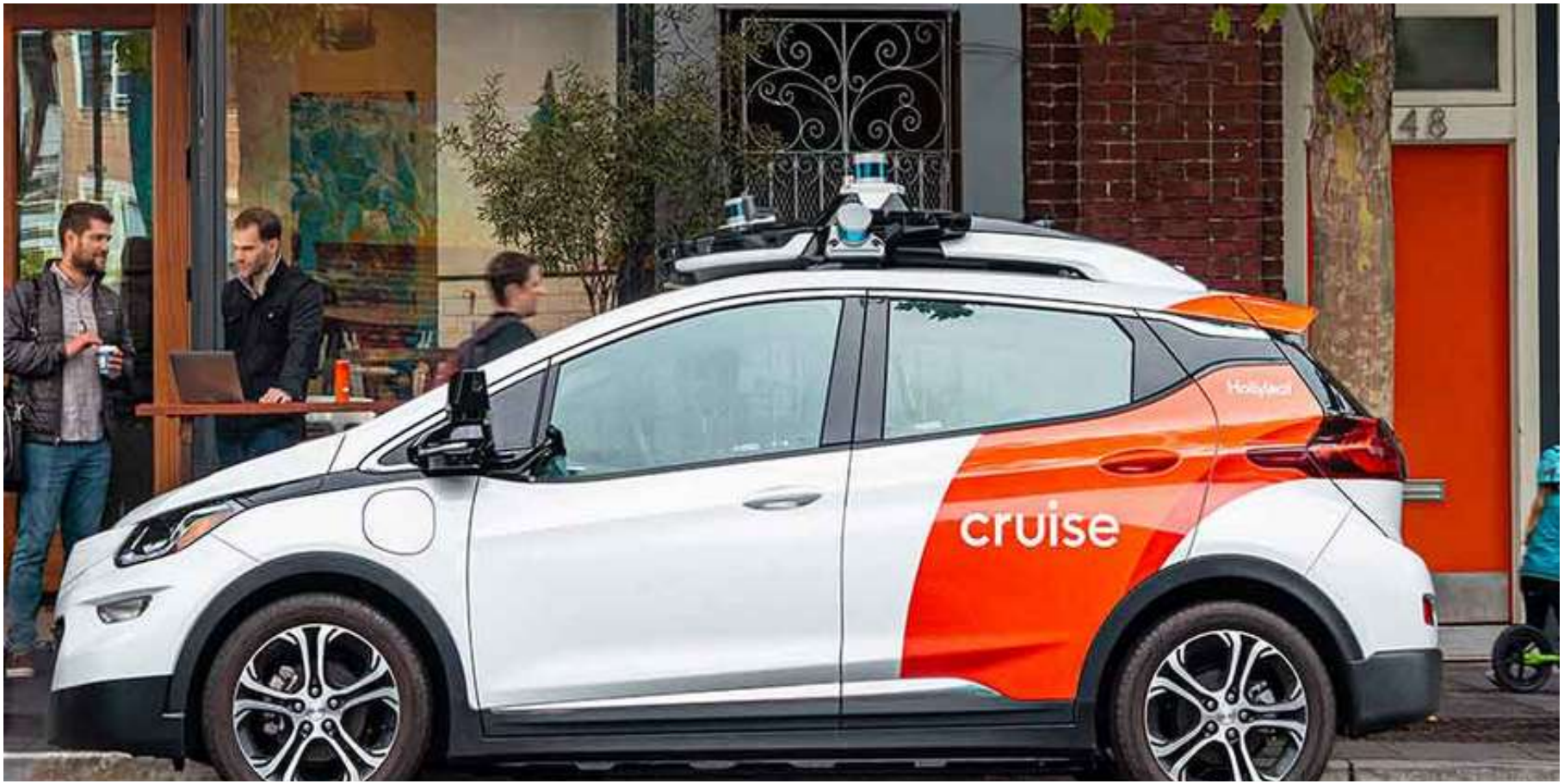
DARPA 2005

Source: https://en.wikipedia.org/wiki/DARPA_Grand_Challenge_(2005)#/media/File:BeerBottlePass.JPG

Wayme One

Source: https://waymo.com/

Cruise LLC

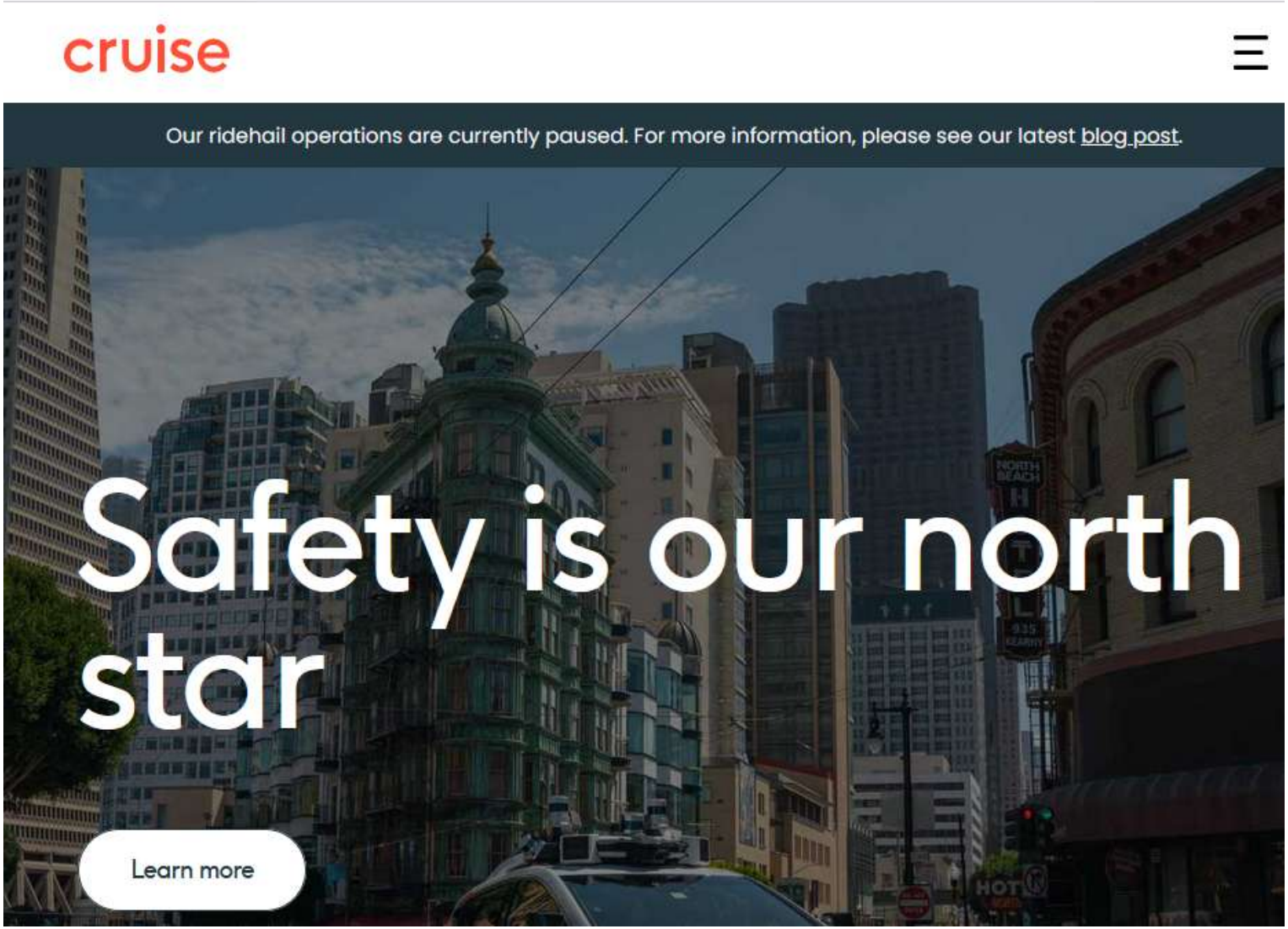


Source: https://getcruise.com/

Stalled self-driving taxis clog streets of San Francisco

Source: https://www.youtube.com/watch?v=uVwbP6N3l24

Cruise Website



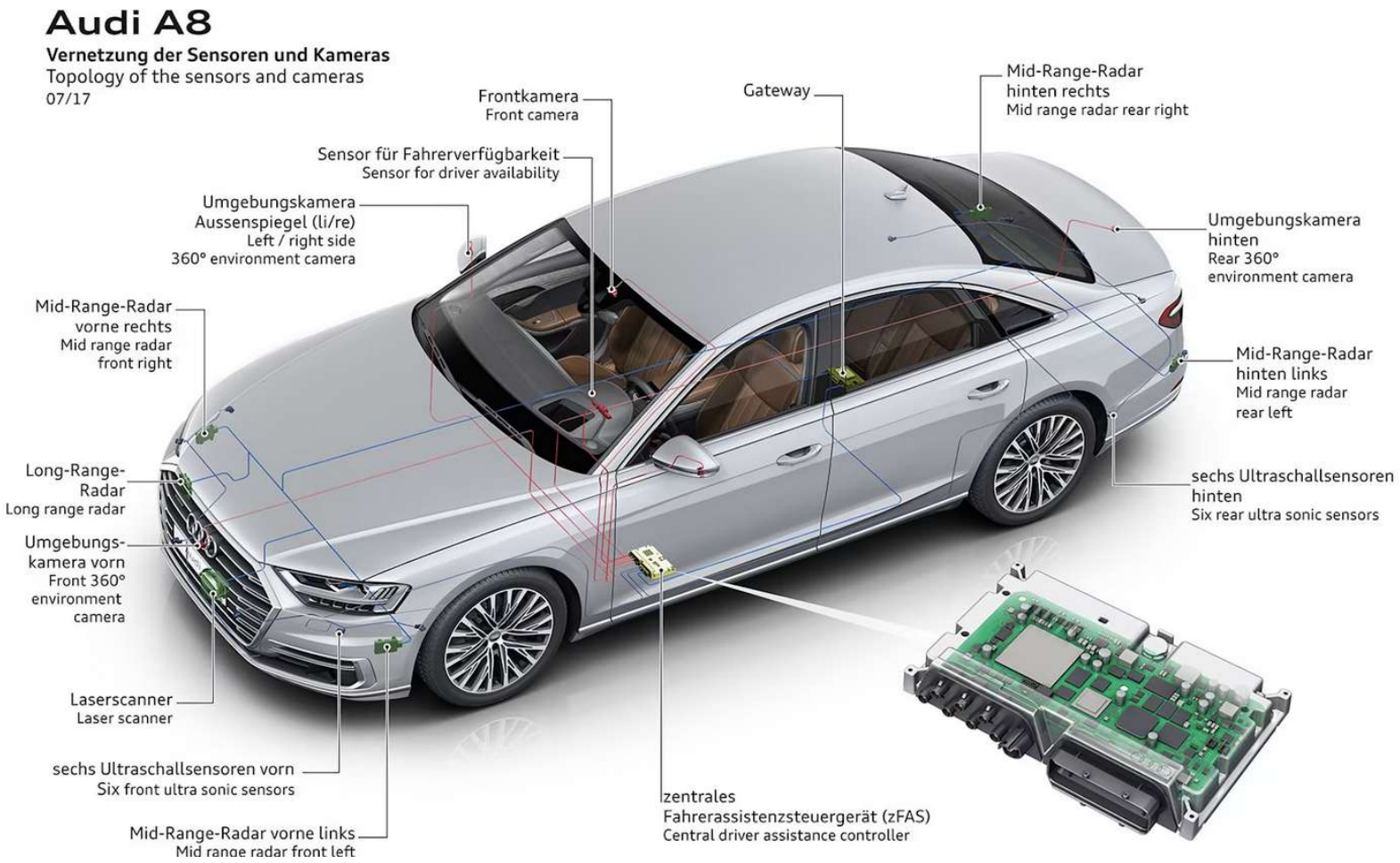
Automation Levels

Full automation

0	1	2	3	4	5
					
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving Assist features may be included in the vehicle design.	Vehicle has combined automated function, like acceleration and Steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving function under certain conditions. The driver may have the options to control the vehicle.	The vehicle is capable of performing all driving function under all conditions. The driver may have the options to control the vehicle.

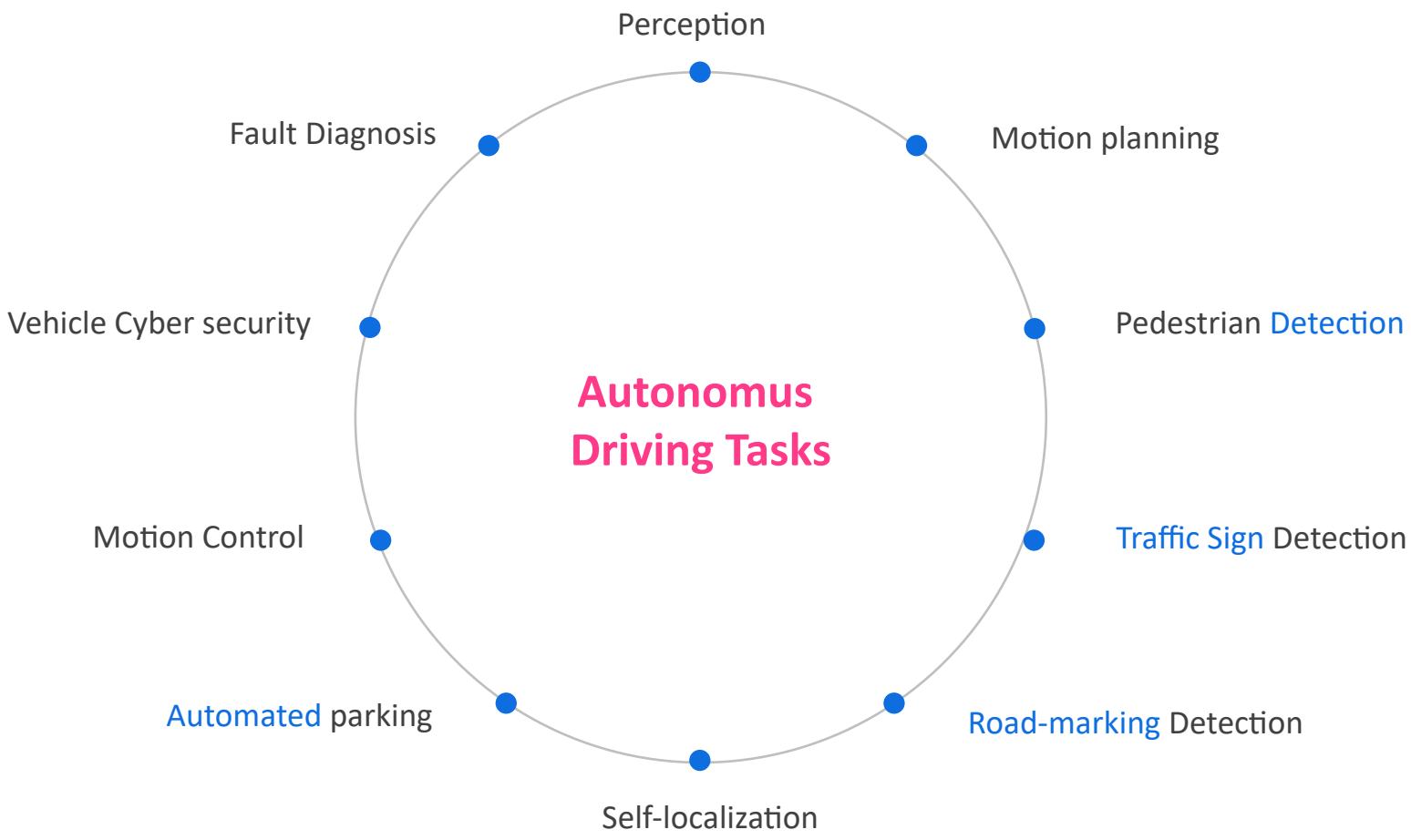
Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

Autonomous driving tasks



Source: https://www.drive.com.au/news/2018-audi-a8-weve-driven-the-worlds-first-level-3-autonomous-vehicle/

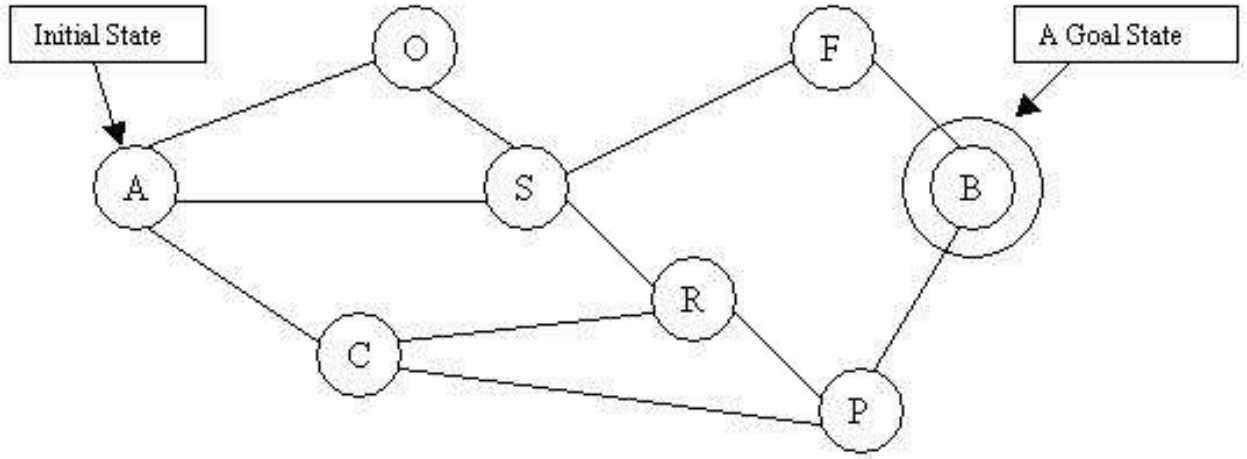
Autonomous driving tasks



Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

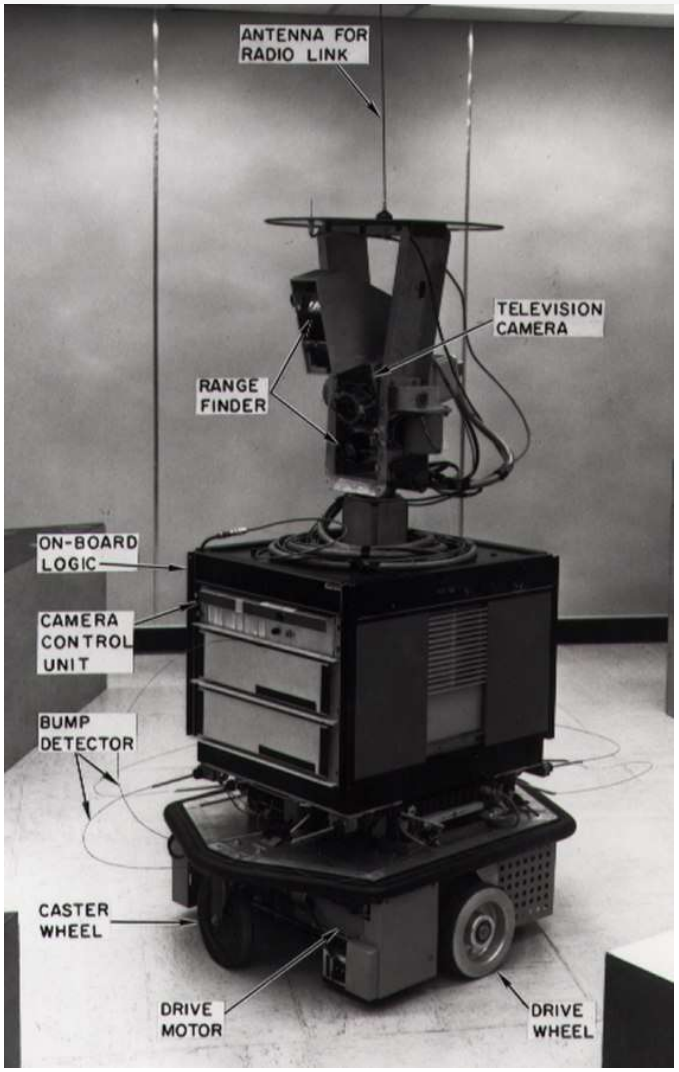
A problem can be defined formally by following components:

- Together, the initial state, actions, and transition model implicitly define the **state space** of the problem—the set of all states reachable from the initial state by any sequence of actions. The state space forms a directed network or graph in which the nodes are states and the links between nodes are actions.
- The **goal test**, which determines whether a given state is a goal state. Sometimes there is an explicit set of possible goal states, and the test simply checks whether the given state isone ofthem.



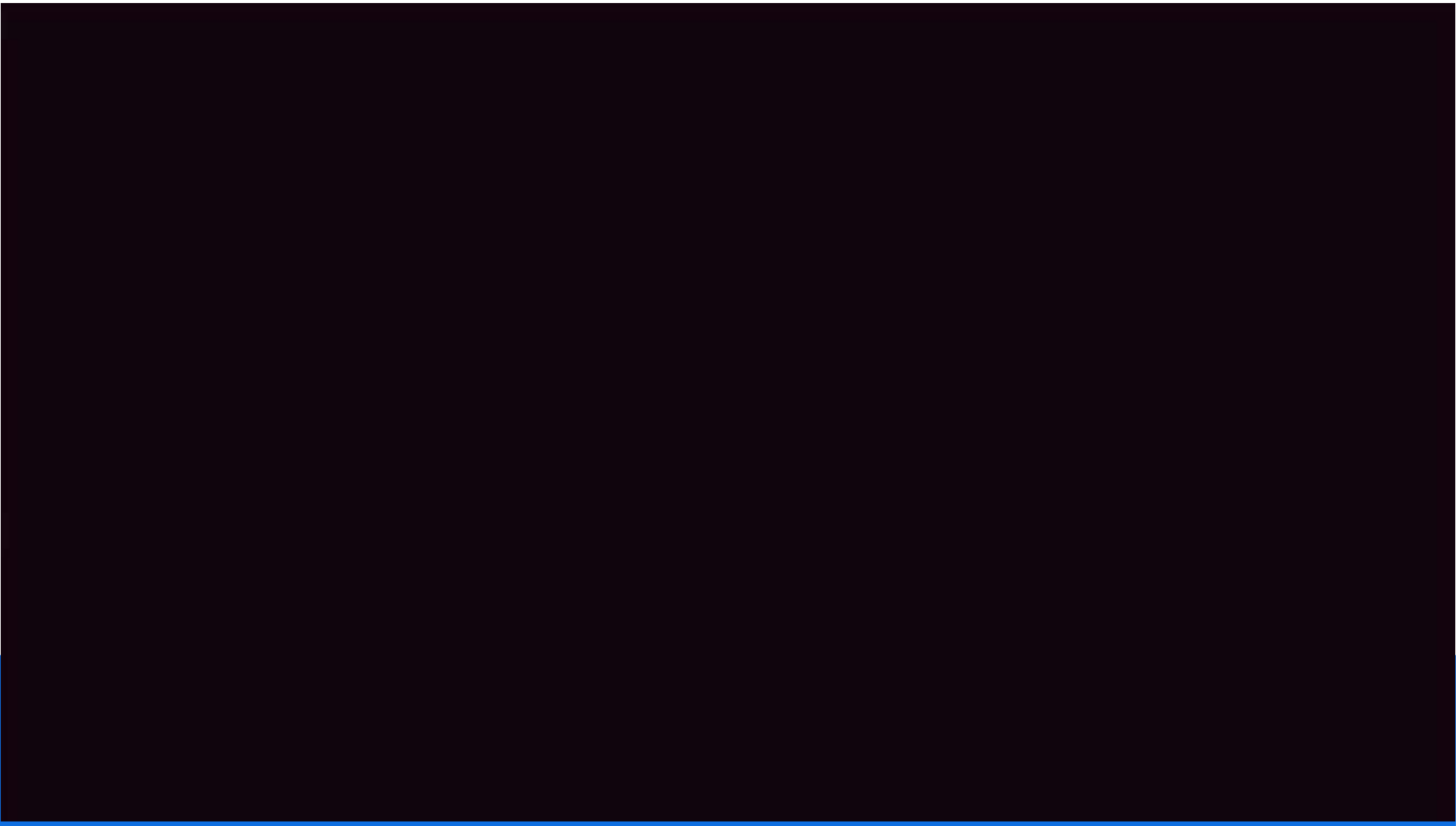
Source: Artificial Intelligence A Modern Approach, Third Edition, S. Russel, P. Norving

Shakey the Robot's path planning



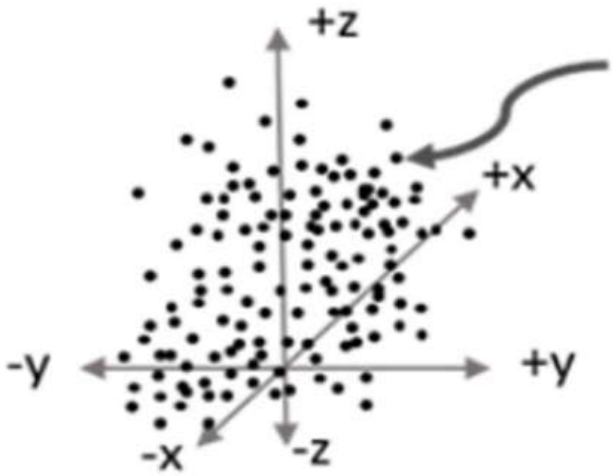
Source:https://en.wikipedia.org/wiki/File:SRI_Shakey_with_callouts.jpg

Search

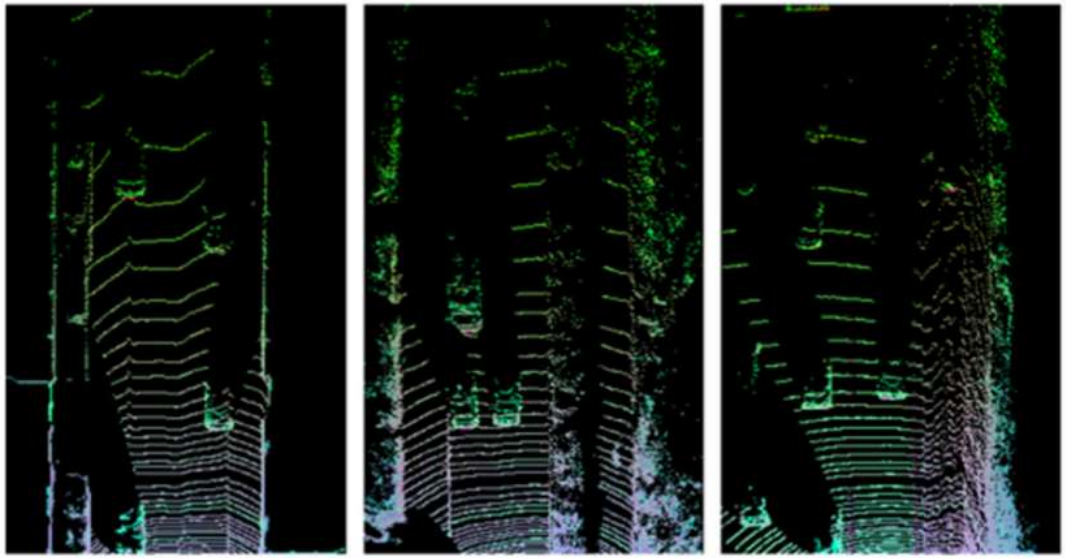


Source: https://www.youtube.com/watch?v=CgW0HPHqFE8

Perception for autonomous vehicles

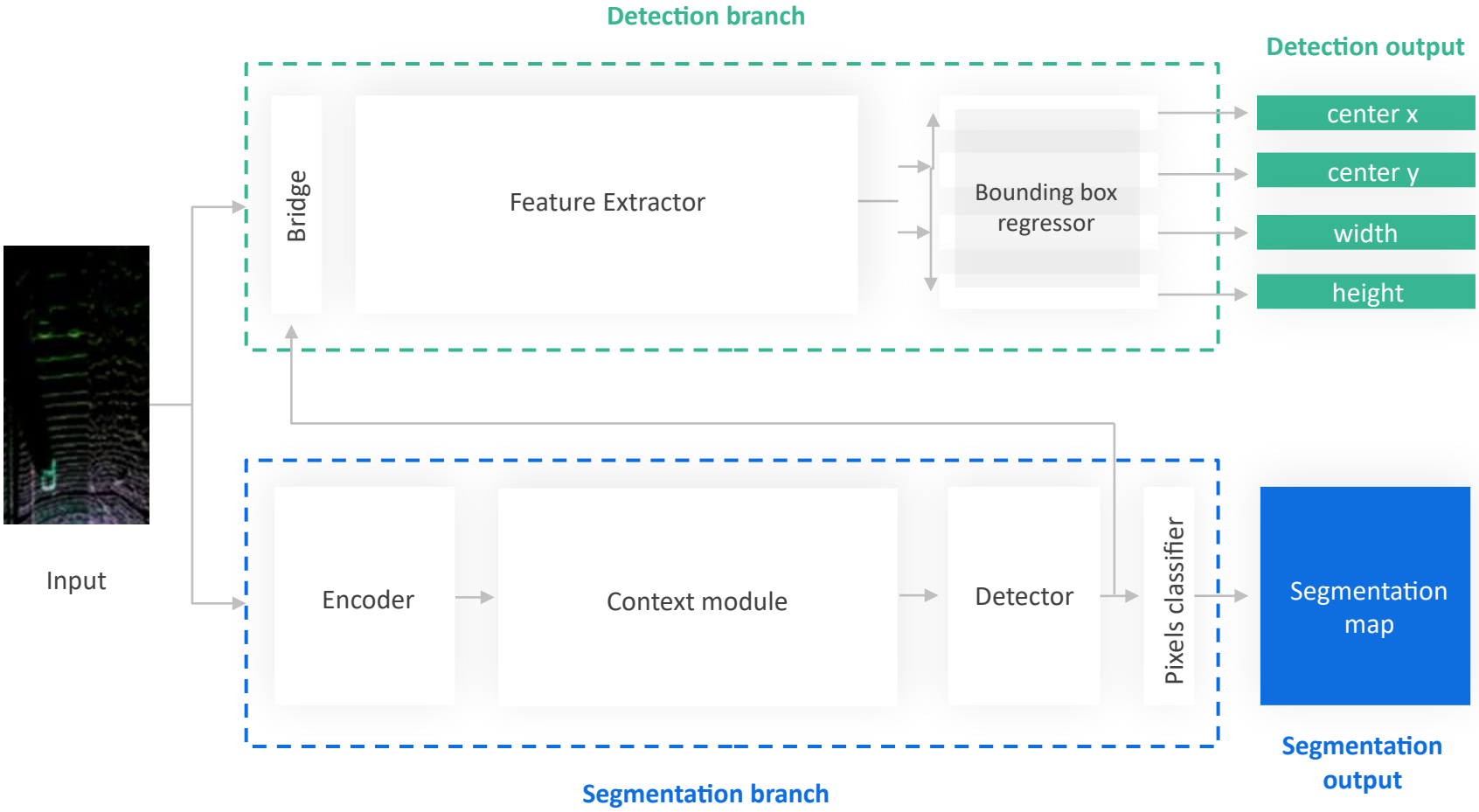


$$[x, y, z, intensity]$$



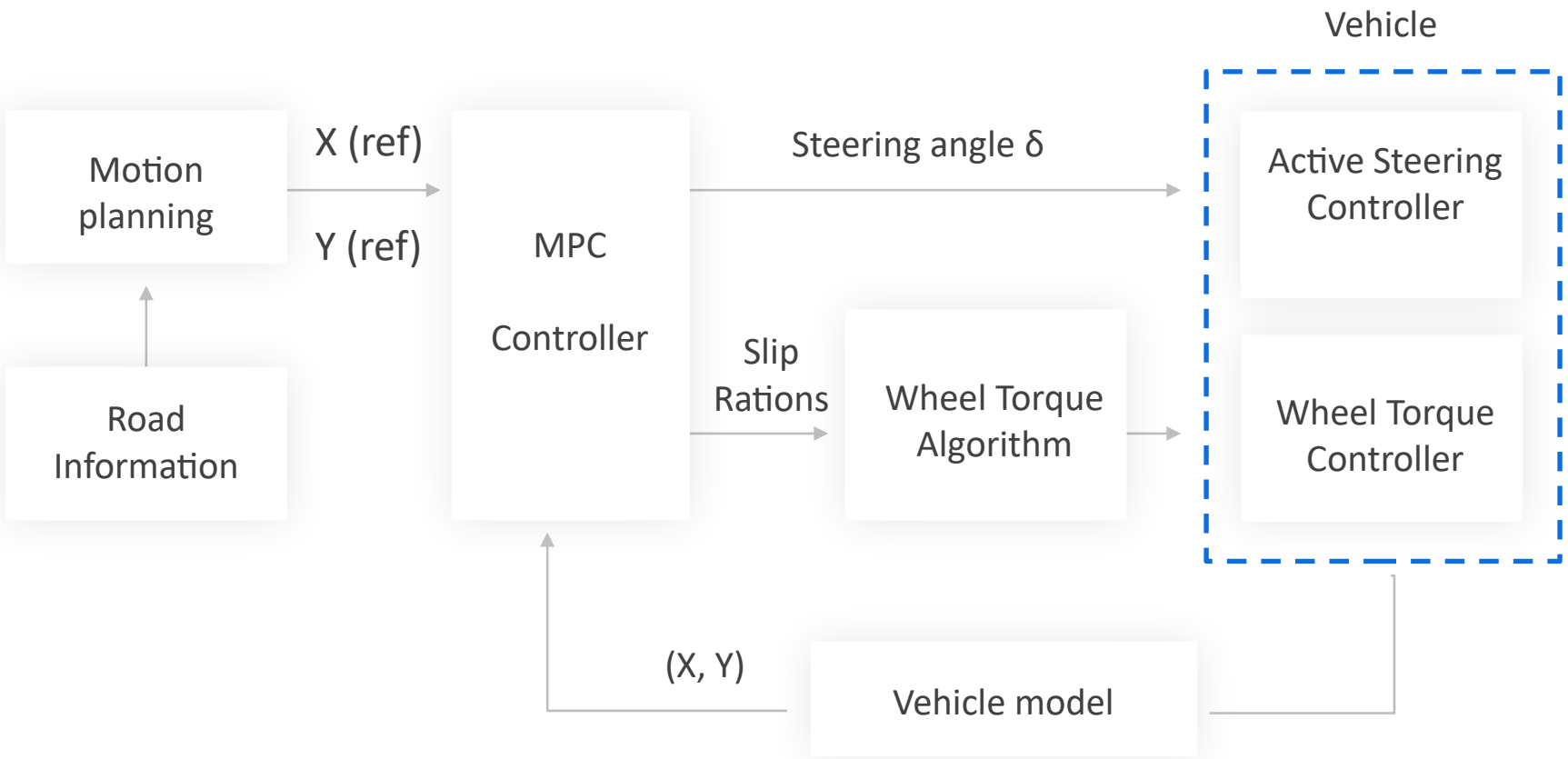
Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

Perception for autonomous vehicles



Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

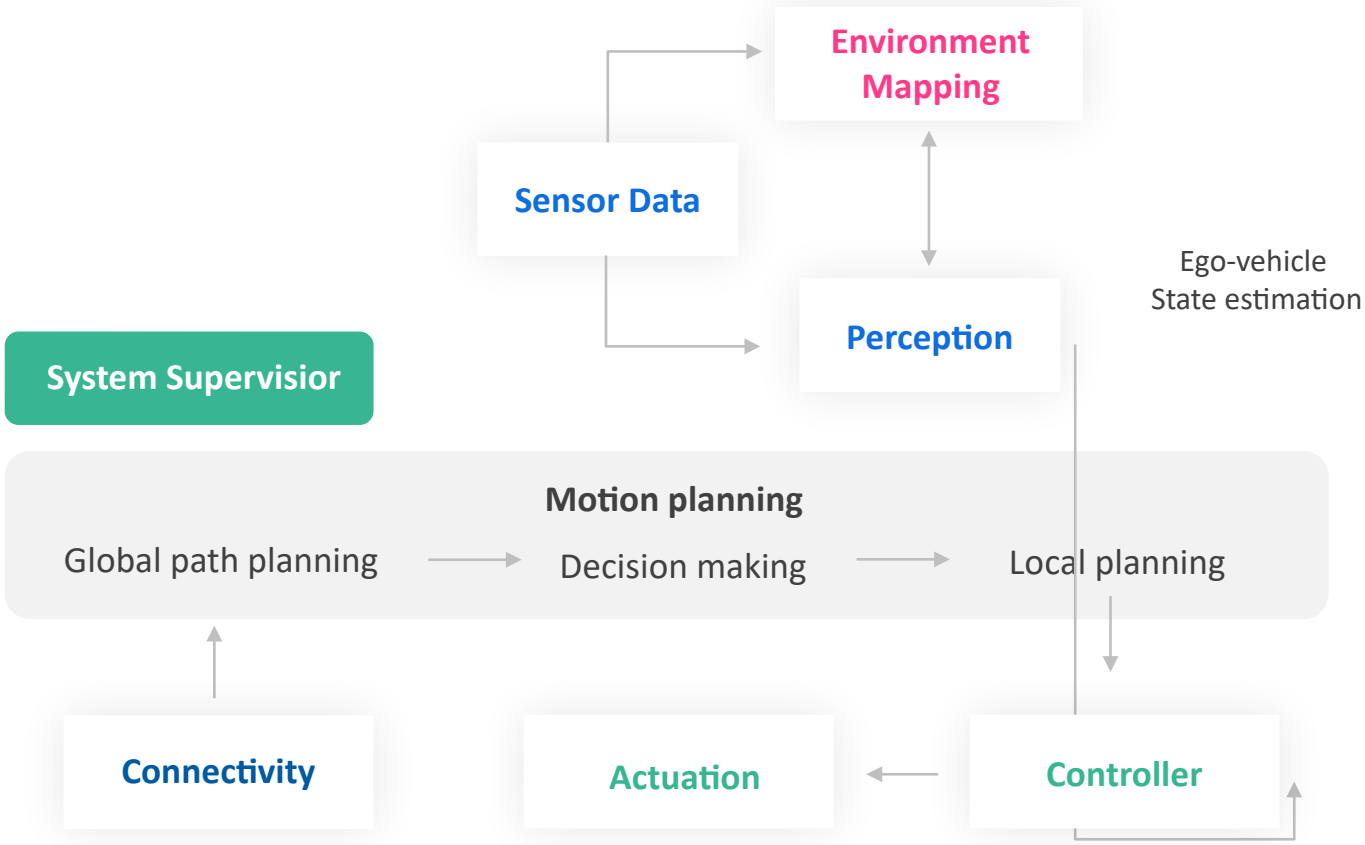
The Control scheme for Autonomous Vehicle



Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

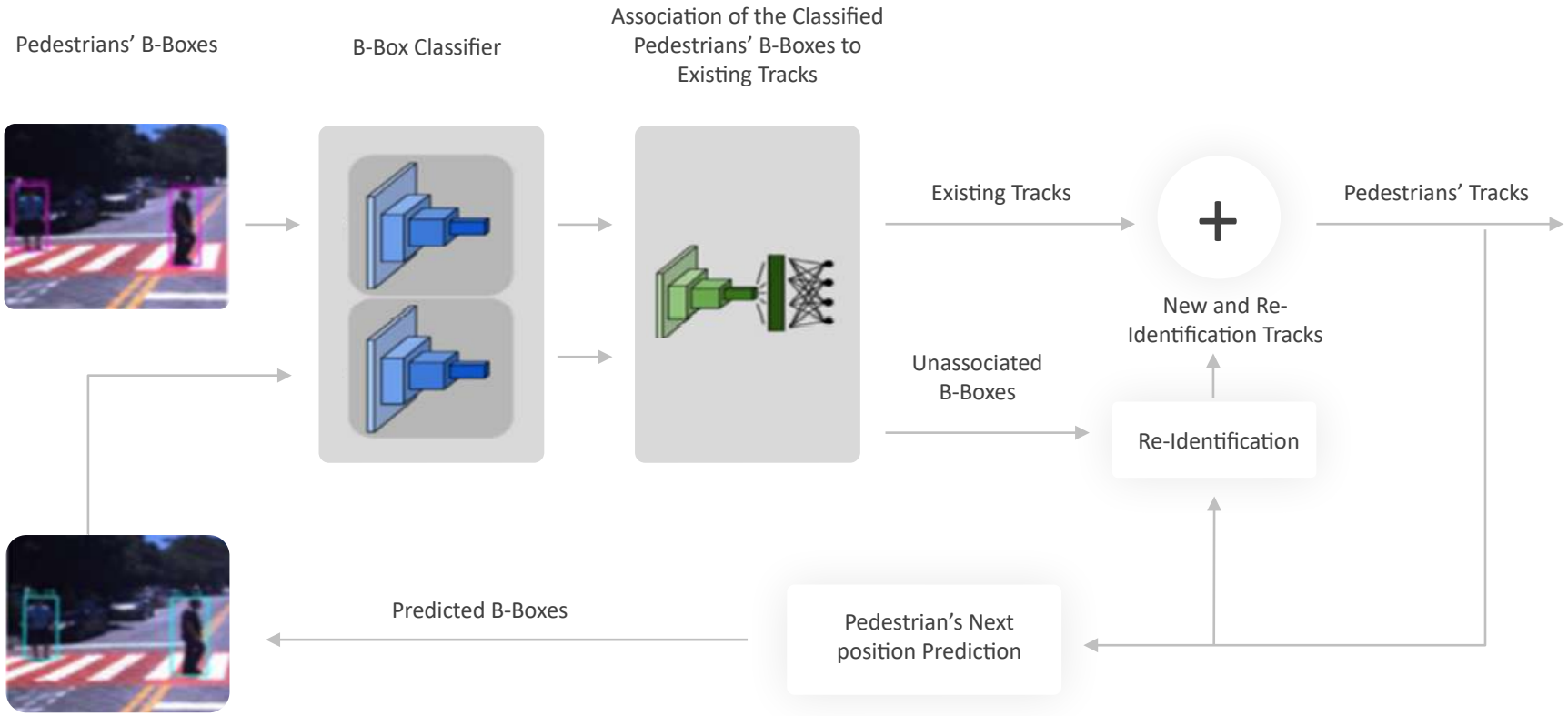
Motion Planning-Autonomous Driving System

The autonomous vehocle system architecture



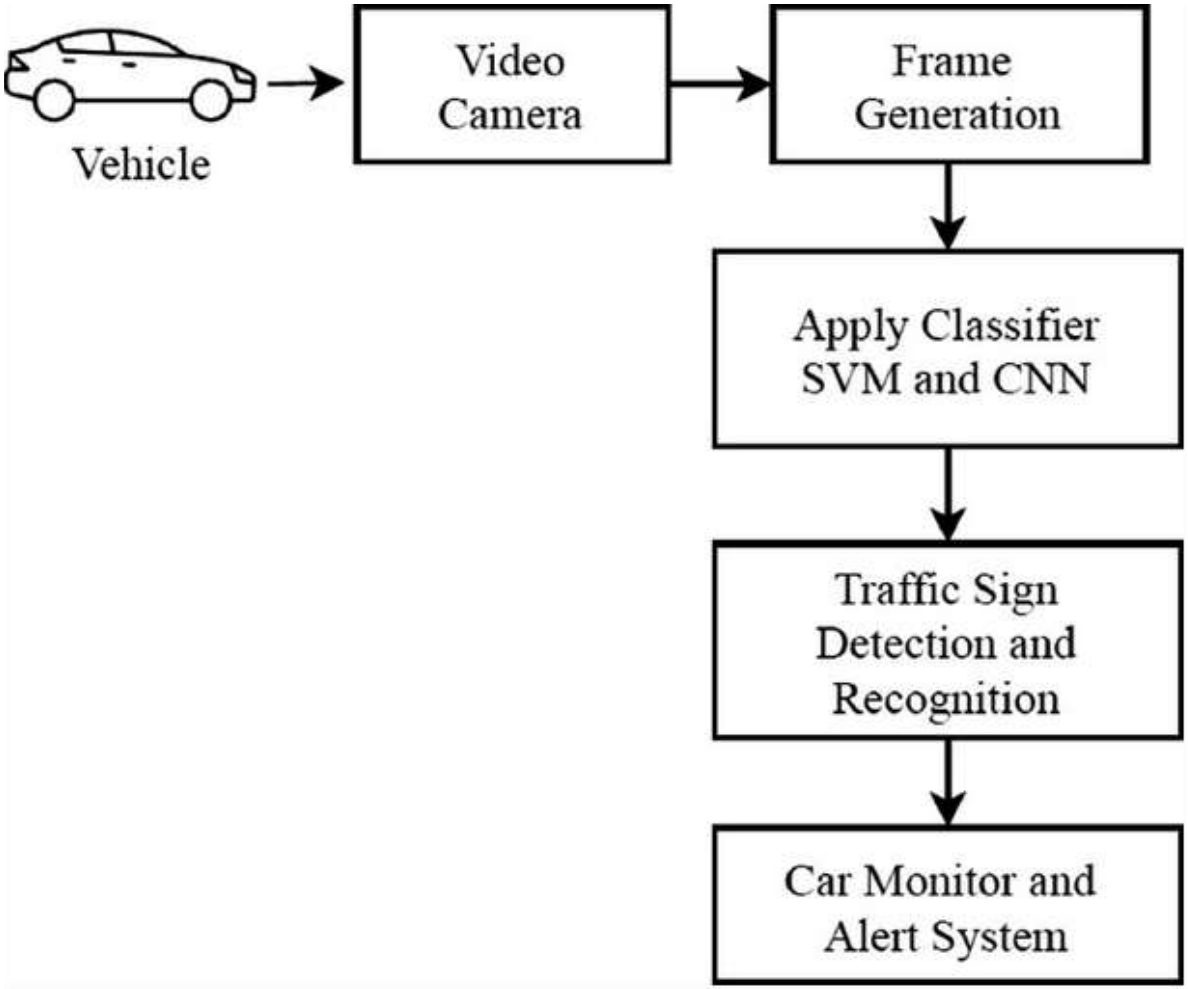
Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

Pedestrian Detection Algorithm



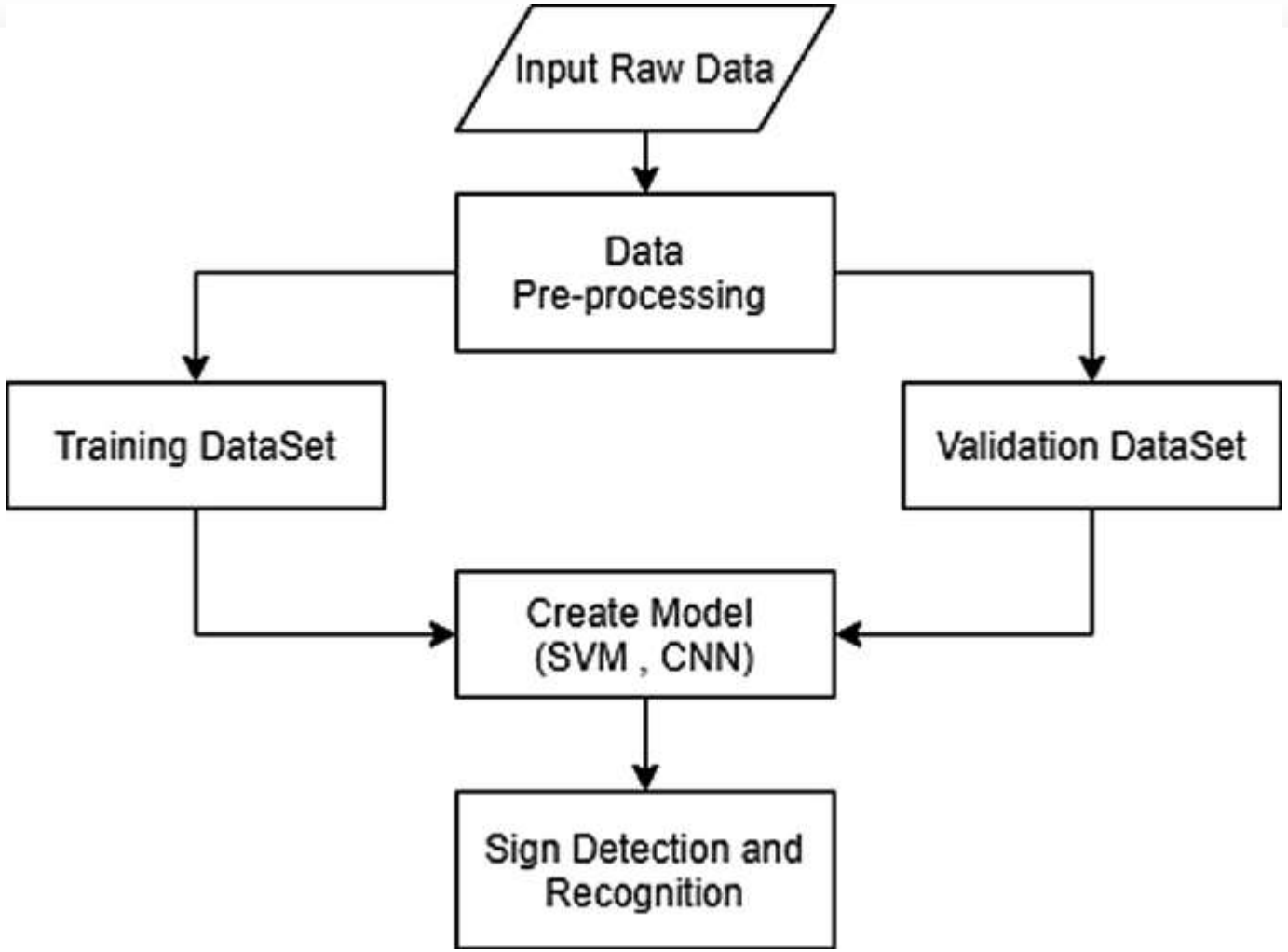
Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

Traffic Sign Recognition System



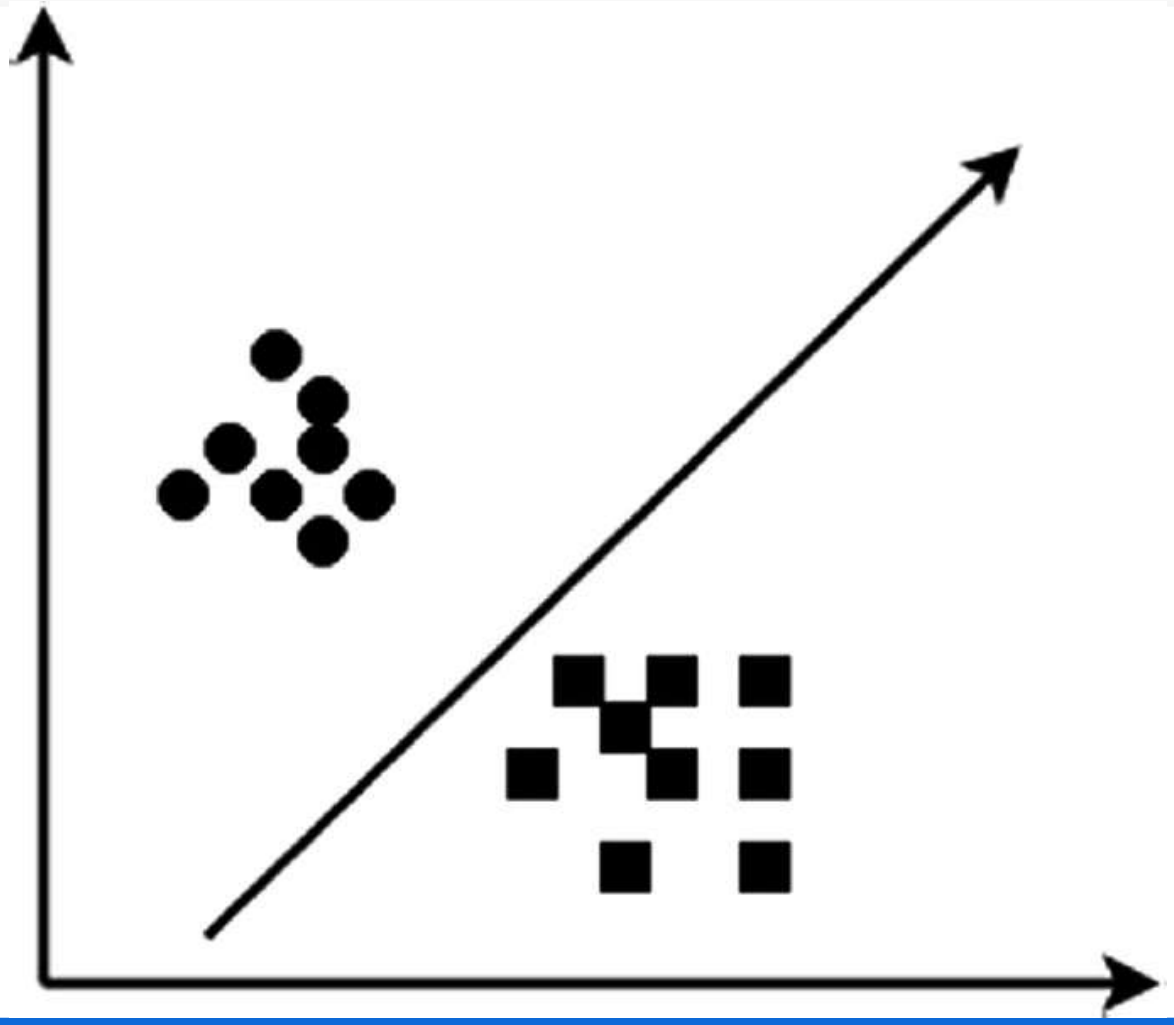
Source: https://link.springer.com/chapter/10.1007/978-981-15-7345-3_6

Traffic Sign Recognition System



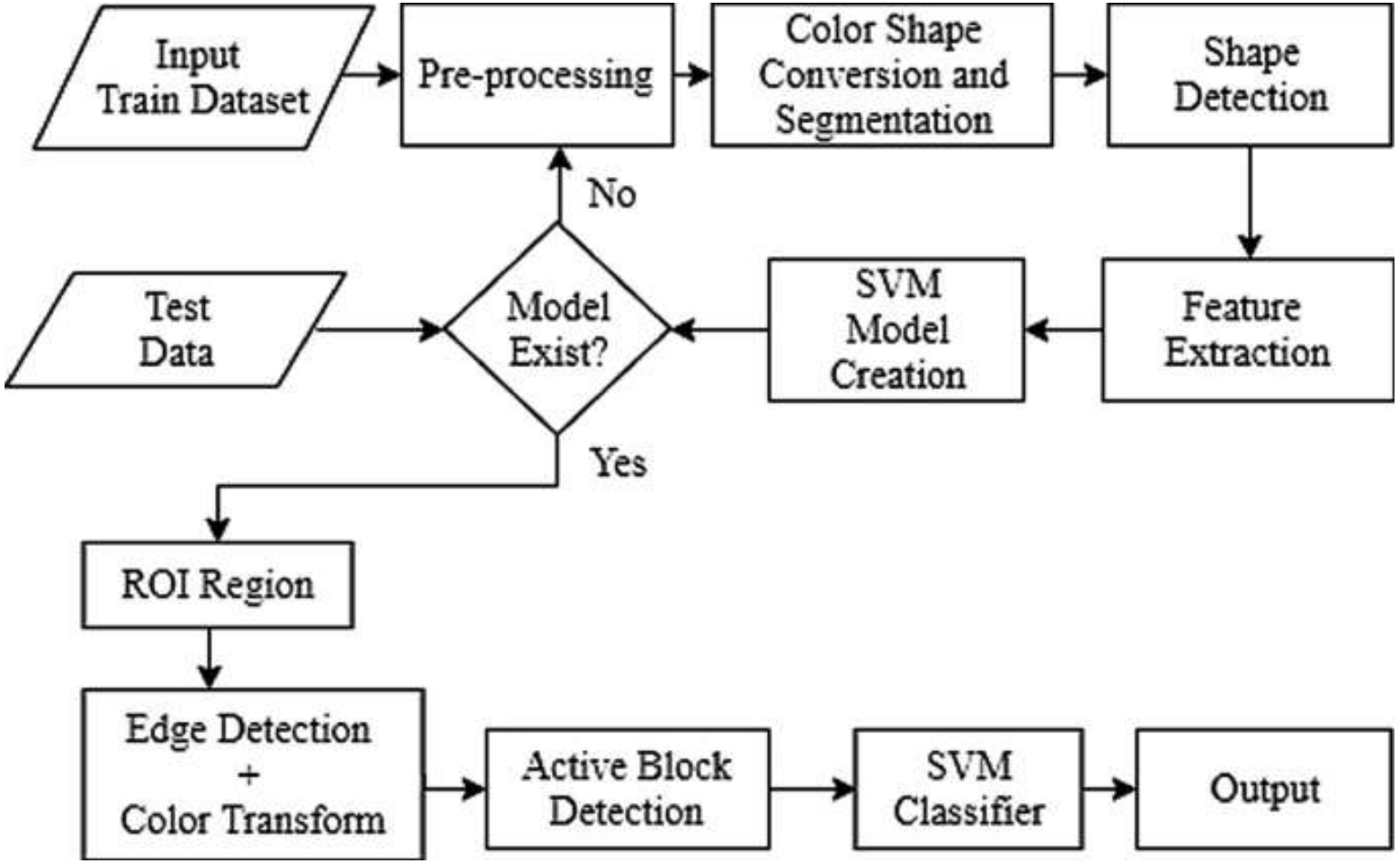
Source: https://link.springer.com/chapter/10.1007/978-981-15-7345-3_6

Traffic Sign Recognition System



Source: https://link.springer.com/chapter/10.1007/978-981-15-7345-3_6

Traffic Sign Recognition System

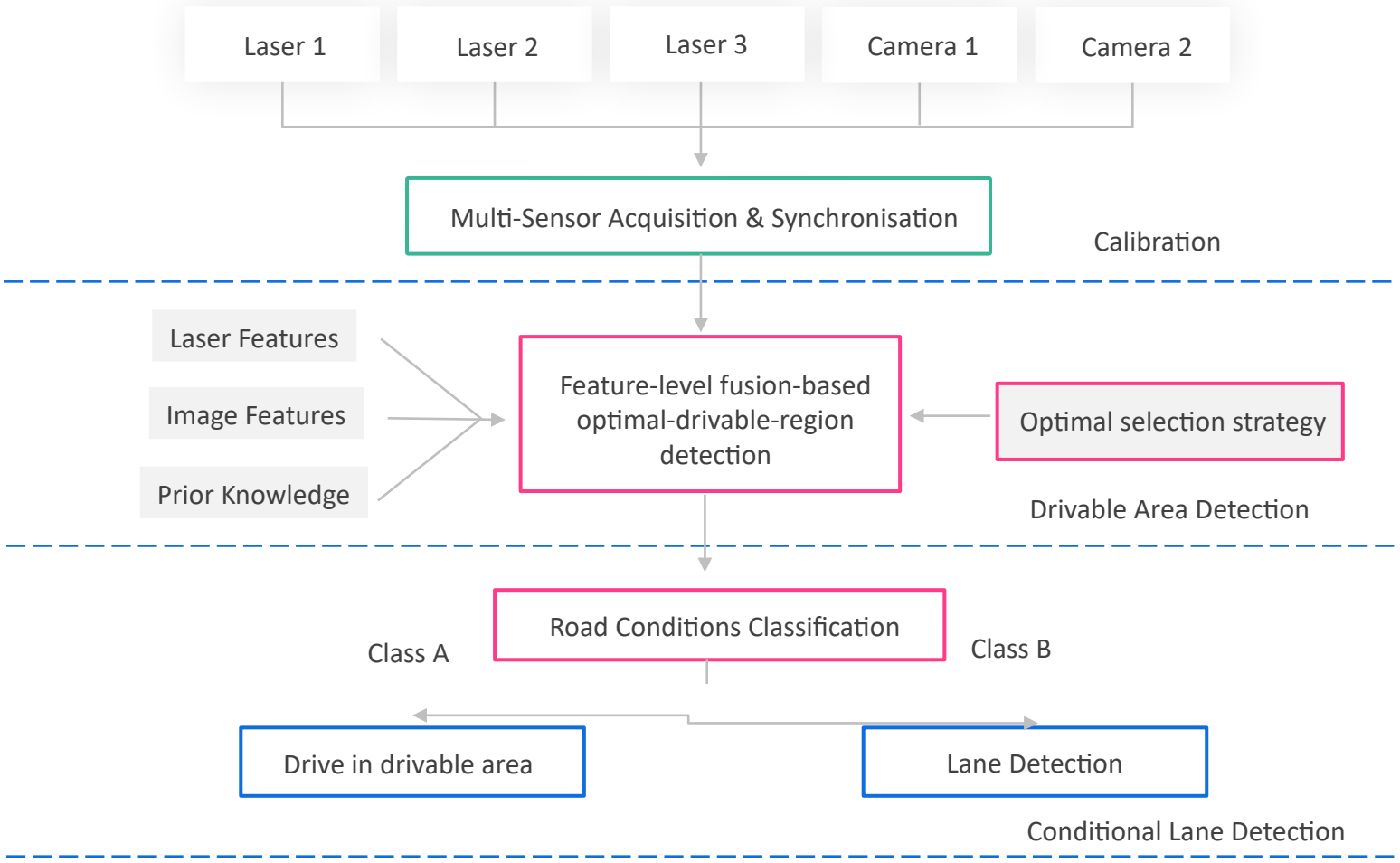


Source: https://link.springer.com/chapter/10.1007/978-981-15-7345-3_6

Traffic Sign Recognition System

Source: https://link.springer.com/chapter/10.1007/978-981-15-7345-3_6

Self-localization in autonomous driving



Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

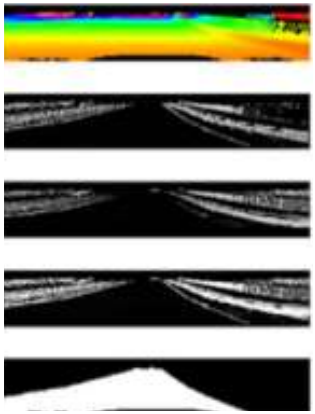
Self-localization in autonomous driving

3D LiDARPoint Cloud

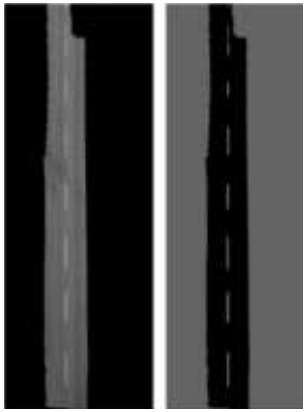
Camera Image

Open Sreet Map

ROI Selection in Range Image



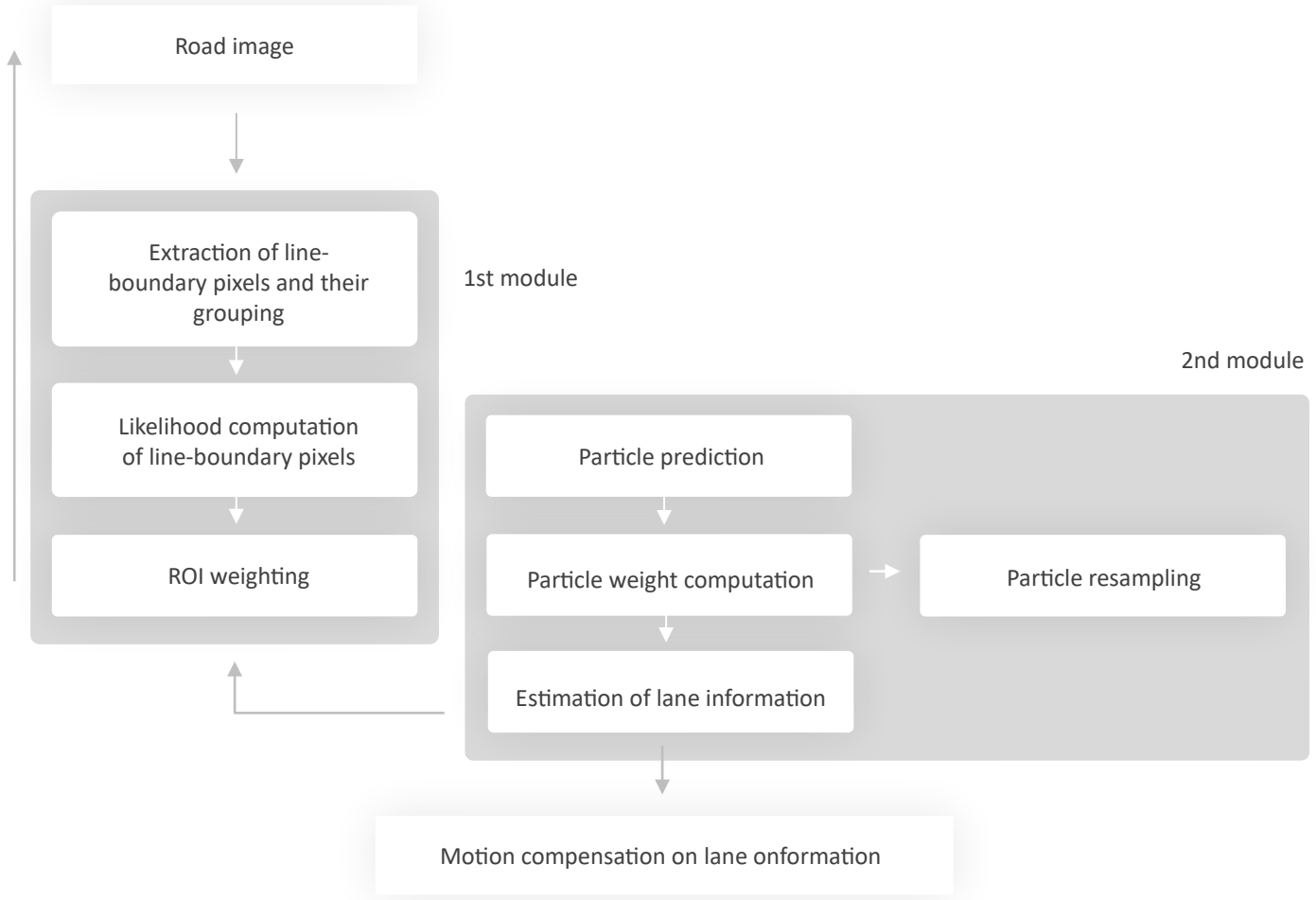
Lane Feature Extraction in BEV Image



Ego-Lane Detection

Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

Self-localization in autonomous driving



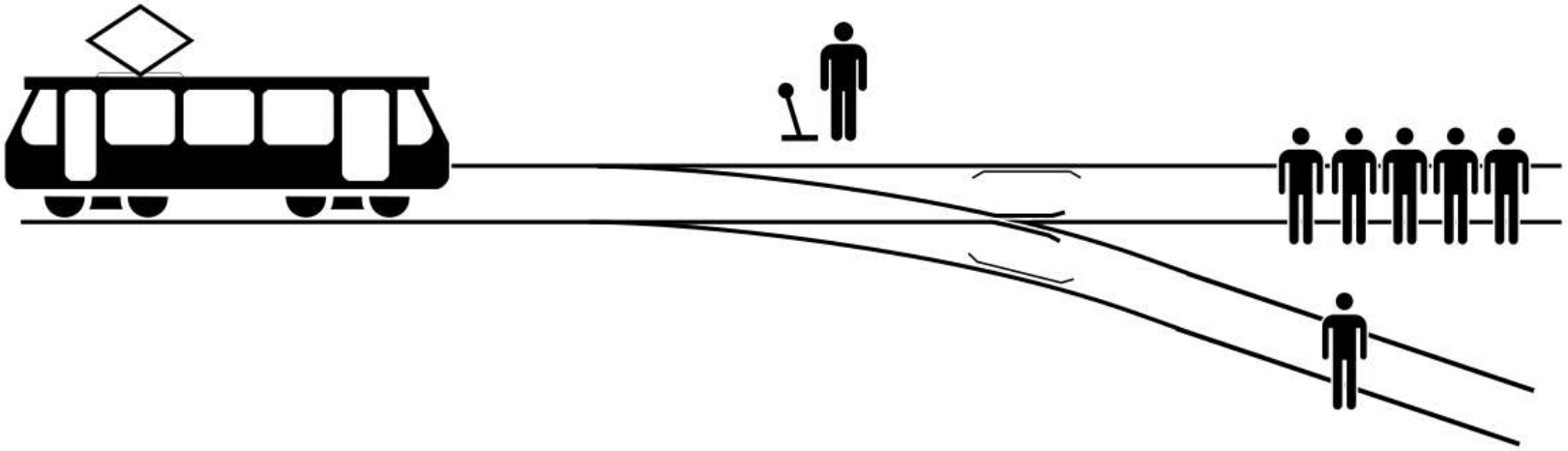
Source: https://www.sciencedirect.com/science/article/pii/S2666827021000827

Liability

„Does your car have any idea why my car pulled it over?”

Source: https://twitter.com/andrewchen/status/684980398556712961

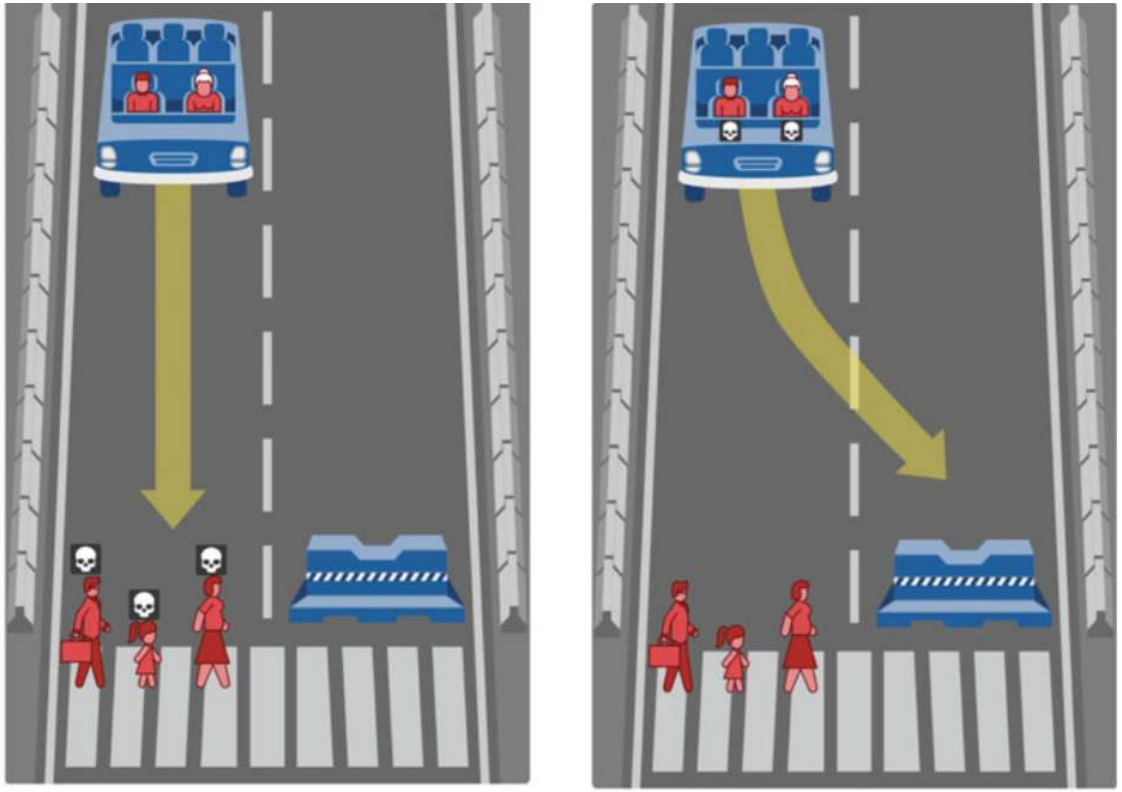
Trolley Problem



Source: https://en.wikipedia.org/wiki/File:Trolley_Problem.svg

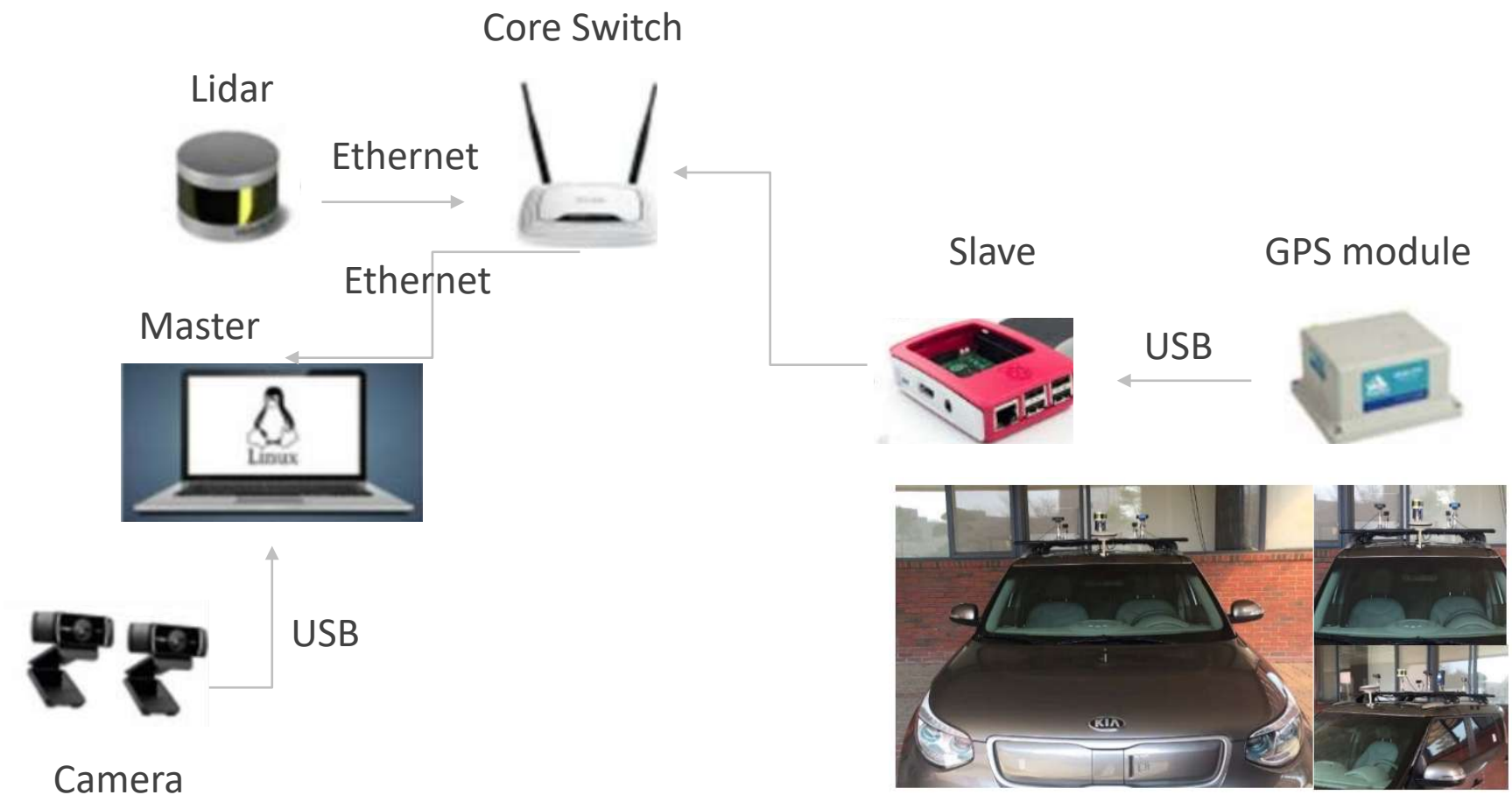
Situations of Unavoidable Accidents

What should the self-driving car do?



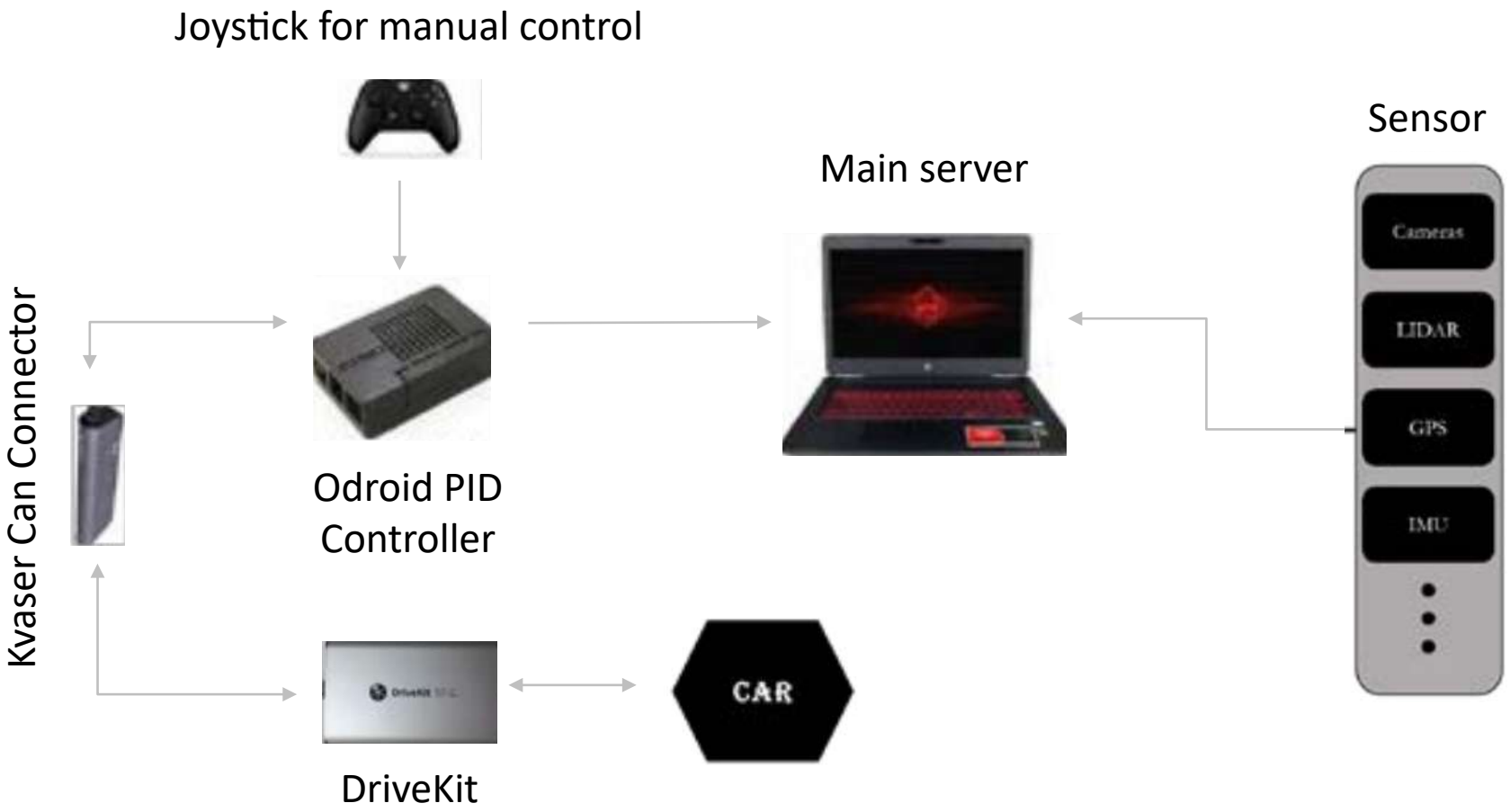
Source: https://www.youtube.com/watch?v=Rs_rAxEsAvI&list=RDCMUC8butISFwT-Wl7EV0hUK0BQ&index=3

Self-Driving Car Architecture



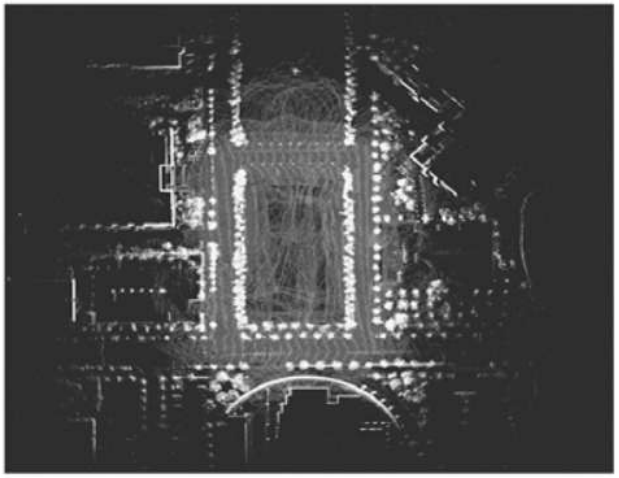
Source: https://www.researchgate.net/publication/330494421_Autonomous_Vehicle_The_Architecture_Aspect_of_Self_Driving_Car

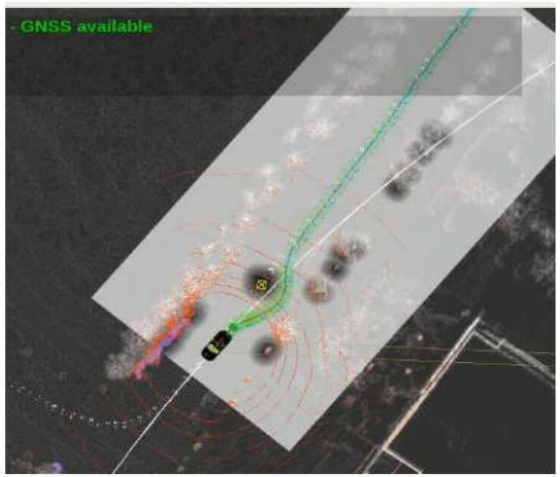
Self-Driving Car Architecture

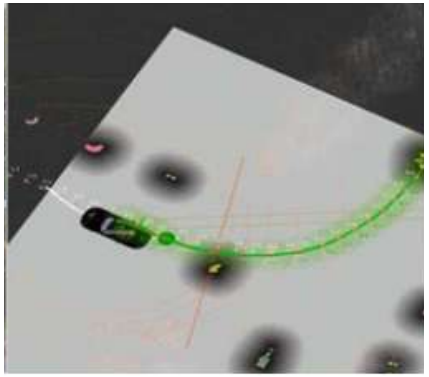


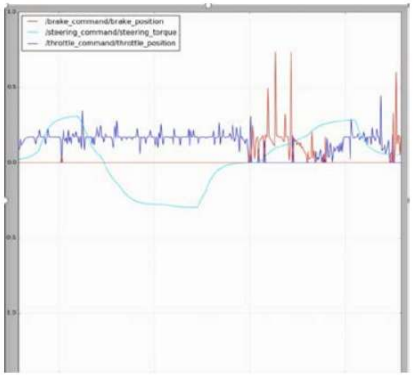
Source: https://www.researchgate.net/publication/330494421_Autonomous_Vehicle_The_Architecture_Aspect_of_Self_Driving_Car

Self-Driving Car Architecture





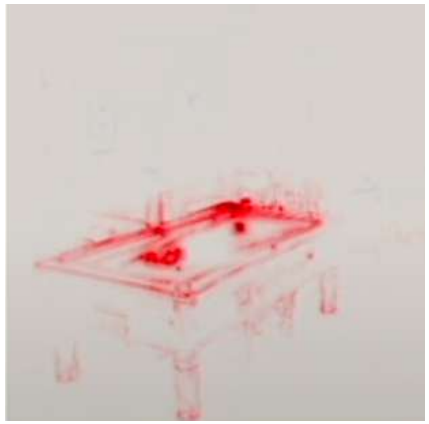




Source: https://www.researchgate.net/publication/330494421_Autonomous_Vehicle_The_Architecture_Aspect_of_Self_Driving_Car

Explaining Predictions

„why a given image is classified as a pool table”

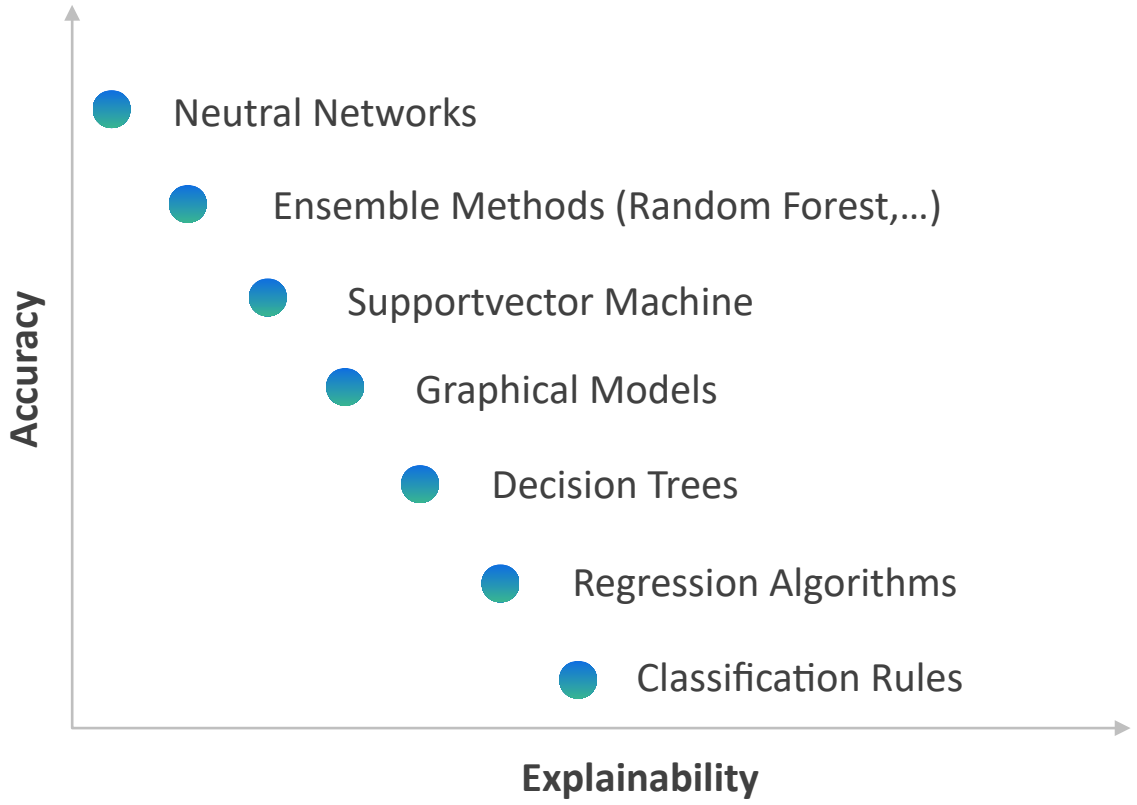


some pool table

why it is classified as a pool table

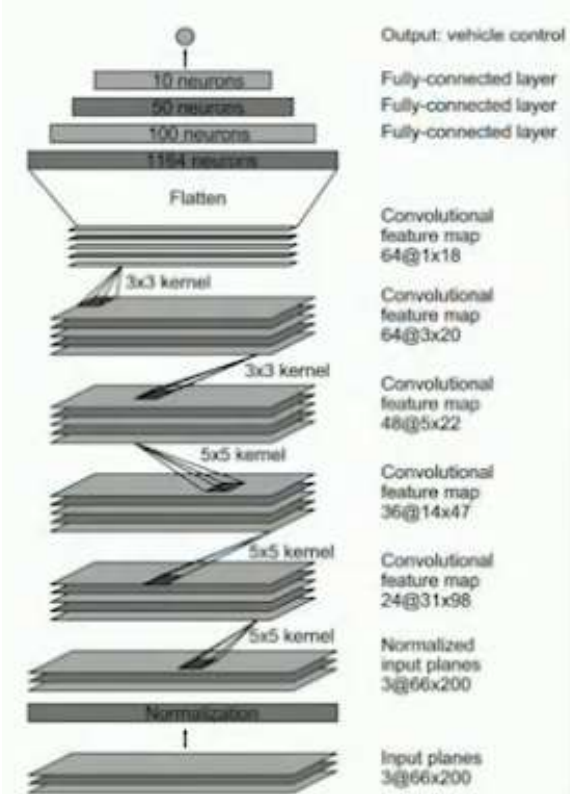
Source: Explainable AI - Methods, Applications & Recent Developments - Dr. Wojciech Samek | ODSC Europe 2019

XAI

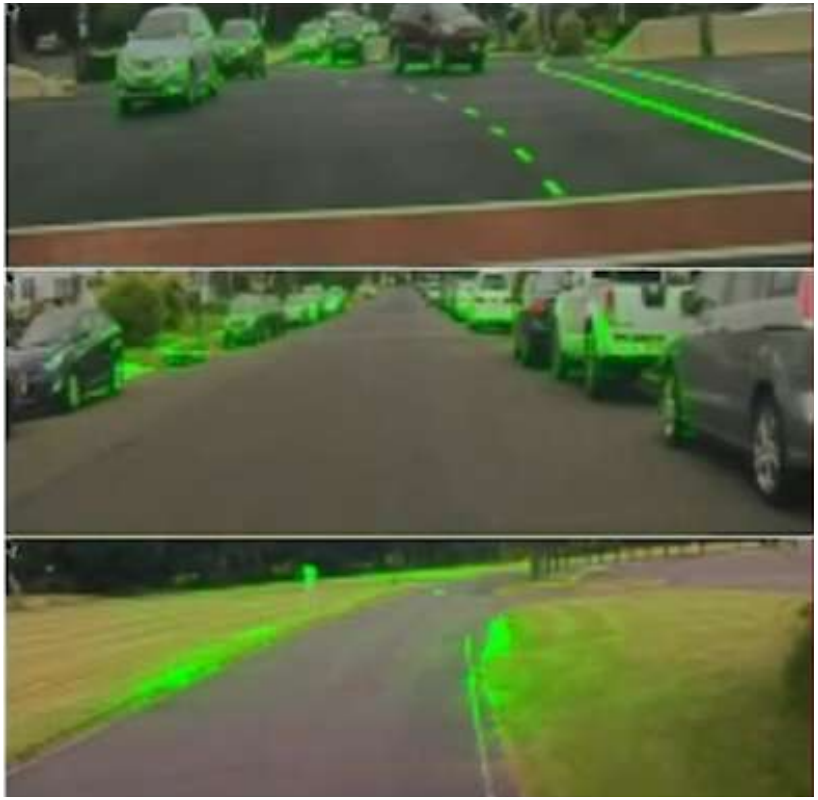


Source: Explainable AI - Methods, Applications & Recent Developments - Dr. Wojciech Samek | ODSC Europe 2019

XAI



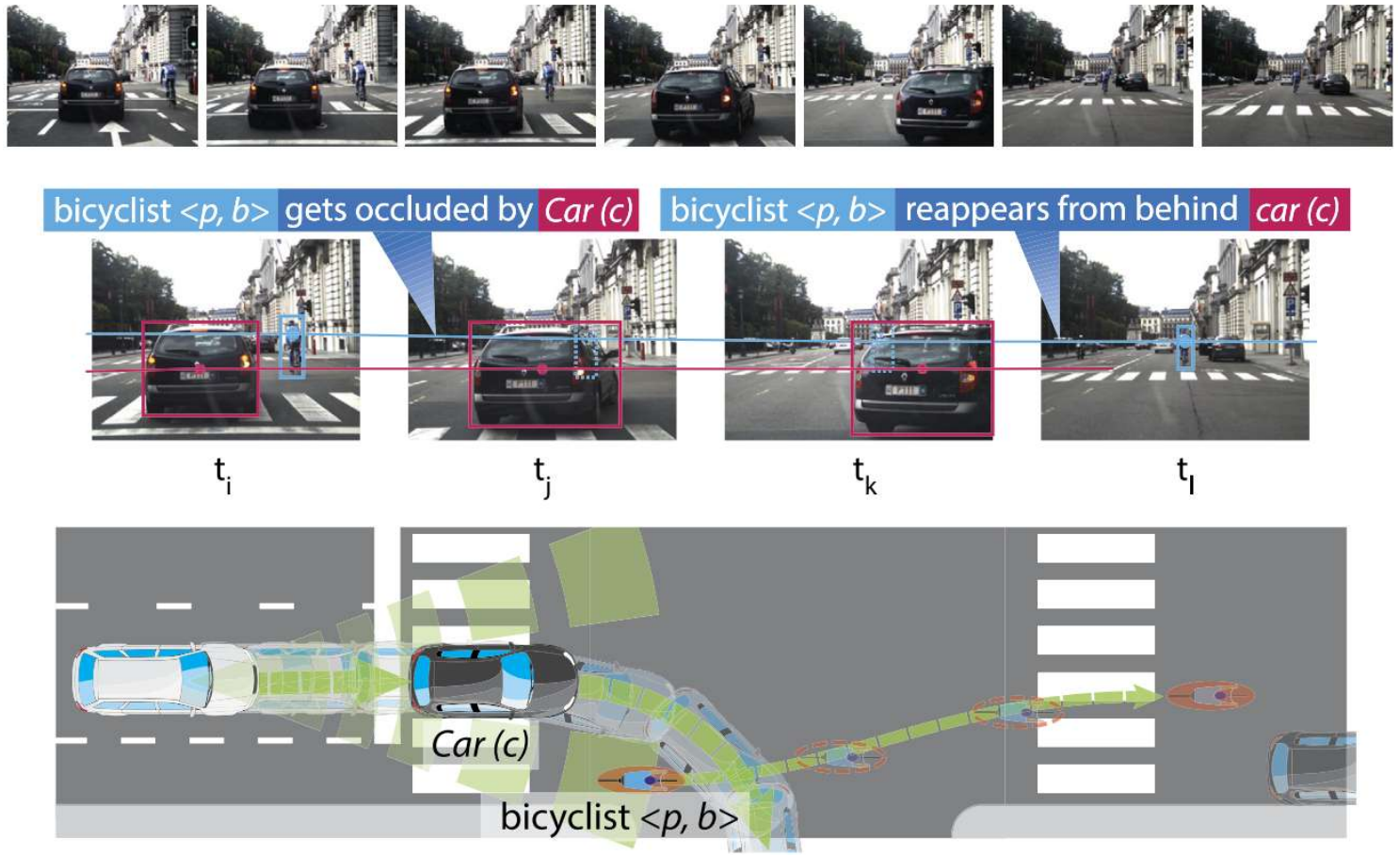
PilotNet architecture
NVIDIA/Google, 2017



Highlghtning the parts of images
which affect turning steeringwheel

Source: Explainable AI - Methods, Applications & Recent Developments - Dr. Wojciech Samek | ODSC Europe 2019

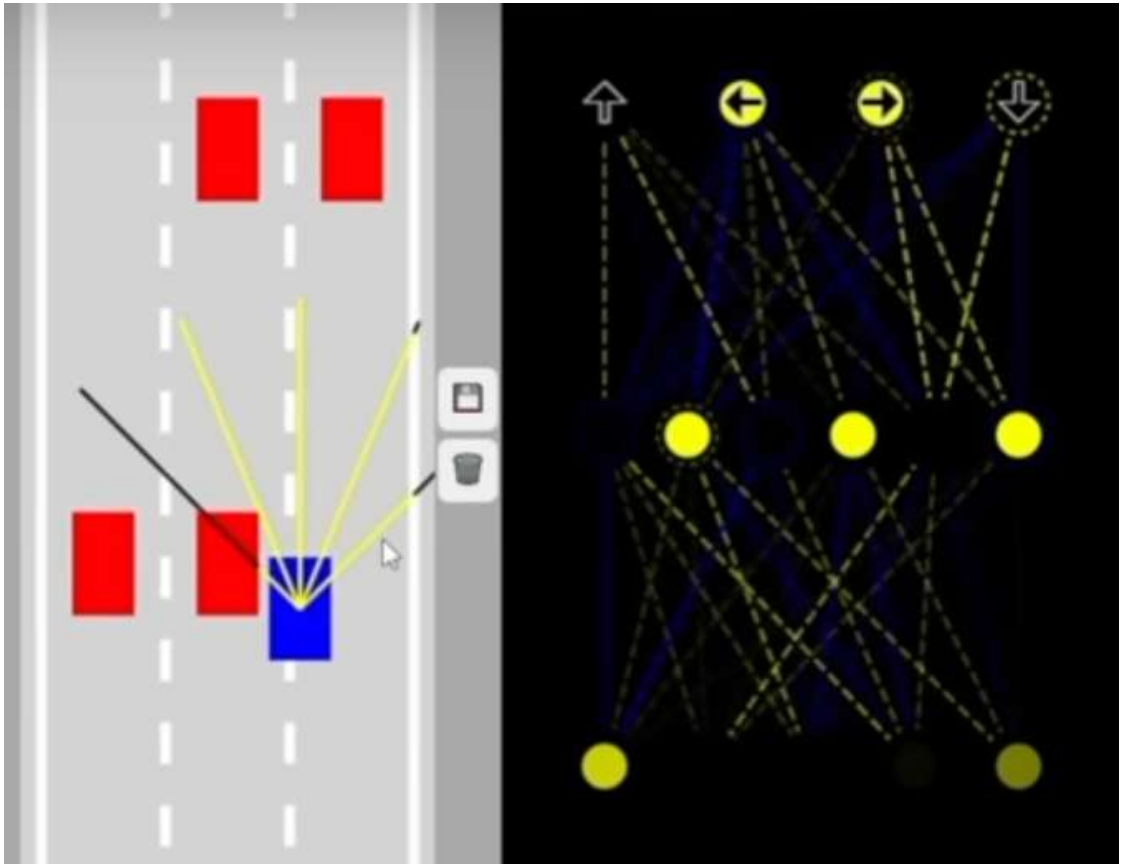
Commonsense visual sensemaking



Source: https://www.sciencedirect.com/science/article/pii/S0004370221000734

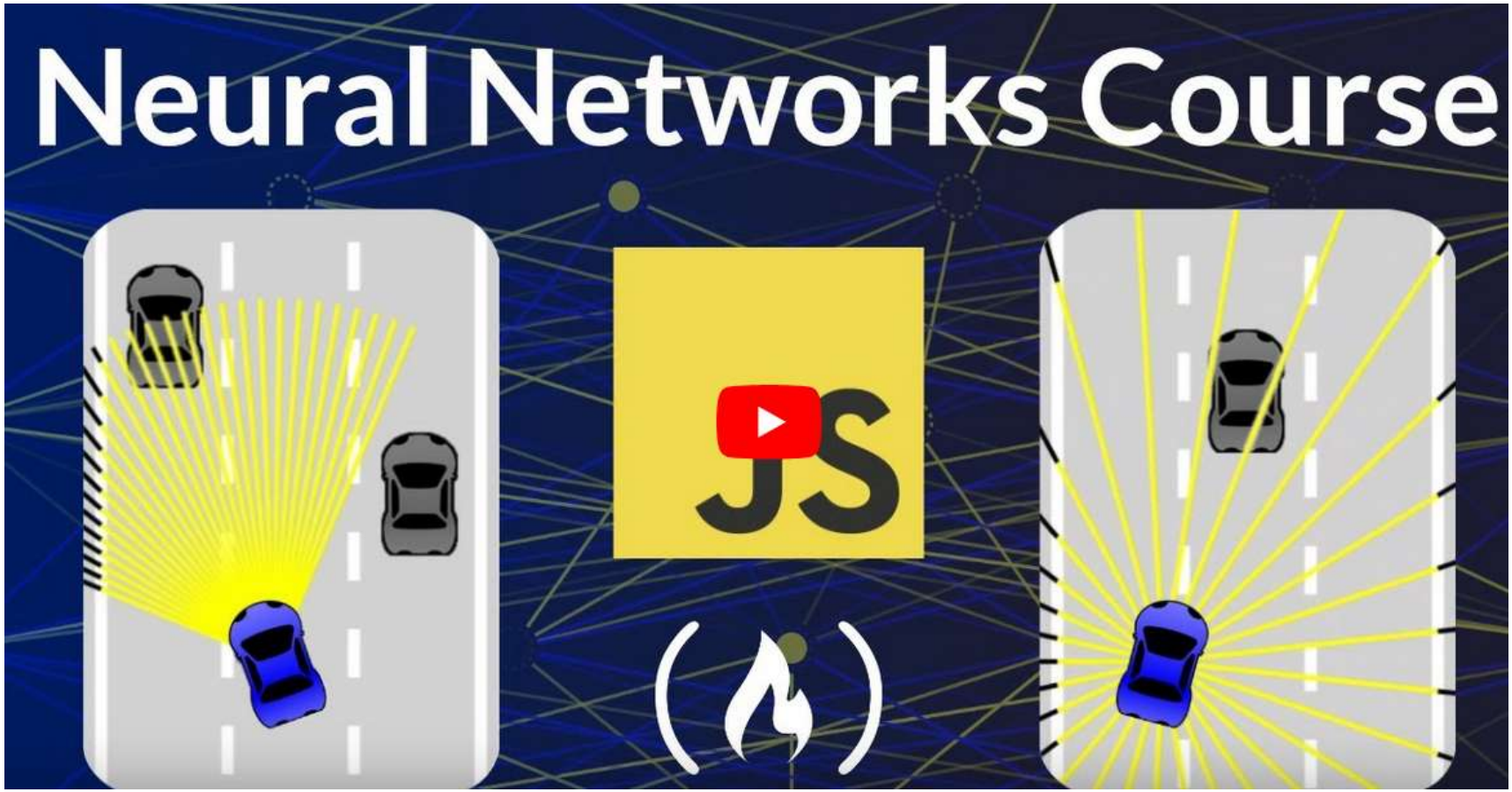
Self-Driving Car with JavaScript

- Car driving mechanics
- Defining the road
- Artificial sensors
- Collision detection
- Simulating traffic
- Neural network
- Parallelization
- Genetic algorithm



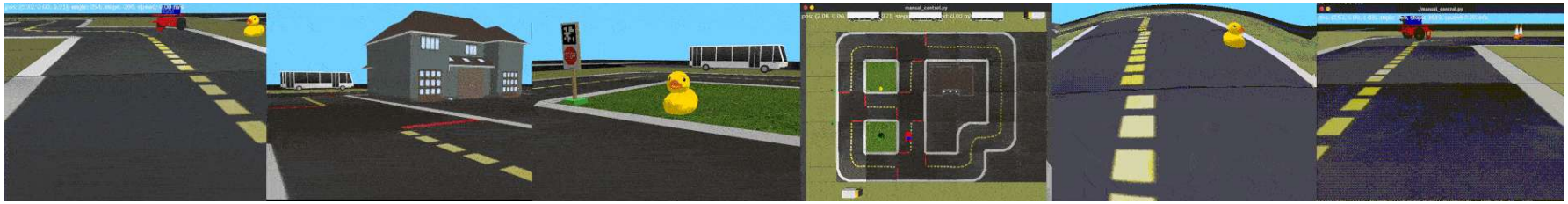
Source: https://www.youtube.com/watch?v=Rs_rAxEsAvI&list=RDCMUC8butISFwT-Wl7EV0hUK0BQ&index=3

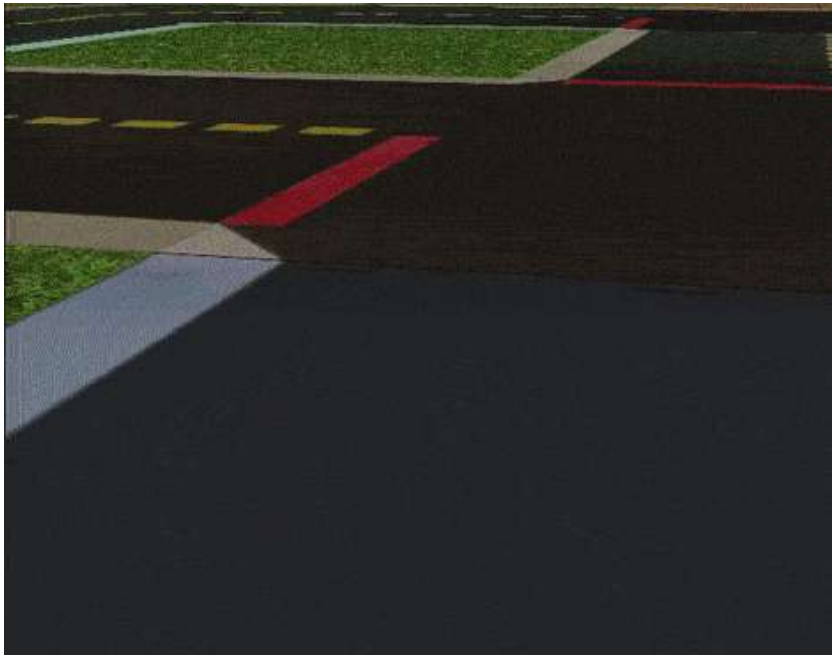
Self-Driving Car with JavaScript

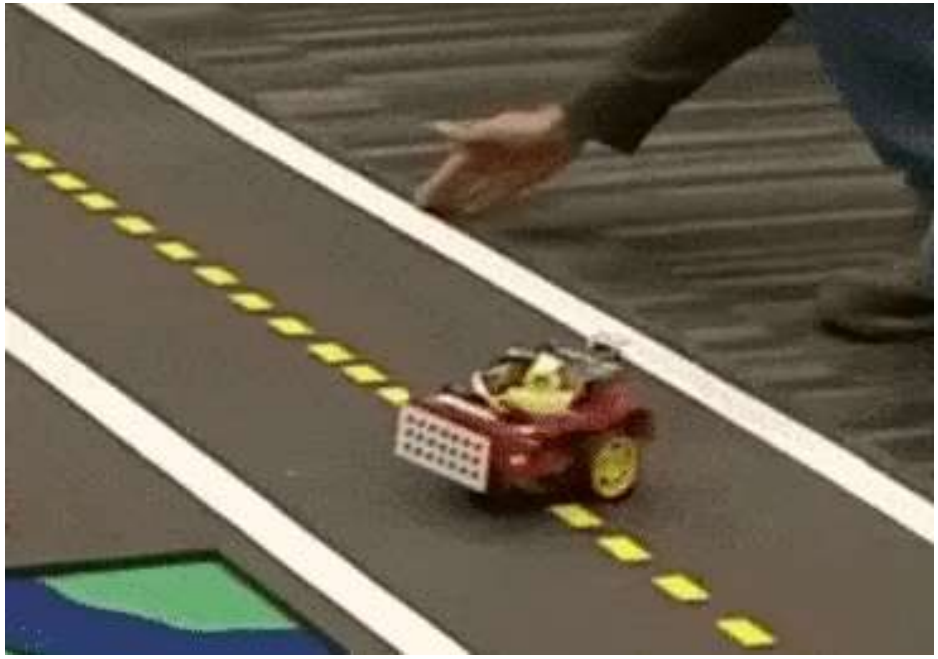


Source: https://www.youtube.com/watch?v=Rs_rAxEsAvI&list=RDCMUC8butISFwT-WI7EV0hUK0BQ&index=3

Gym-Duckietown







Source: https://github.com/duckietown/gym-duckietown

Gym-Duckietown

```
python3 pytorch_rl/main.py \
        --algo a2c \
        --env-name Duckietown-loop_obstacles-v0 \
        --lr 0.0002 \
        --max-grad-norm 0.5 \
        --no-vis \
        --num-steps 20
```

```
{
  'acceleration': array([-264.26913452, -227.578125  ,  105.16122437]),
  'angular_acceleration': array([210980.234375, 105423.765625,  38187.28125 ]),
  'angular_velocity': array([2.59908962, 3.8214705 , 1.87282801]),
  'brake': 0.0,
  'camera_count': 1,
  'cameras': [{  'aspect_ratio': 1.0,
                 'capture_height': 227,
                 'capture_width': 227,
                 'depth_data': array([0.9995  , 0.9995  , 0.9995  , ...,
                    0.005146, 0.005146, 0.005146], dtype=float16),
                 'horizontal_field_of_view': 1.7654,
                 'id': 1,
                 'image': array([[[ 40.,  78., 110.] ..., dtype=float32),
                 'image_data': array([0.283  , 0.557  , 0.82,
                    ..., 0.02321, 0.02574, 0.02599], dtype=float16),
                 'image_raw': array([[[144, 195, 233]..., dtype=uint8),
                 'type': 0
              }],
```

Source: https://github.com/duckietown/gym-duckietown

Self-Driving Deep Drive


```
import deepdrive

def main():
    env = deepdrive.start()
    forward = deepdrive.action(steering=0, throttle=1, brake=0)
    done = False
    while not done:
        observation, reward, done, info = env.step(forward)

if __name__ == '__main__':
    main()
```

Source: https://deepdrive.io/index.html

Thank you
for your attention!