MSAI Robotics course

Lecture 1

# Introduction to Robotics Sensors

Vladislav Goncharenko
Materials by Oleg Shipitko
MIPT, 2022

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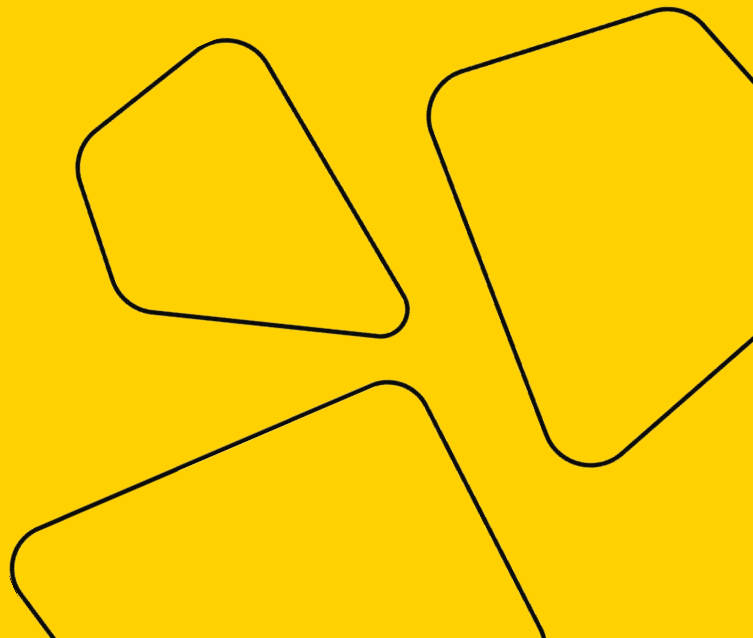

# Outline

1. Course organization
2. What is robot
3. Types of robots
4. Mobile (wheeled) robots
5. Robotic sensors

# Course organization

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01

# Lecturer

Vladislav Goncharenko

- Head of perception at Evocargo
- PhD student an IITP, lab of Vision Systems
- Professor and course author at MIPT, Big data academy at mail.ru, Harbour Space and others
- Open source projects contributor

Telegram: @white_pepper
Github: v-goncharenko
LinkedIn: vladislav-goncharenko

# COURSE CONTENT

1. **Introduction to Mobile Robotics (Lectures)**
    a. What is robot? Types of robots and sensors
    b. Localization / Mapping
    c. Path planning
    d. Robot control
2. **Robot Operating System (ROS) (Seminars)**
    a. History and core principles of ROS
    b. Creation and compilation of ROS-package
    c. Creation of simple nodes: Publisher and Subscriber
    d. Custom Msg-files and services
    e. Bag-files (recording, analyzing and playing)
    f. Additional ROS-instruments: Tf, RviZ, Gazebo

# COURSE AIMS

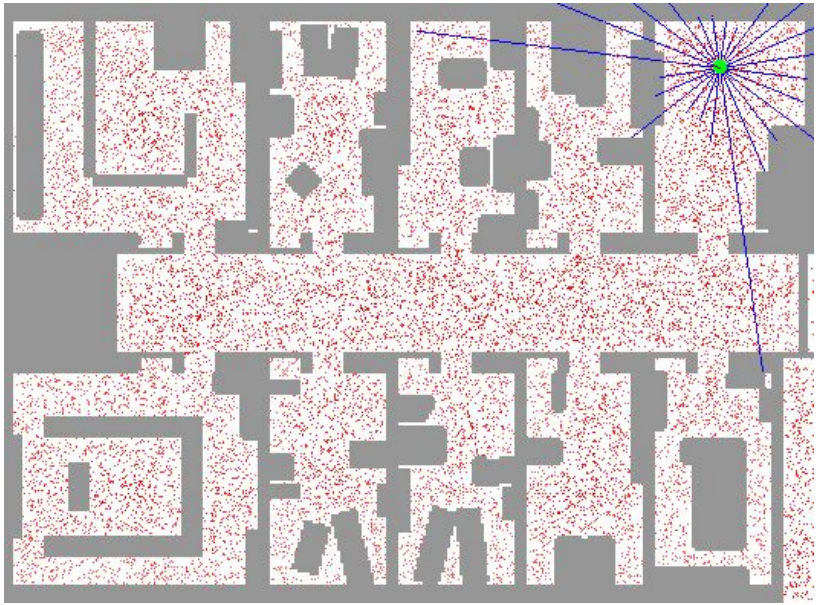
1. Overview of classical areas and methods of mobile robotics
2. Introduction to probabilistic robotics
3. Overview of modern research areas
4. Introduction to ROS (Robot Operating System)
5. Practical experience in solving robotics projects

# COURSE ORGANIZATION

1. One lecture and one seminar each week
2. 3-4 homework assignments

# HOMEWORK ASSIGNMENTS

## Localization



## Control

# What is robot

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# WHAT IS ROBOT?

A **ROBOT** (Czech. “robot”, from “robota” — «slave labor») is a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer.

Definition of 'robot'. Oxford English Dictionary.

The word «**ROBOT**» was invented by czech writer Karel Čapek and first used in his play «R. U. R.» («Rossumovi Univerzální Roboti [Rossum's Universal Robots]», 1920).

# WHAT IS ROBOT?

**ROBOT = PERCEPTION + ACTUATION + COMPUTING**

# WHAT IS ROBOT?

**ROBOT = SENSORS + ACTUATORS + COMPUTERS**

# WHAT IS ROBOT?

Is ...

- ❑ washing machine
- ❑ electric kettle
- ❑ satellite
- ❑ RC-car
- ❑ automatic transmission

... a **robot**?

Manipulating inside or outside of itself

# Types of robots

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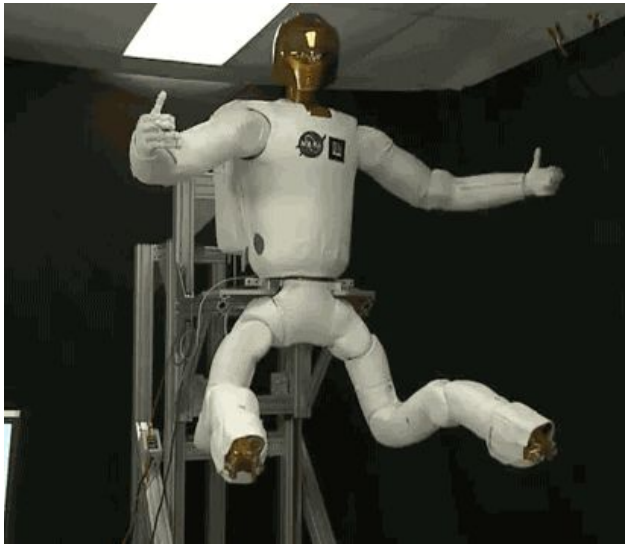
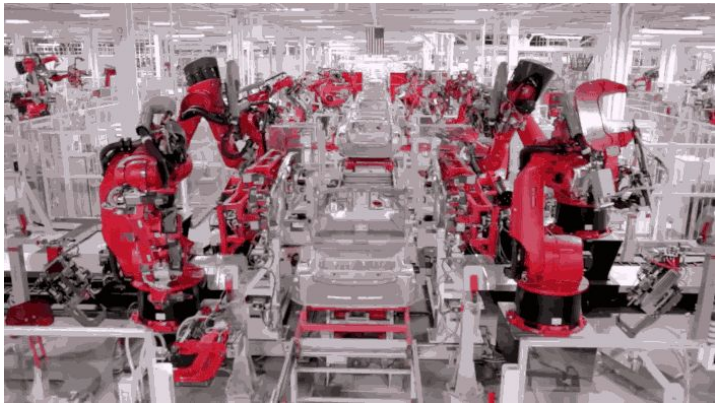
03

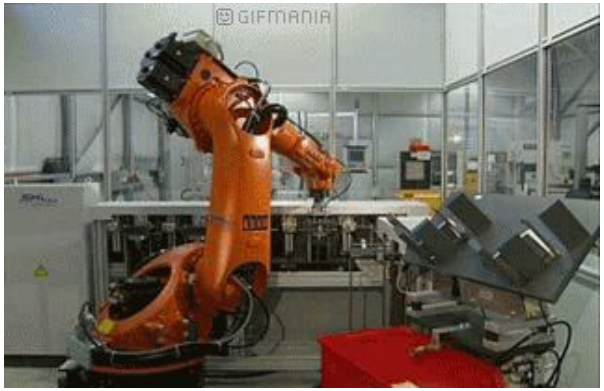
# AEROSPACE

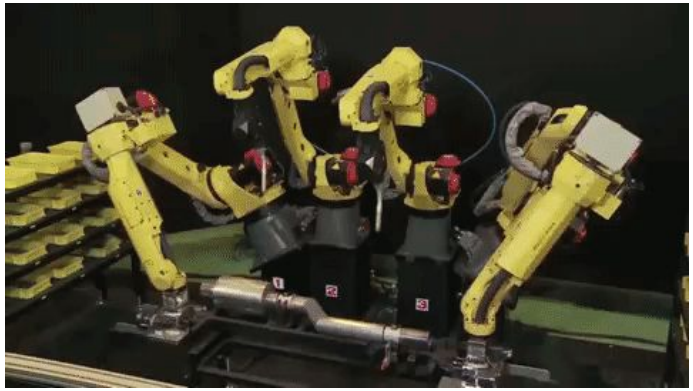
Dust deposition on Curiosity rover - sols 84 & 613
NASA/JPL-Caltech/MSSS/Thomas Appéré

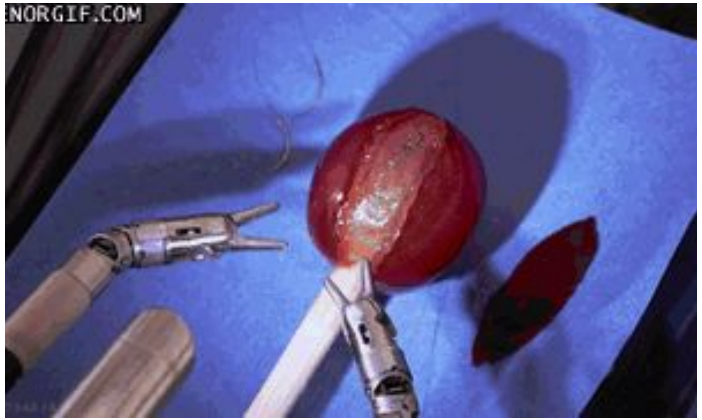
# INDUSTRIAL



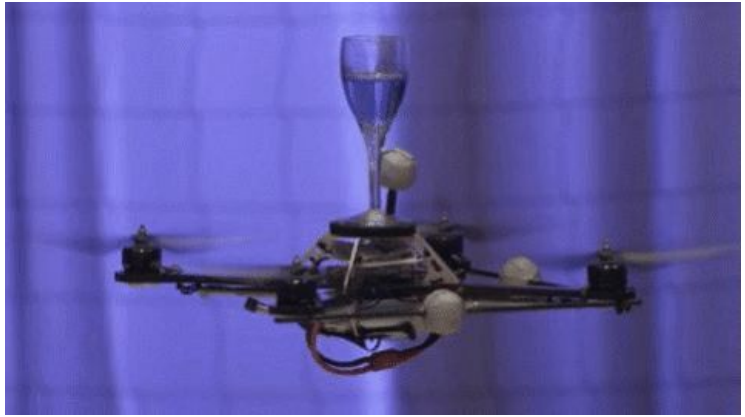



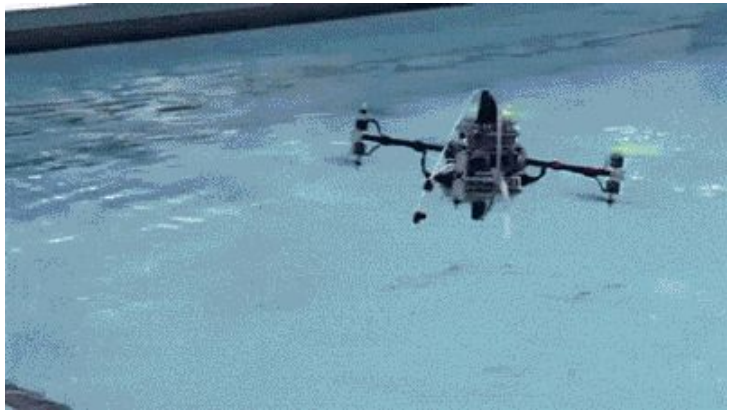



# MEDICAL



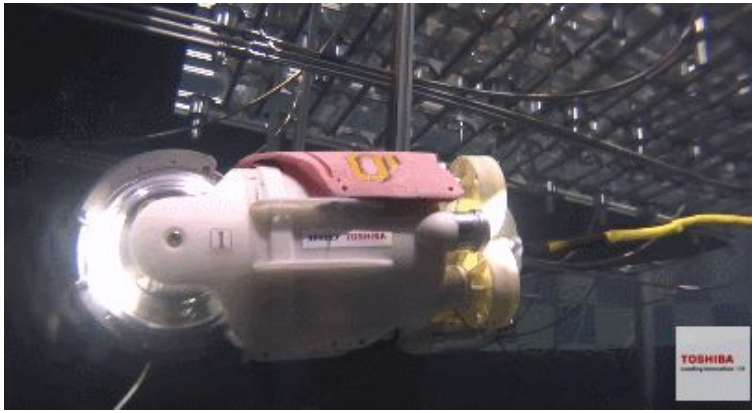

# DRONES

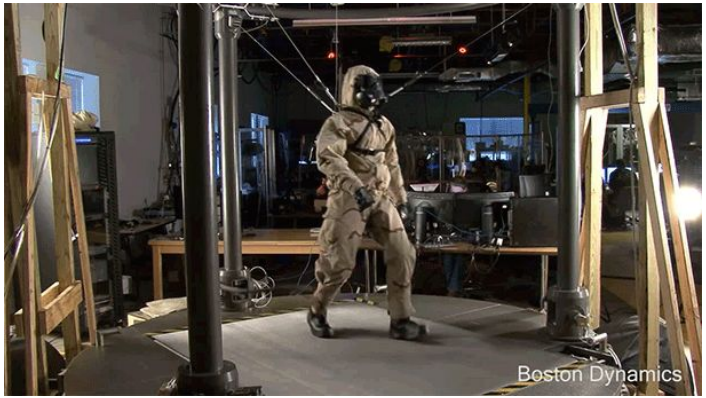


# EXTREME ROBOTICS

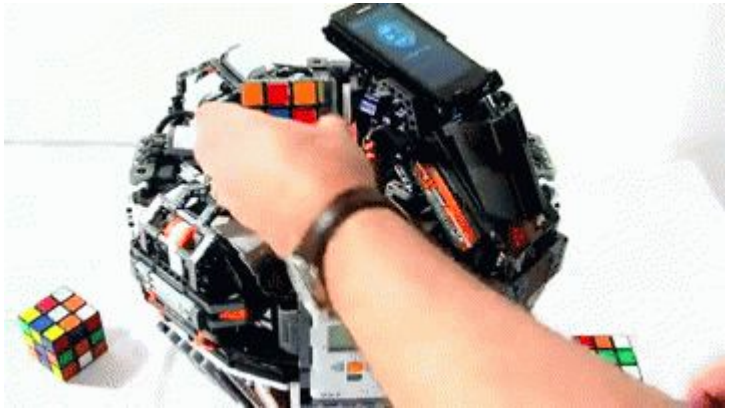
## 3D (dirty, dangerous and demeaning)

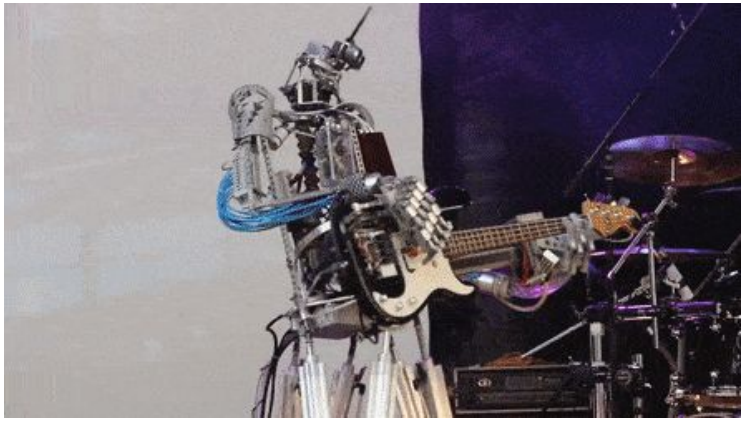

# MILITARY

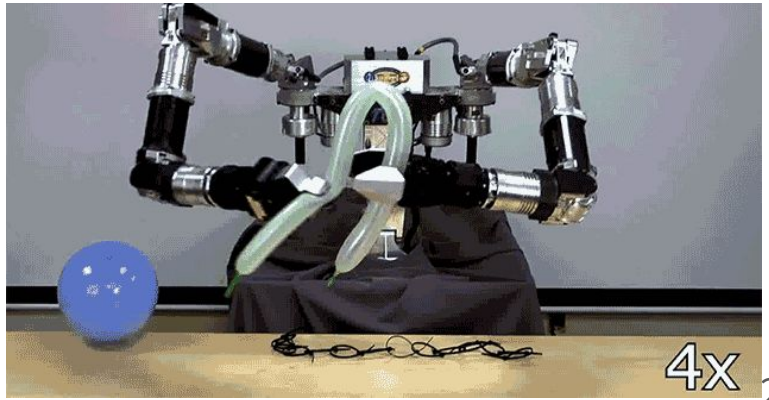


# EDUCATIONAL

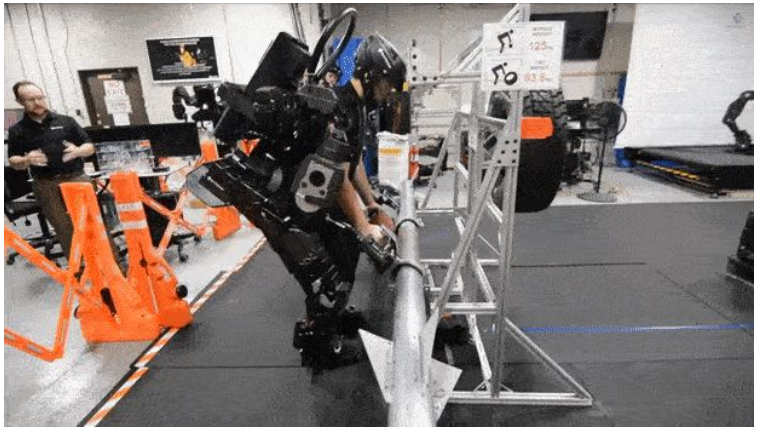


# FOR ENTERTAINMENT

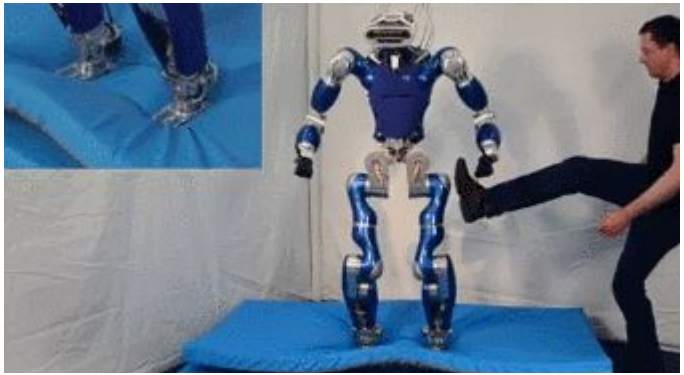


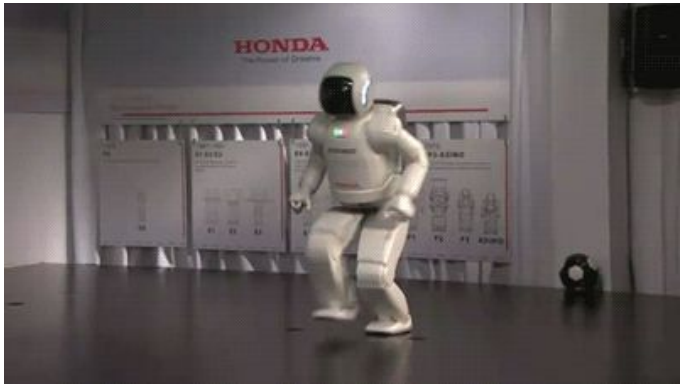



# EXOSKELETONS

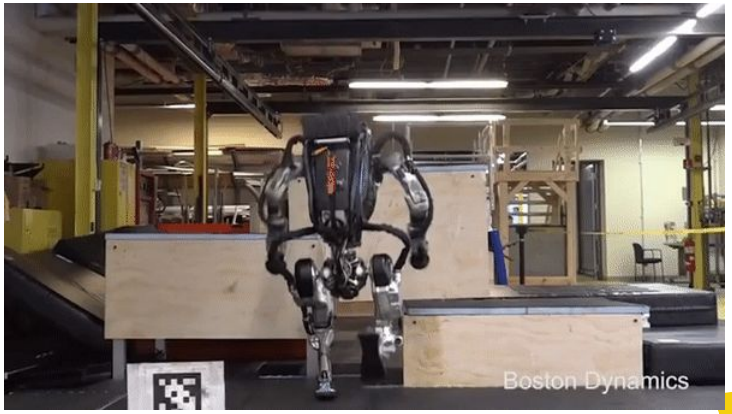


# ANTHROPOMORPHIC

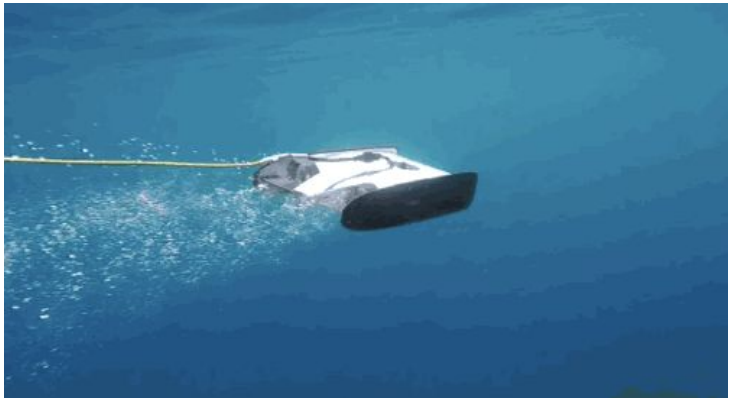




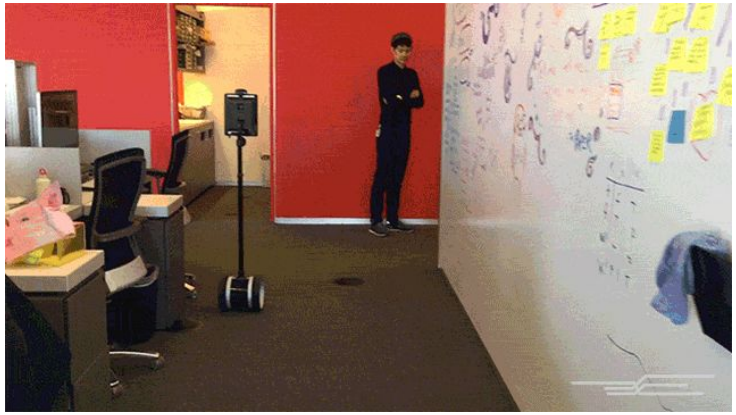




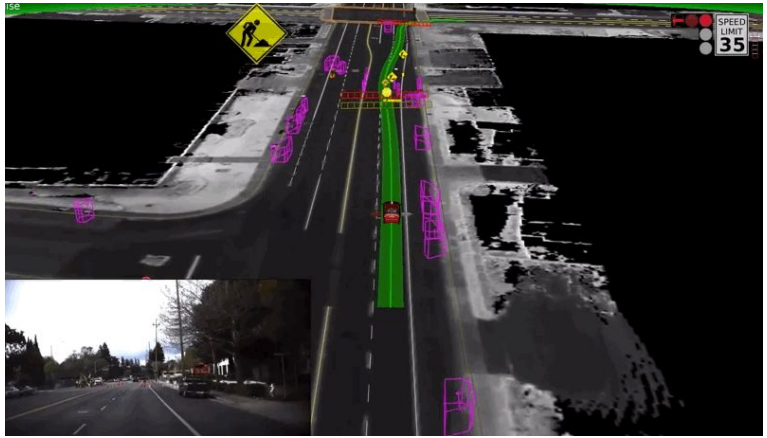
# MARINE



# TELEPRESENCE



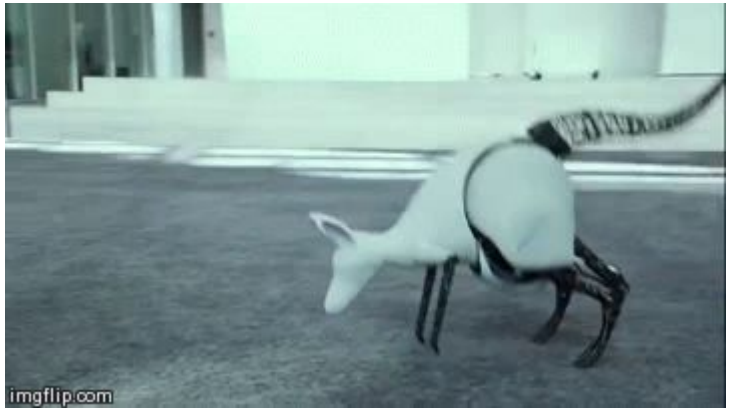
# AUTONOMOUS CARS

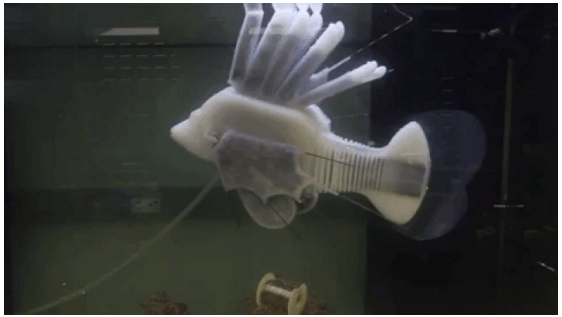


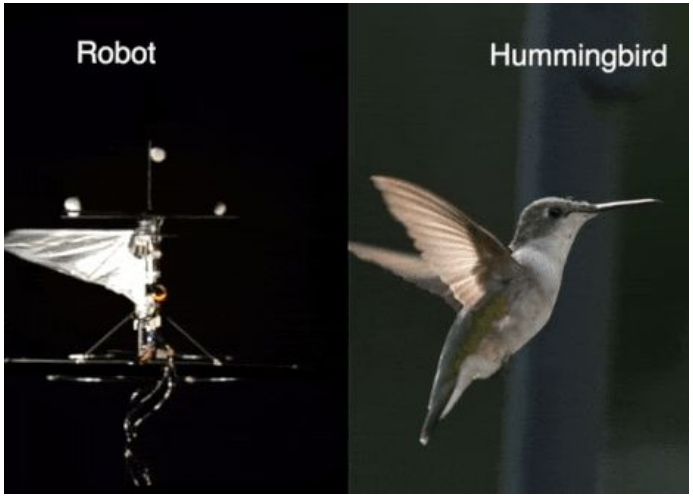


[Brief history of self-driving cars [ru]]

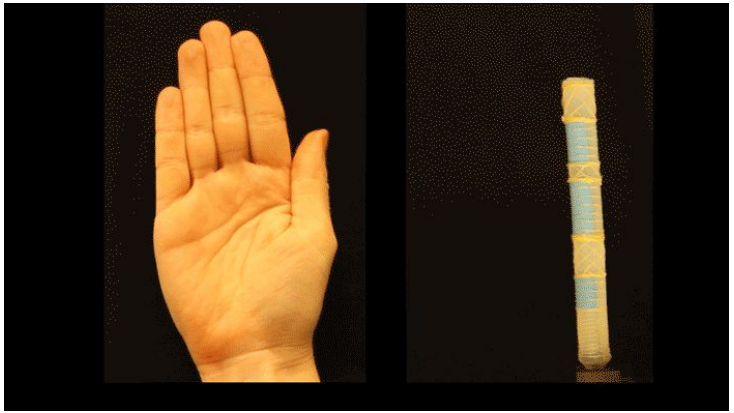
# BIOINSPIRED

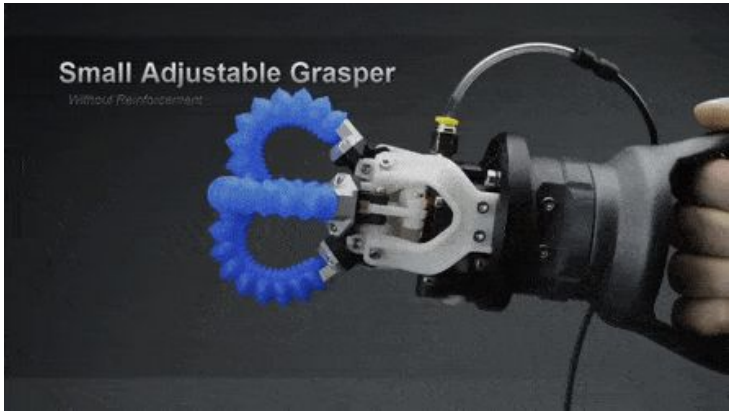


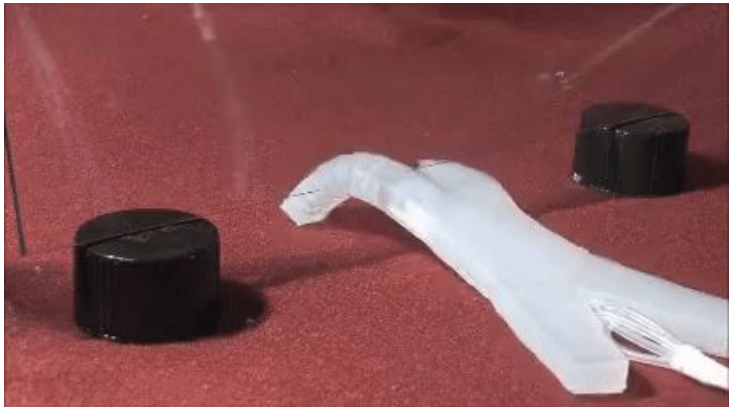



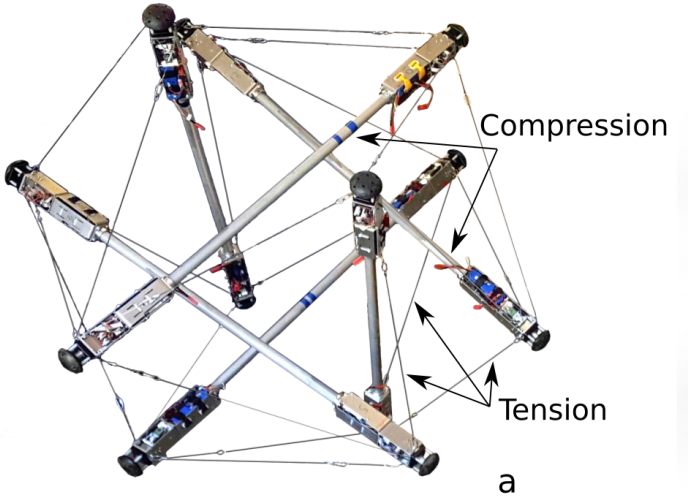
# SOFT





# TENSEGRITY

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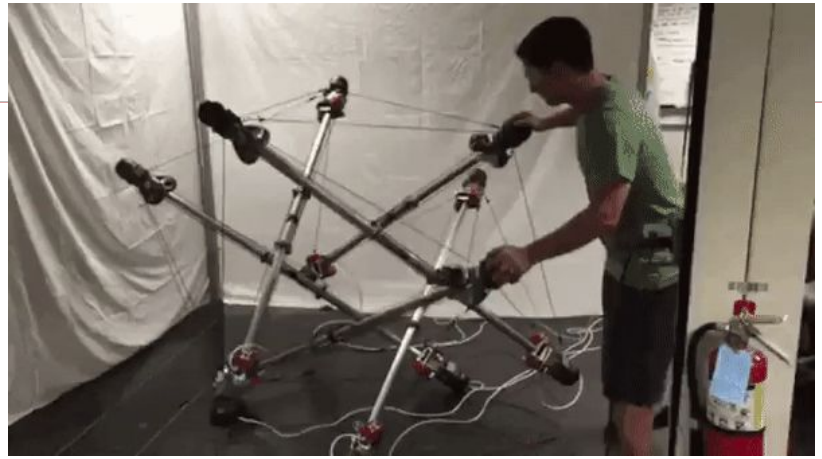
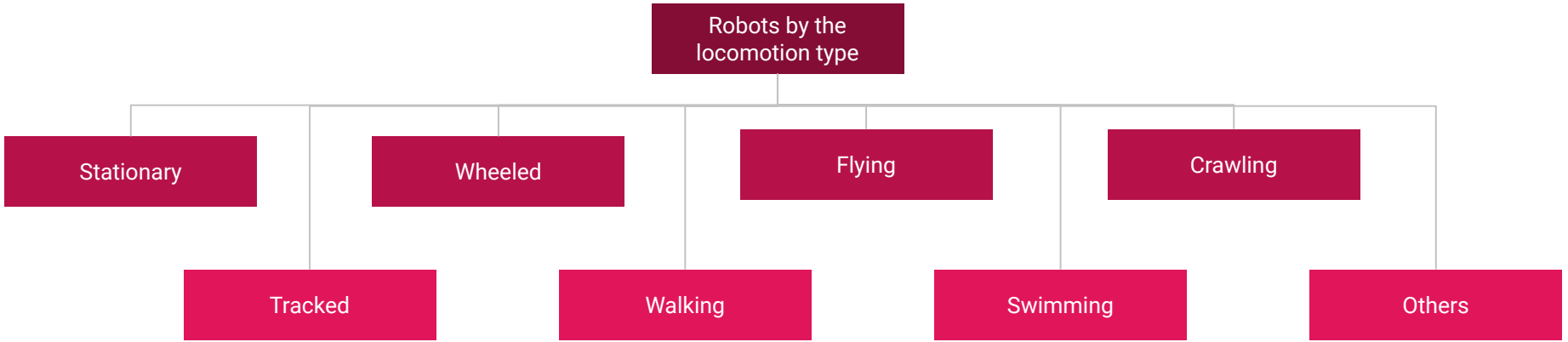


# ROBOTS BY THE TYPE OF LOCOMOTION (MOVEMENT)



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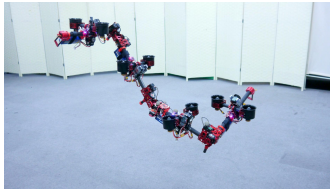
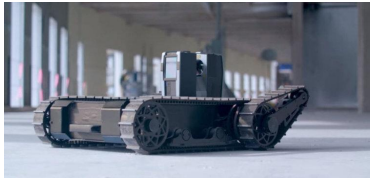
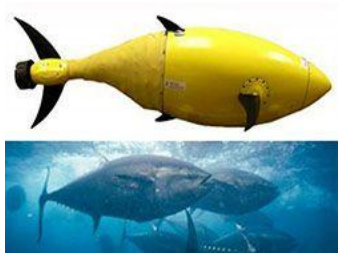


Robots by the locomotion type

- Stationary
- Wheeled
- Flying
- Crawling
- Tracked
- Walking
- Swimming
- Others





# Mobile (wheeled) robots

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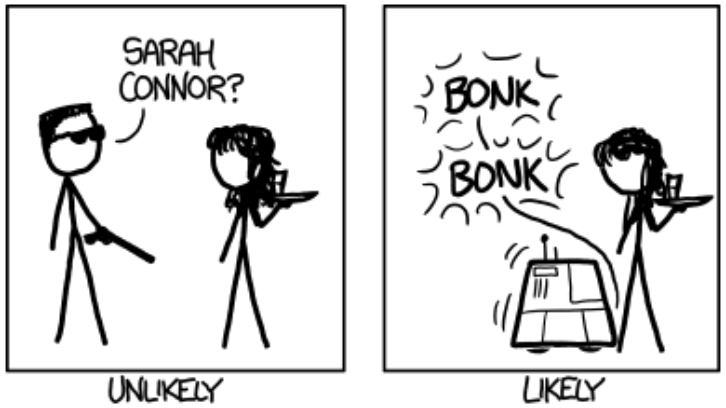
# MOBILE (WHEELED) ROBOTS


# MOBILE (WHEELED) ROBOTS

# WHY MOBILE ROBOTS?

1. Simple (construction and control)
2. Maneuverable
3. Stable
4. Fast

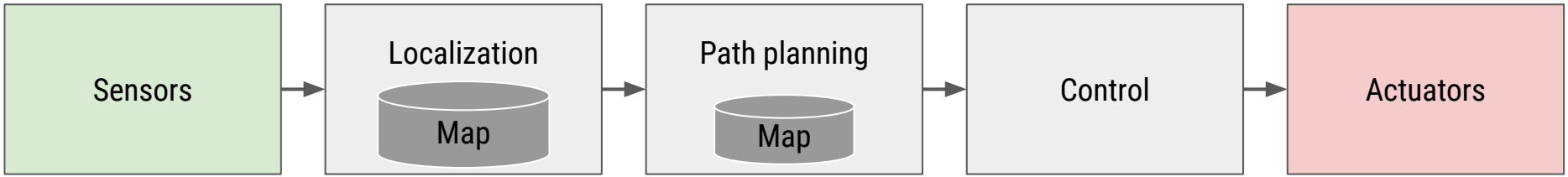



All of this makes mobile robots one of the most common family of robots used in real applications.

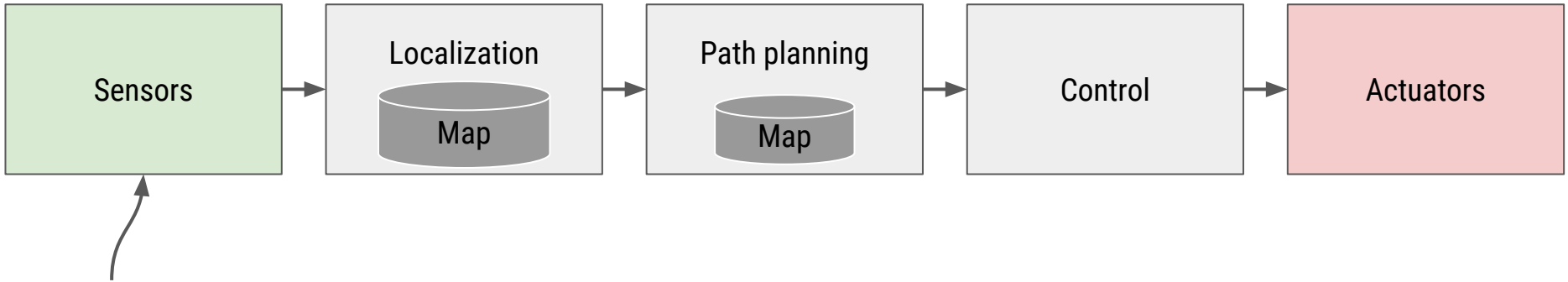


Source: https://what-if.xkcd.com/

# (SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



# (SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



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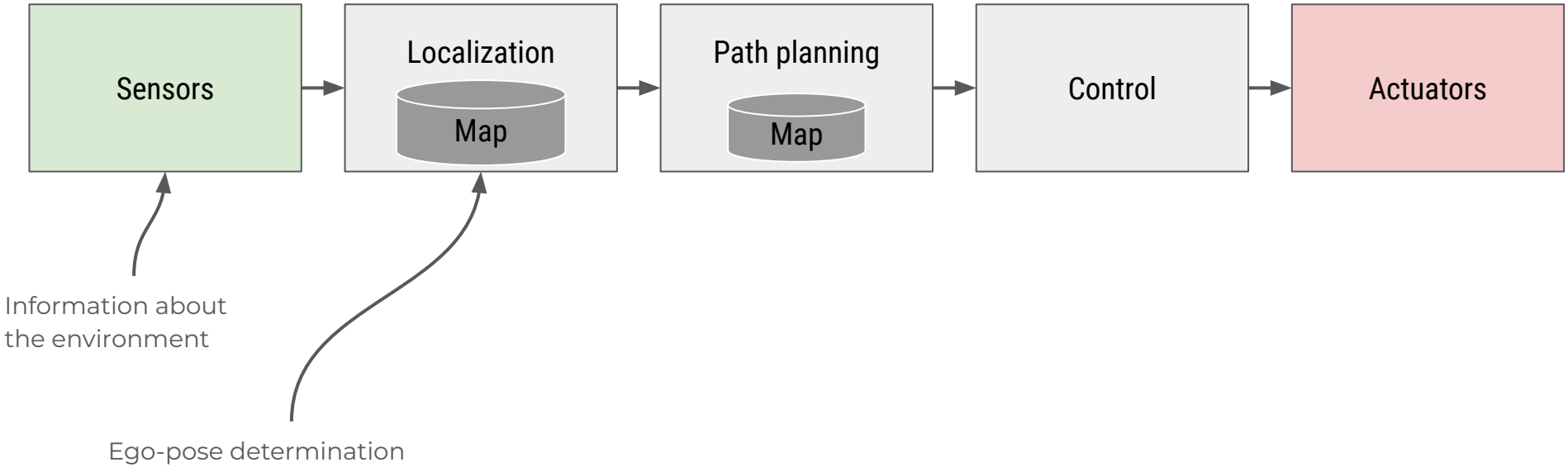

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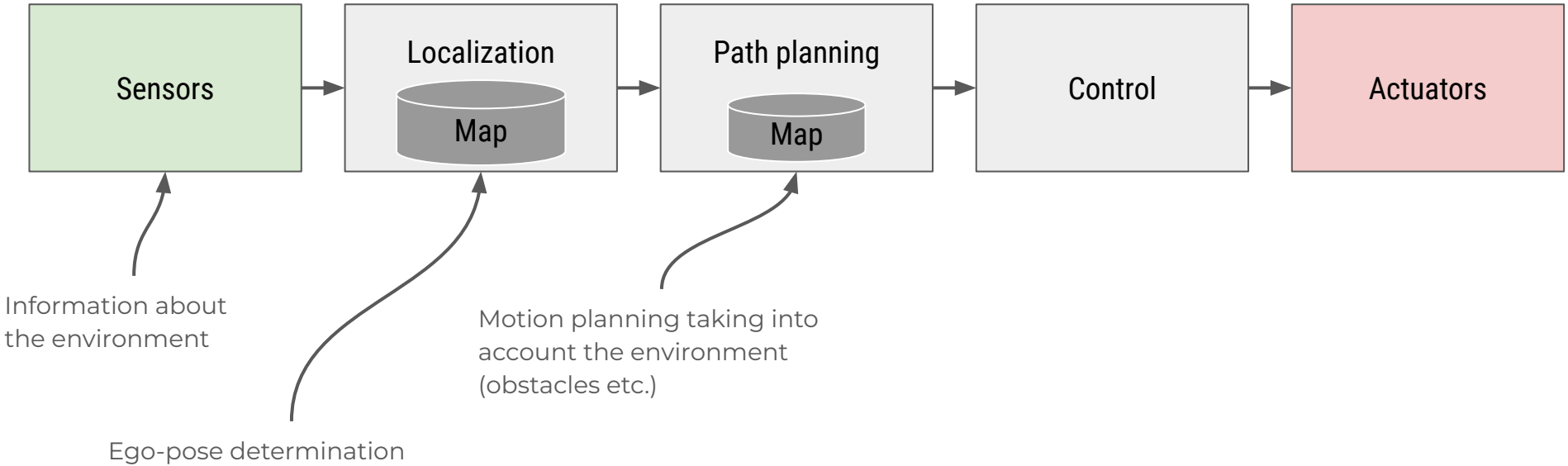
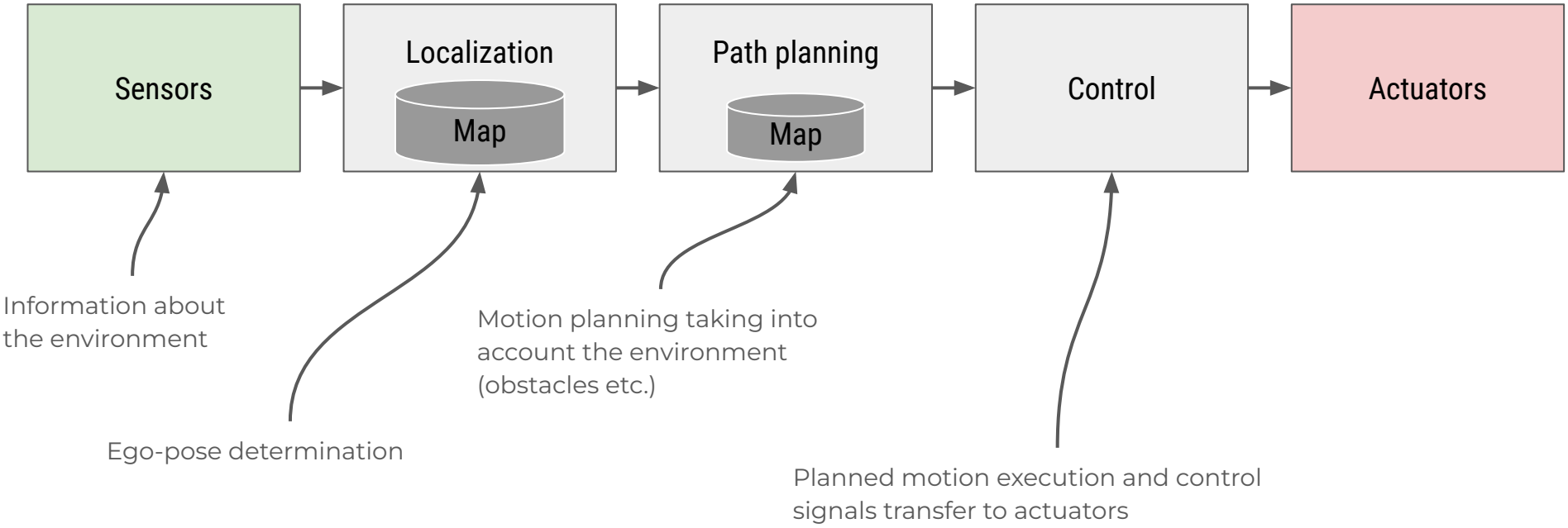


# (SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



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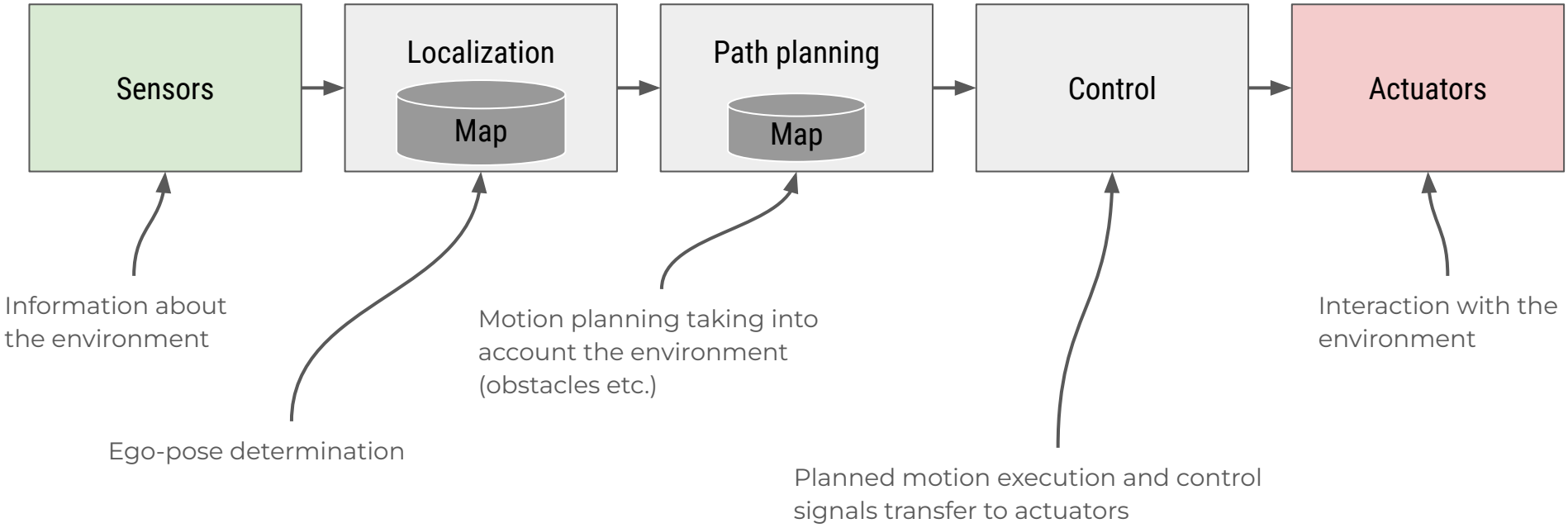


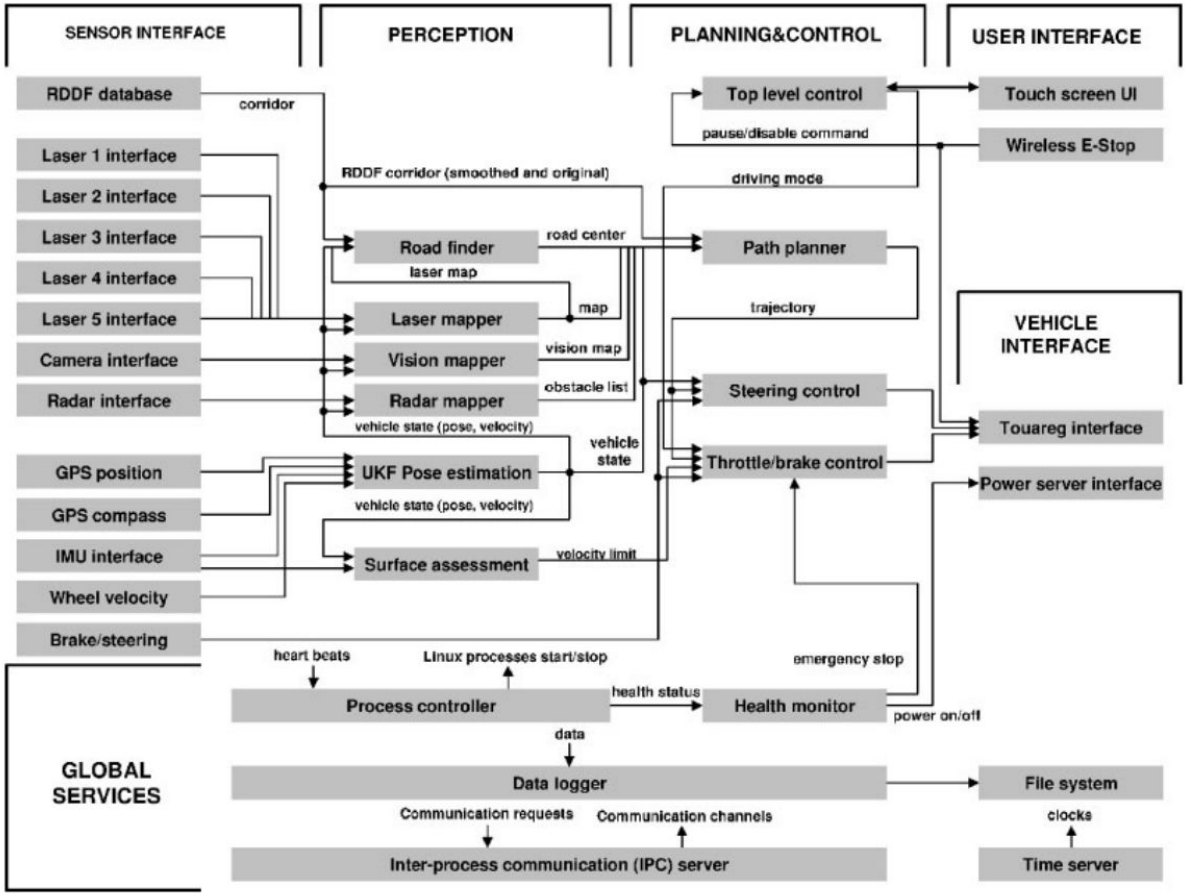




Thrun S. et al. Stanley: The robot that won the DARPA Grand Challenge //Journal of field Robotics. – 2006. – Т. 23. – №. 9. – С. 661-692.

# Robotic sensors

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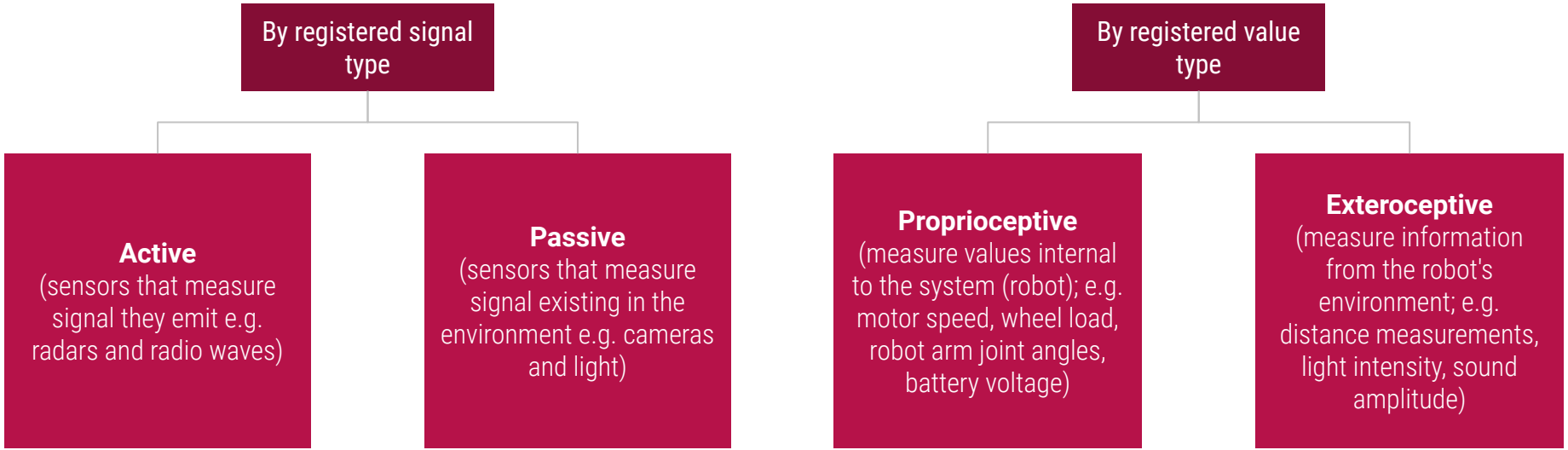
05

# SENSORS TYPES



# SENSORS TYPES

**Proprioceptive**

- ❏ Enoders
- ❏ Inertial measurement systems (IMU, VRU, AHRS)
  - ❏ Accelerometers
  - ❏ Gyroscopes
  - ❏ Magnetometers
  - ❏ Altimeters

**Exteroceptive**

- ❏ Light Detection and Ranging (LIDARs)
- ❏ Sound Navigation and Ranging (SONARs)
- ❏ Infrared distance/proximity sensors
- ❏ Cameras
  - ❏ Mono-
  - ❏ Stereo-
  - ❏ RGB-D (based on different principles)
  - ❏ Infrared (IR)
  - ❏ Multispectral
- ❏ Radio Detection and Ranging (RADARs)
- ❏ Global Navigation Systems (GNSS: GPS, GLONASS etc.)

# SENSORS TYPES

**Proprioceptive**

- ❏ Enoders
- ❏ Inertial measurement systems (IMU, VRU, AHRS)
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**Exteroceptive**

- ❏ **Light Detection and Ranging** (LIDARs)
- ❏ Sound Navigation and Ranging (SONARs)
- ❏ Infrared distance/proximity sensors
- ❏ **Cameras**
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  - ❏ Stereo-
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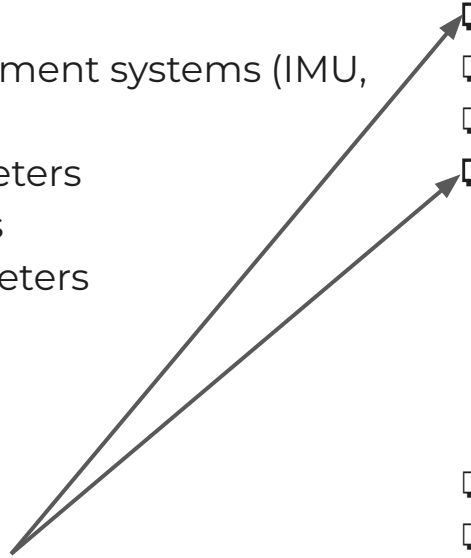
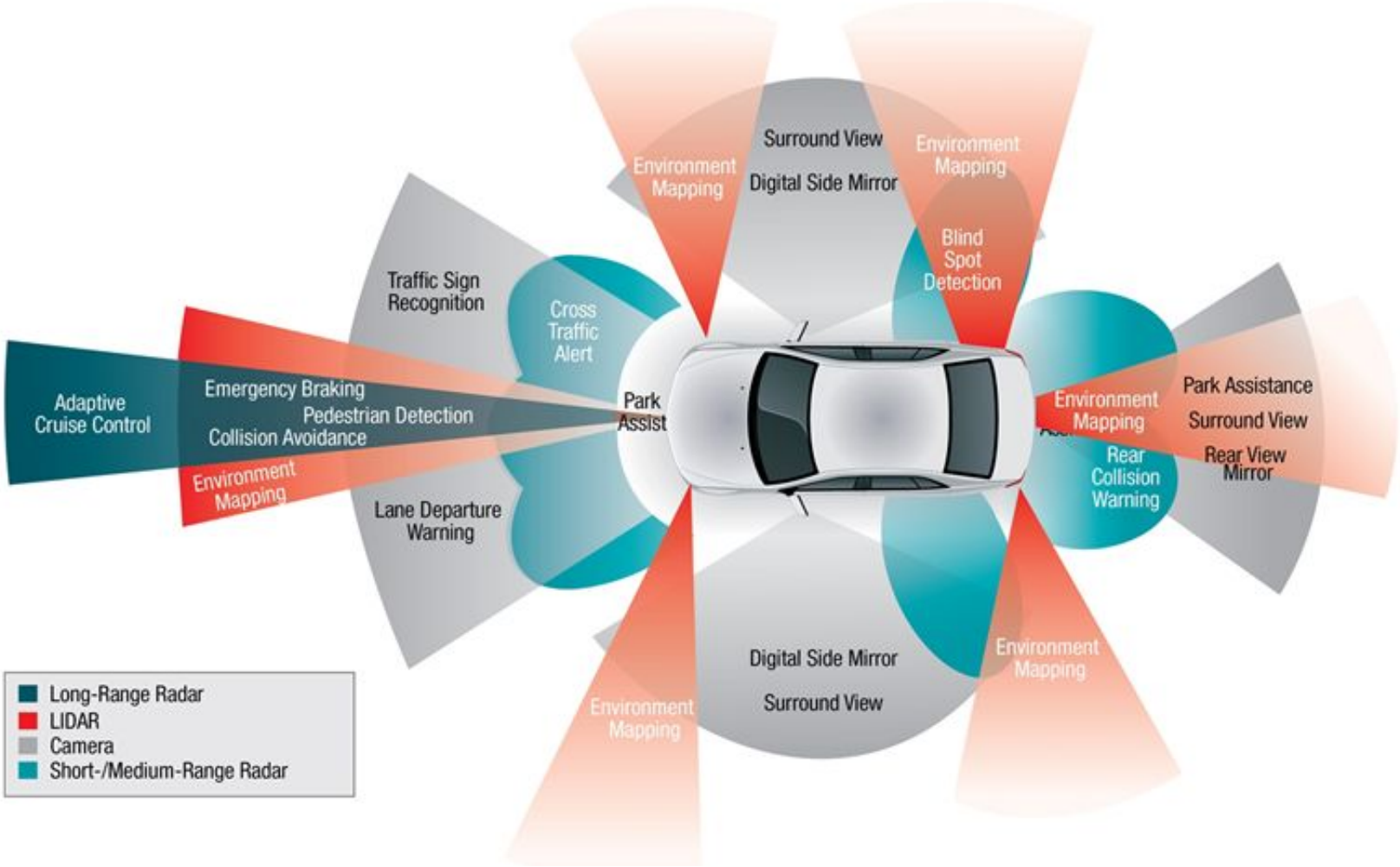
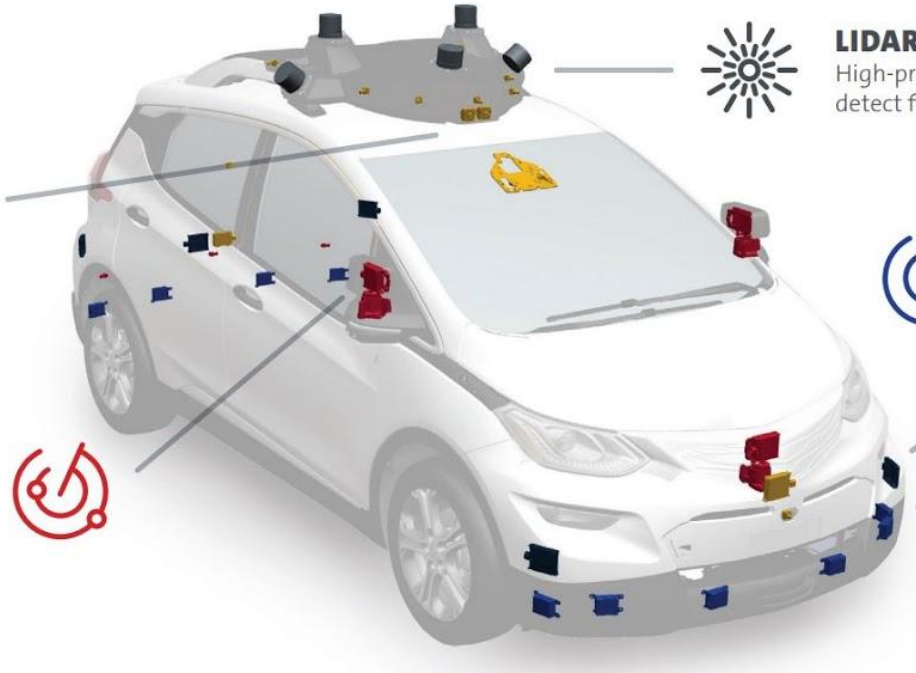
- ❏ Radio Detection and Ranging (RADARs)
- ❏ Global Navigation Systems (GNSS: GPS, GLONASS etc.)



Can be used as both **proprioceptive** and **exteroceptive** sensors


Adaptive Cruise Control
Emergency Braking
Pedestrian Detection
Collision Avoidance
Environment Mapping
Traffic Sign Recognition
Lane Departure Warning
Cross Traffic Alert
Park Assist
Environment Mapping
Surround View
Digital Side Mirror
Environment Mapping
Blind Spot Detection
Environment Mapping
Rear Collision Warning
Park Assistance
Surround View
Rear View Mirror
Environment Mapping
Digital Side Mirror
Surround View
Environment Mapping
Long-Range Radar
LIDAR
Camera
Short-/Medium-Range Radar



**LIDARS**
High-precision laser sensors that detect fixed and moving objects

**CAMERAS**
Detect and track pedestrians / cyclists, traffic lights, free space and other features

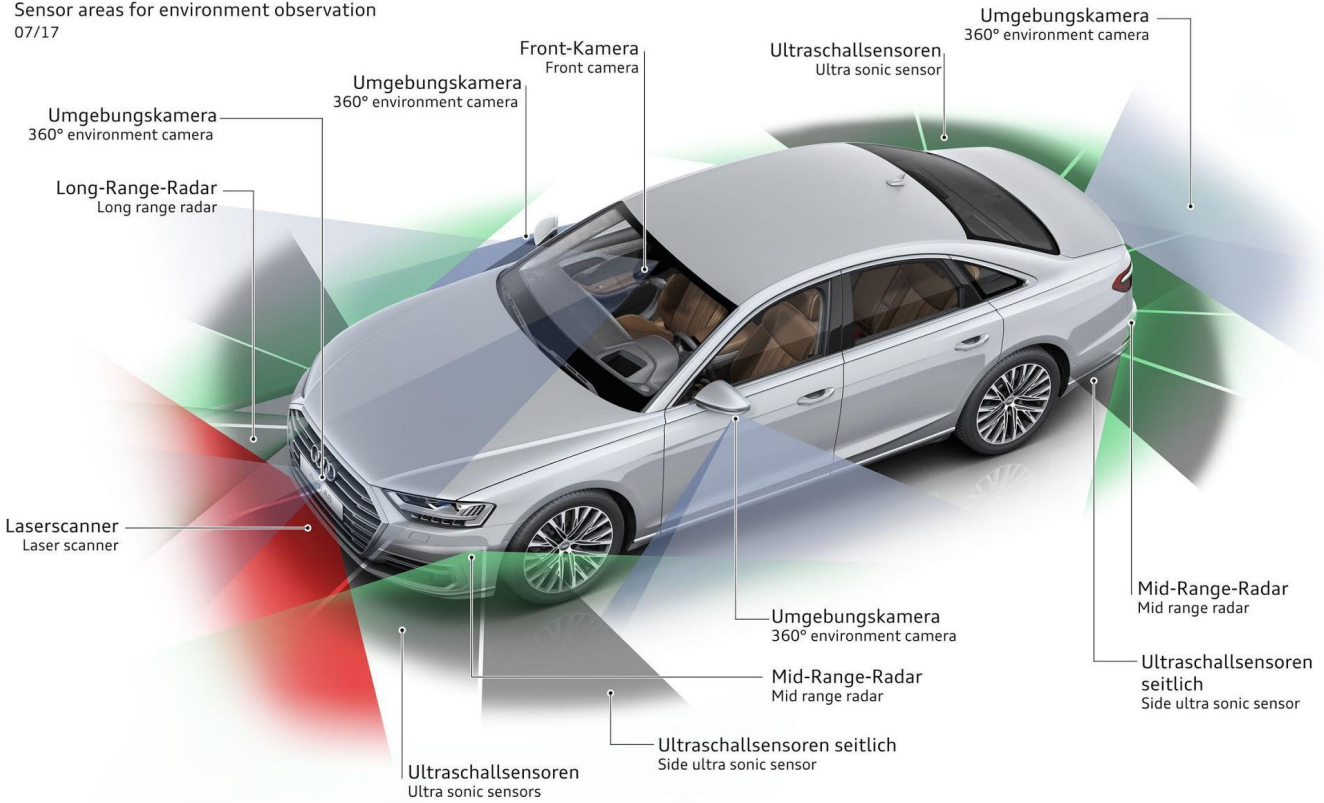
**ARTICULATING RADARS**
Detect moving vehicles at long range over a wide field of view

**LONG-RANGE RADARS**
Detect vehicles and measure velocity

**SHORT-RANGE RADARS**
Detect objects around the vehicle

# Audi A8

**Sensorfelder der Umfeldüberwachung**
Sensor areas for environment observation
07/17

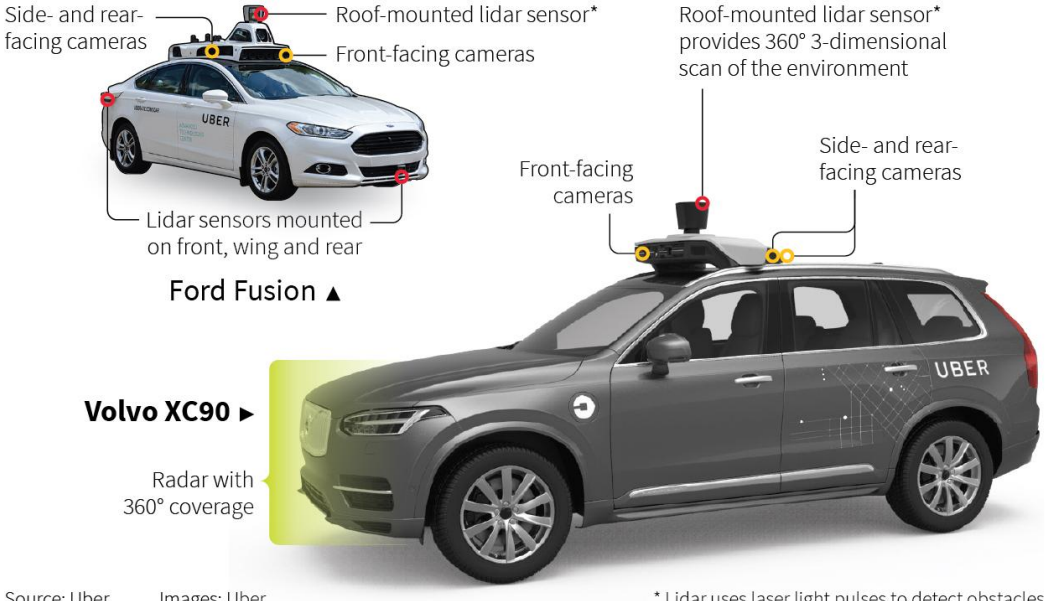


# How Uber altered safety sensors on newest test cars

Uber's self-driving Volvo SUV that struck and killed a pedestrian last week in Tempe, Arizona, used fewer safety sensors than the self-driving Ford Fusions that Uber phased out of its test fleet last year.

**UBER SELF-DRIVING VEHICLE SAFETY SENSOR SUITE**

| | LIDAR | RADAR | CAMERA |
|---|---|---|---|
| **Volvo XC90** | 1 | 10 | 7 |
| Ford Fusion | 7 | 7 | 20 |




Source: Uber Images: Uber

* Lidar uses laser light pulses to detect obstacles

W. Foo, 28/03/2018

REUTERS

# 12 different types of sensors

# SENSORS TYPES

**Proprioceptive**

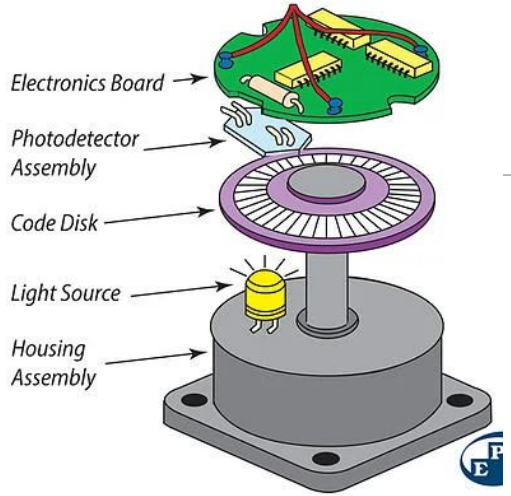
- ❏ Enoders
- ❏ Inertial measurement systems (IMU, VRU, AHRS)
  - ❏ Accelerometers
  - ❏ Gyroscopes
  - ❏ Magnetometers
  - ❏ Altimeters

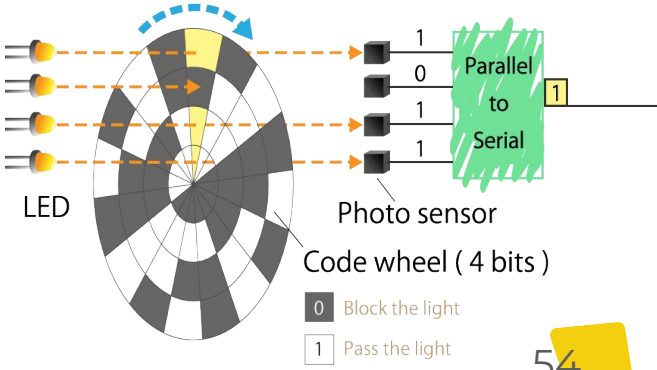
**Exteroceptive**

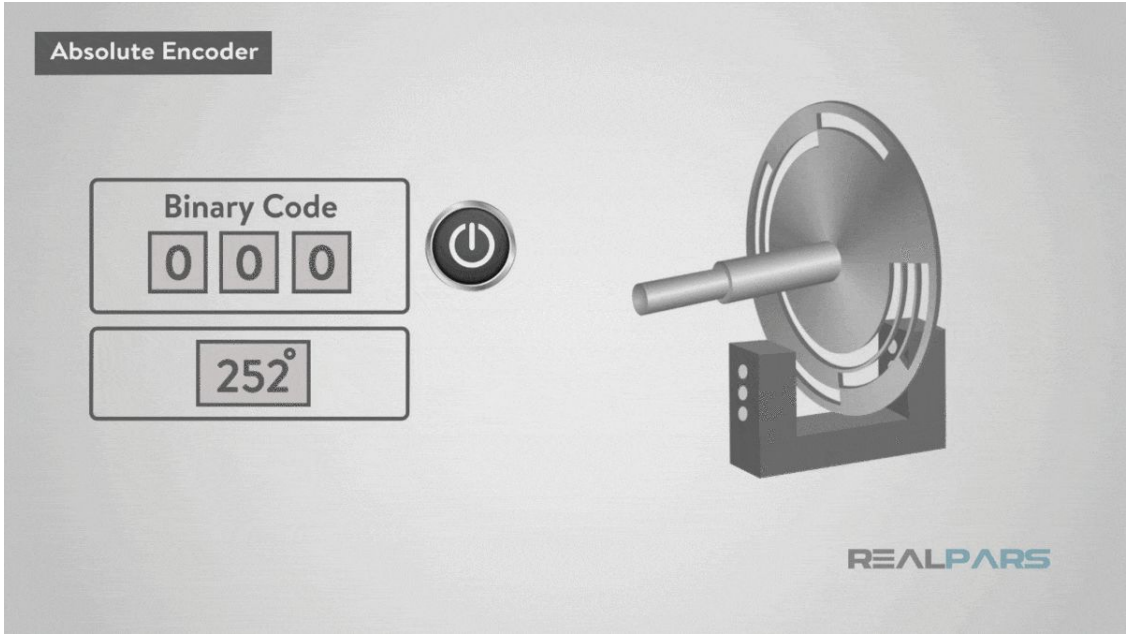
- ❏ Light Detection and Ranging (LIDARs)
- ❏ Sound Navigation and Ranging (SONARs)
- ❏ Infrared distance/proximity sensors
- ❏ Cameras
  - ❏ Mono-
  - ❏ Stereo-
  - ❏ RGB-D (based on different principles)
  - ❏ Infrared (IR)
  - ❏ Multispectral
- ❏ Radio Detection and Ranging (RADARs)
- ❏ Global Navigation Systems (GNSS: GPS, GLONASS etc.)

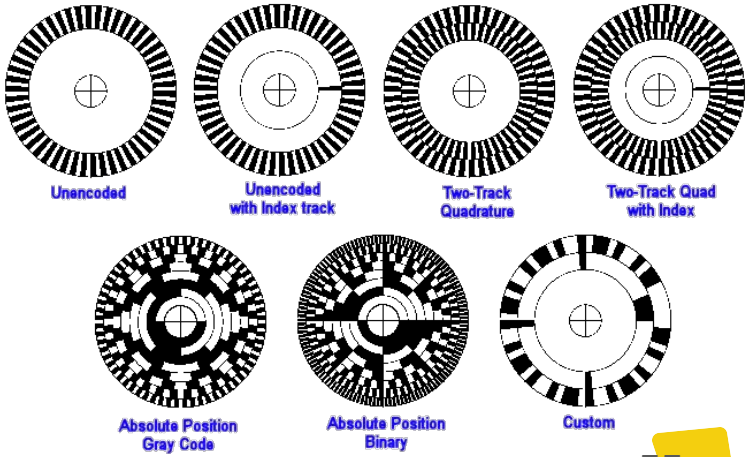
# ENCODERS

- **Encoders** — is an electro-mechanical device that converts the angular position or motion of a shaft or axle to analog or digital output signals.
- Optical encoder: the **light signals** generated by the **light source** are detected by the **detector**, then they are counted and **converted** into a **sequence of electrical impulses** using electronic circuits located inside the encoder housing.
- Encoders based on different physical principles:
  - Magnetic
  - Capacitive
  - Mechanical
  - Optical
- Depending on initial value there are two types of encoders:
  - Absolute — maintain position value even when powered off
  - Incremental — start counting from “zero” when powered on



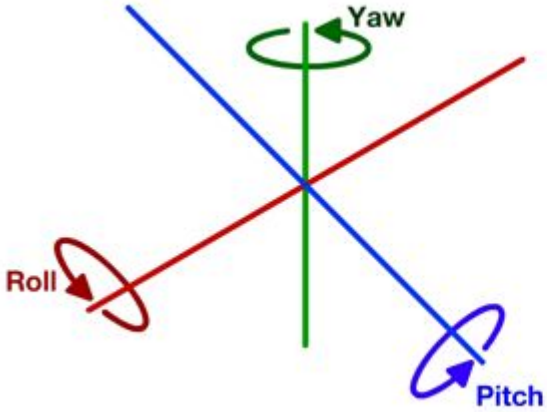



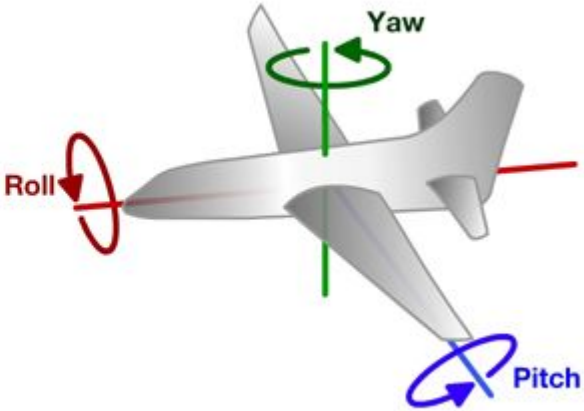



Motor shaft rotation angle → **Encoders** →

- Speed
- Distance
- Acceleration
- Yaw angle (for steering wheel)

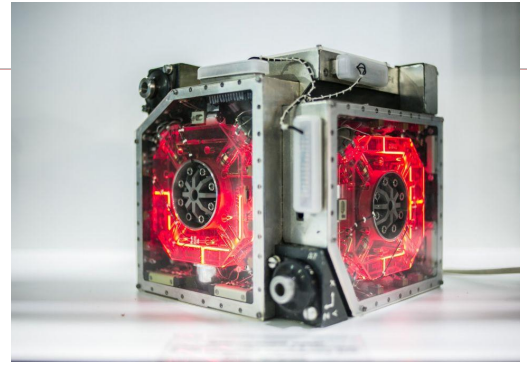

Yaw
Roll
Pitch

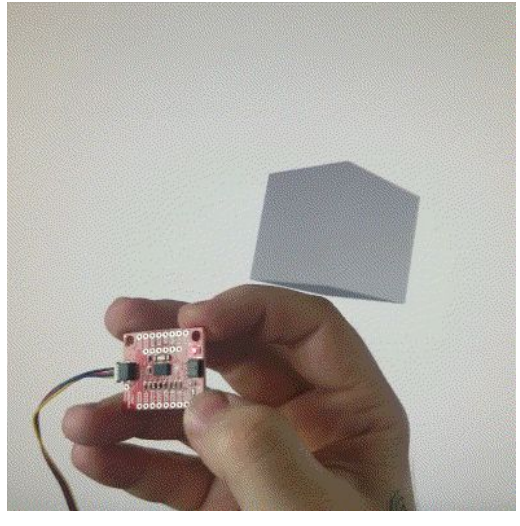

Yaw
Roll
Pitch

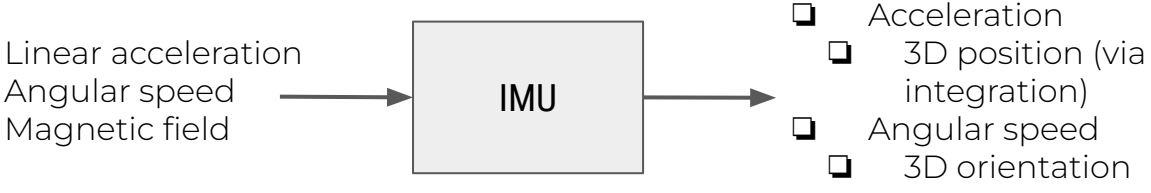

Oz
Yaw (ψ)
Roll (φ)
Ox
Oy
Pitch (θ)

# INERTIAL MEASUREMENT SYSTEMS (IMU, VRU, AHRS)

- Inertial measurement systems (IMU, VRU, AHRS)
  - Accelerometers
  - Gyroscopes
  - Magnetometers
  - Altimeters

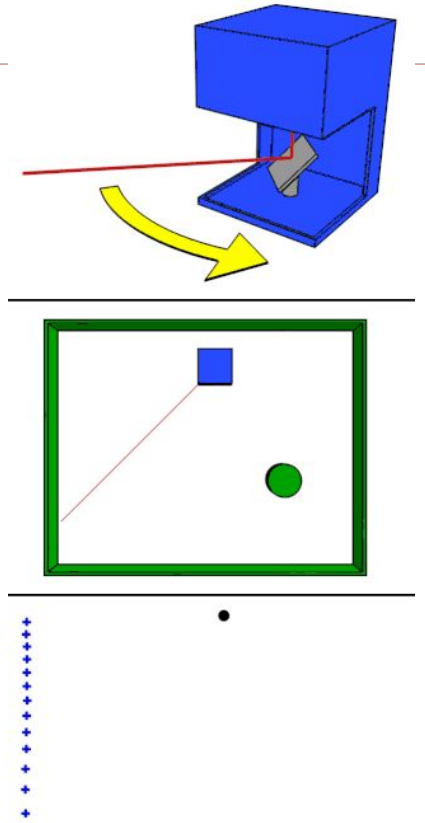


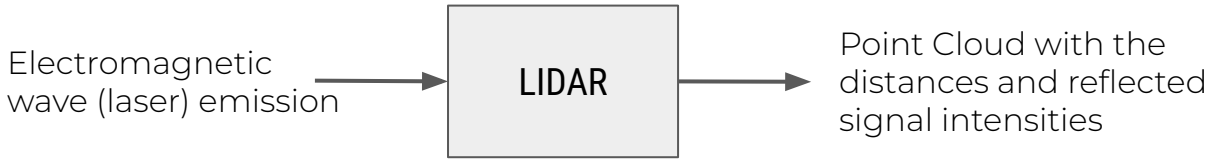


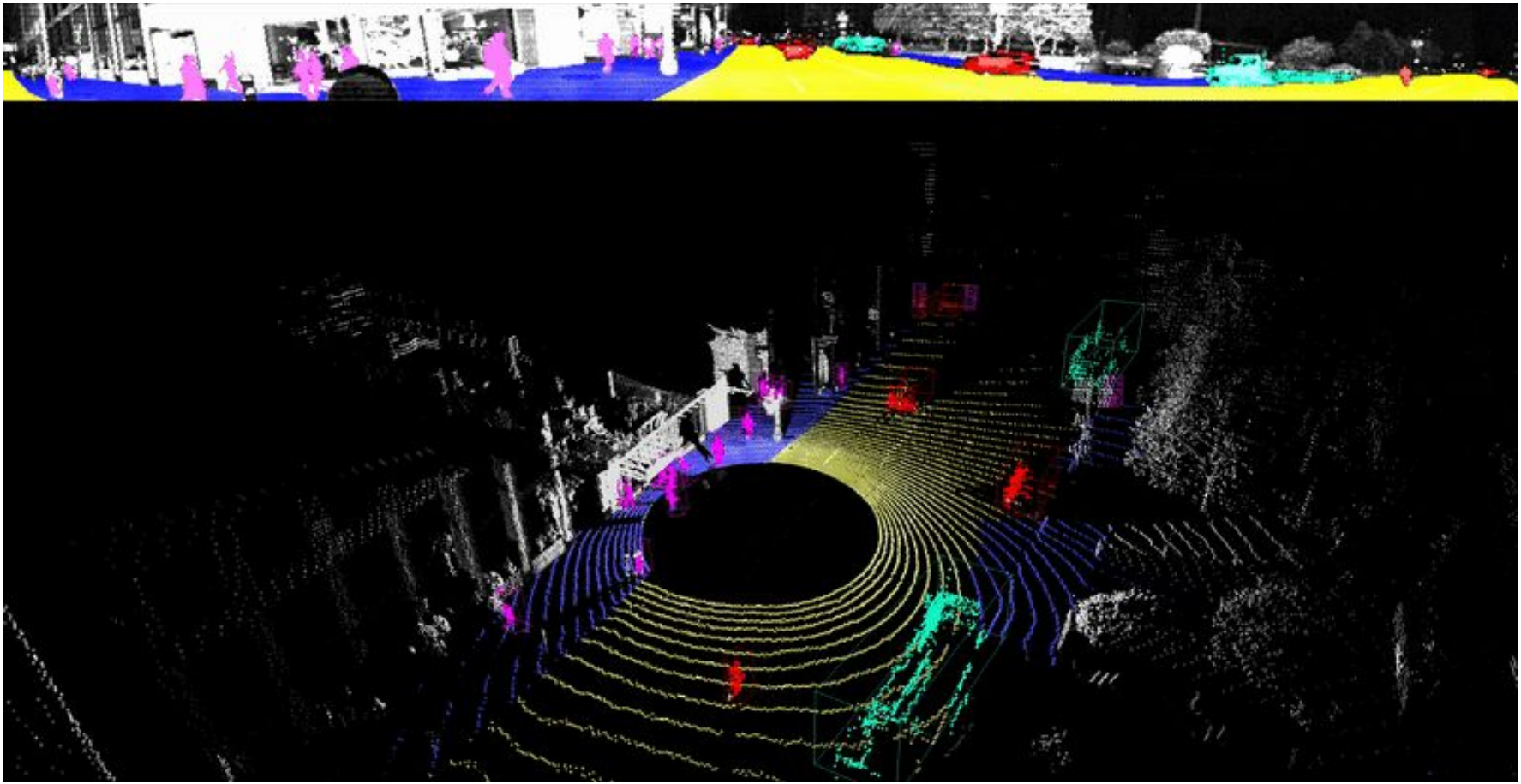


# LIGHT DETECTION AND RANGING (LIDARs)

- **LIDAR** (Light Detection and Ranging or Laser Induced Direction and Range System) — detection, identification and ranging by using light source
- Operating principle:
  - The directional beam of the light signal source is reflected from the targets, returns to the source and is captured by the highly sensitive receiver
  - Response time is directly proportional to target distance
- In addition to the impulse distance measurement method, a phase method is used, based on the determination of the phase difference between the sent and received modulated signals

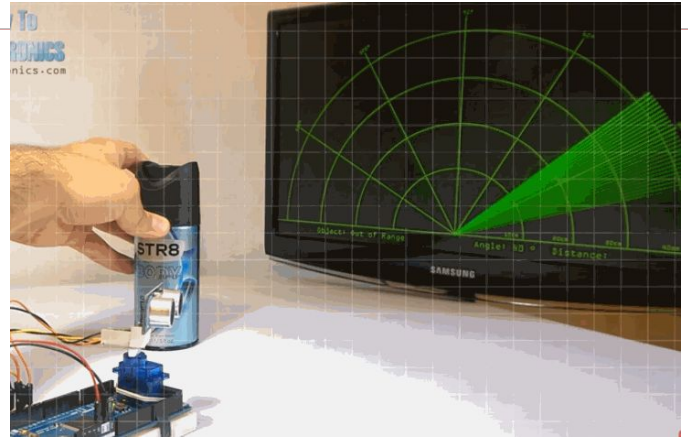


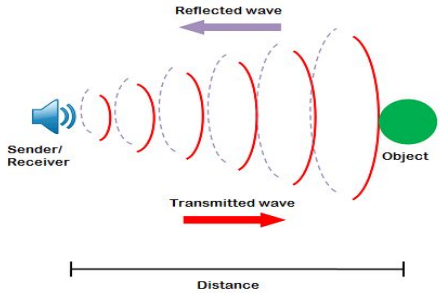


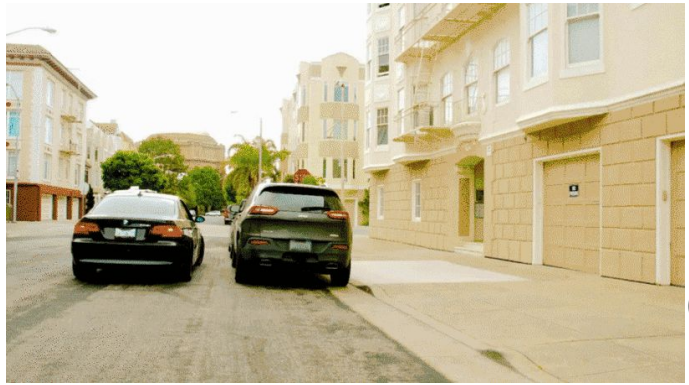


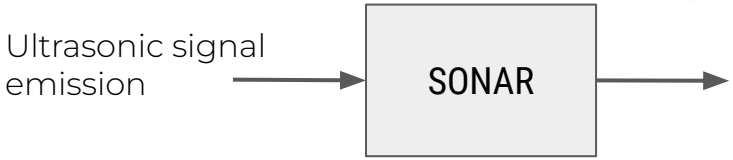
# ULTRASONIC SENSORS (SONARs)

- **Sonar** (sound navigation ranging) — is an instrument that measures the distance to an object using ultrasonic sound waves.
- Operating principle:
  - Emits an ultrasonic signal
  - Mesures time-of-flight and calculates distance to object



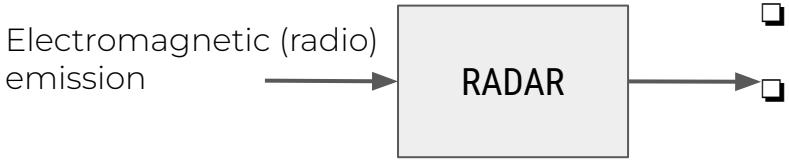





# RADIO DETECTION AND RANGING (RADARs)

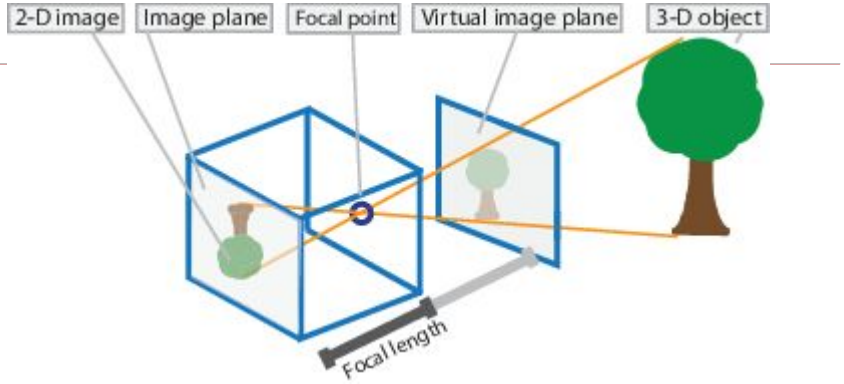
- **Radar** (RAdio Detection And Ranging) — based on the use of the so-called Doppler effect — the changing frequency of the signal reflected from a moving obstacle is compared with the original frequency.
- A radar consists of a transmitter — a source of electromagnetic radiation, a transmitting antenna, a receiving antenna (often the same one), a receiver and a computer for signal processing.

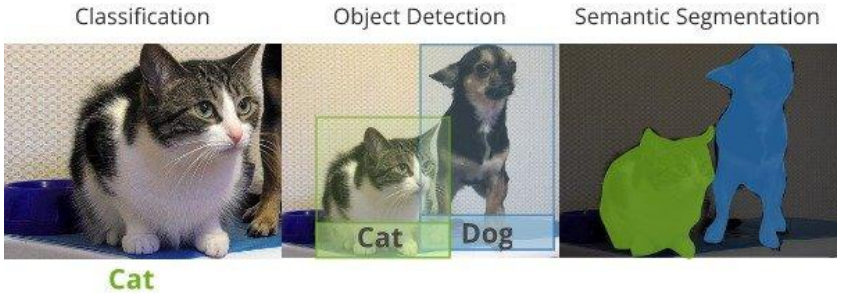


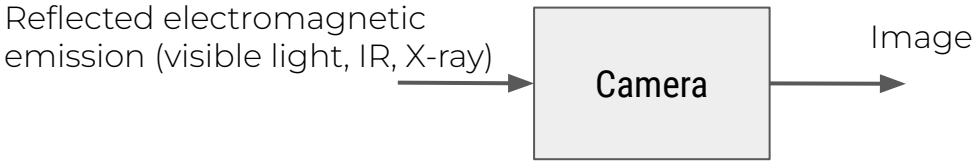

- Distance to obstacles
- Their speed and angular size

# CAMERAS

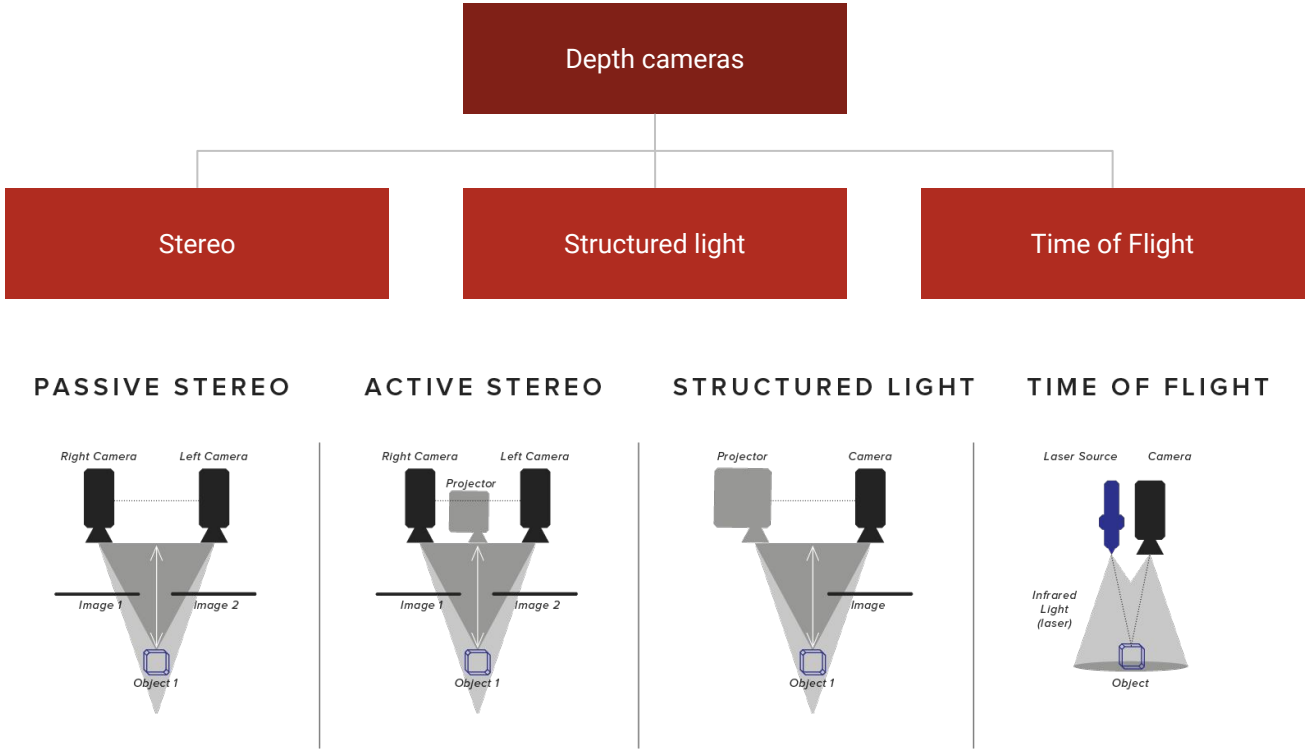
- **Camera** — projective sensor. Projects a 3D world onto a 2D plane.
- Operating principle:
  - Matrix pixels register light reflected from objects (attenuation of radiation in the case of X-rays)
  - The number of photons hitting a pixel is converted into an electrical signal



# DEPTH CAMERAS




DEPTH CAMERAS FOR MOBILE AR: FROM IPHONES TO WEARABLES AND BEYOND. DAQRI. Medium

# DEPTH CAMERAS

# ADDITIONAL RESOURCES

1. Perception: Sensors Autonomous Mobile Robots.Davide Scaramuzza. ETH Zurich
2. Carnegie Mellon. Robotic Autonomy Summer Course. Perception
3. Choosing The Best Sensors For A Mobile Robot

# Thanks for attention!

Questions? Additions? Welcome!

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