

Introduction to Mobile Robotics and Robot Operating System (ROS)

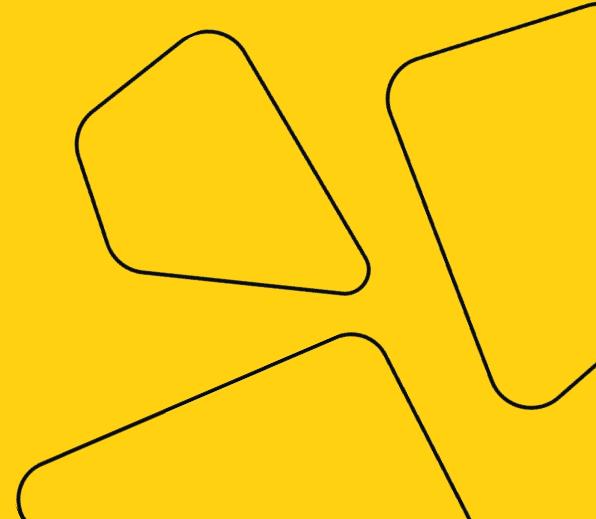
Lecture 1. Introduction to Robotics

Oleg Shipitko,

March 2021



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Outline

- 
- A decorative graphic in the bottom-left corner consists of several white-outlined geometric shapes on a teal background. It includes a large irregular pentagon, a smaller triangle nested within it, and some curved lines.
- 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

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

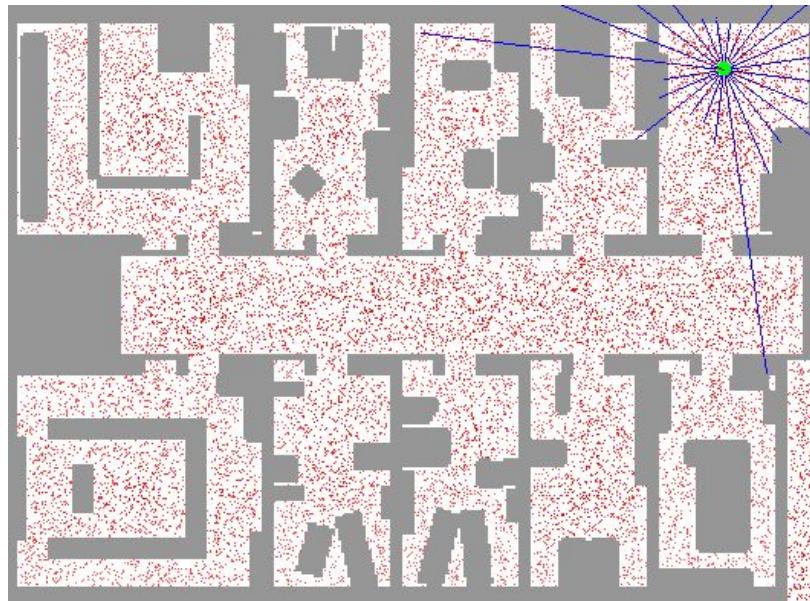
1. Overview of classical areas and methods of mobile robotics
2. Introduction to probabilistic robotics
3. Overview of modern research areas
4. Introduction to ROS (Robot Operating System)
5. Practical experience in solving robotics projects

COURSE ORGANIZATION

1. One lecture and one seminar each week
2. 3 homework assignments
3. Exam in the end of the term
 - a. Theoretical question
 - b. Practical task (probably with ROS [Robot Operating System])

HOMEWORK ASSIGNMENTS

Localization



Control



HOMEWORK ASSIGNMENTS

1. Home assignments and final project can be resubmitted unlimited number of times until the end of the term
2. Percent are mapped to scores from 0 to 100
3. Final score:
 - a. Round (term scores / 10) = final score
 - b. Scores are rounded in favor of student:
Round (7.5) = 8

60%

Home assignments

40%

Exam

What is robot

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02

WHAT IS ROBOT?

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

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**?



Types of robots

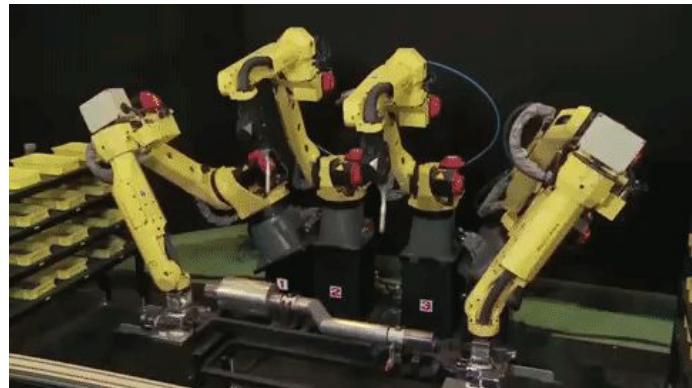
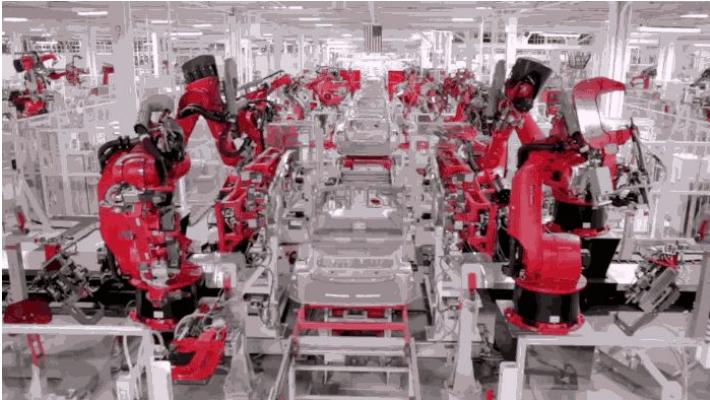
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03

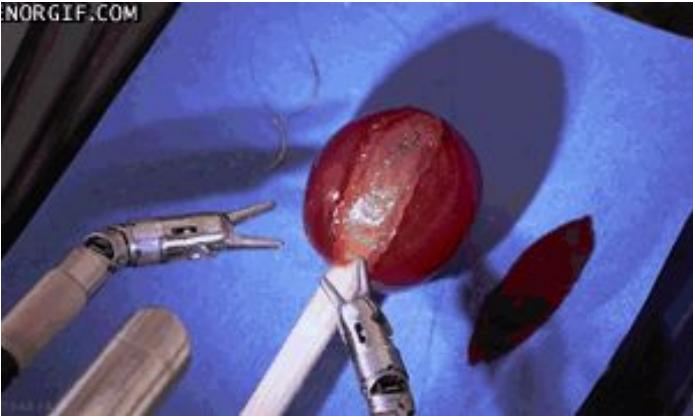
AEROSPACE



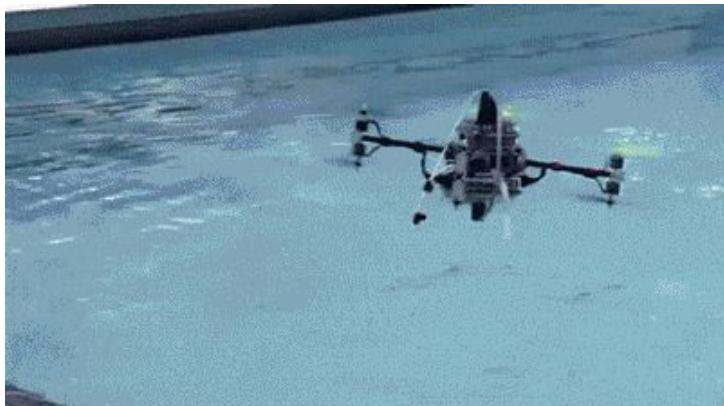
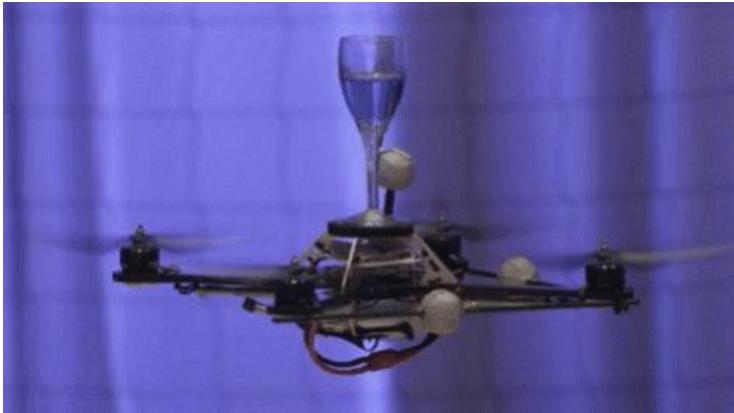
INDUSTRIAL



MEDICAL

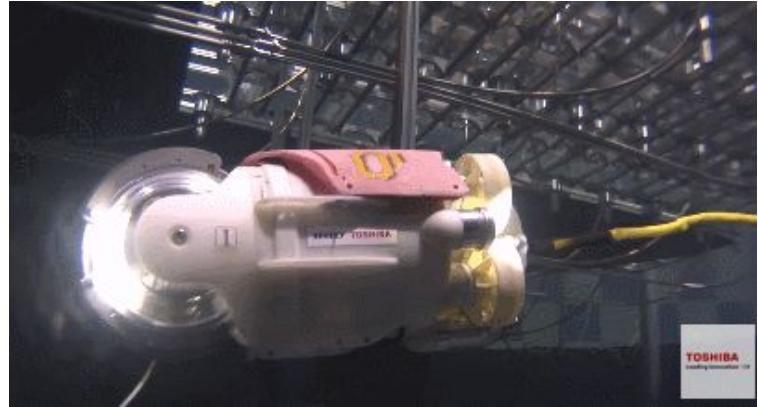


DRONES

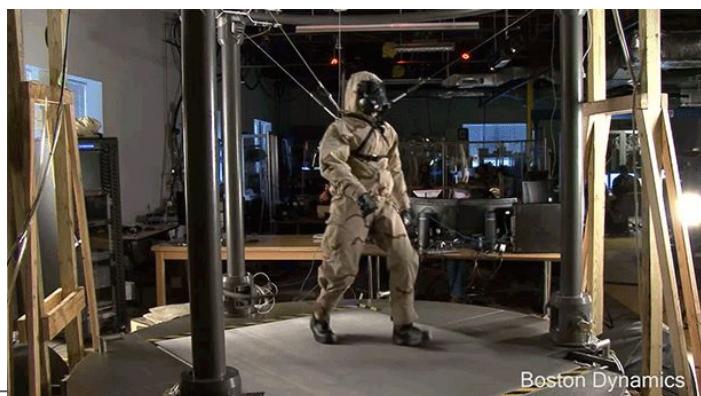


EXTREME ROBOTICS

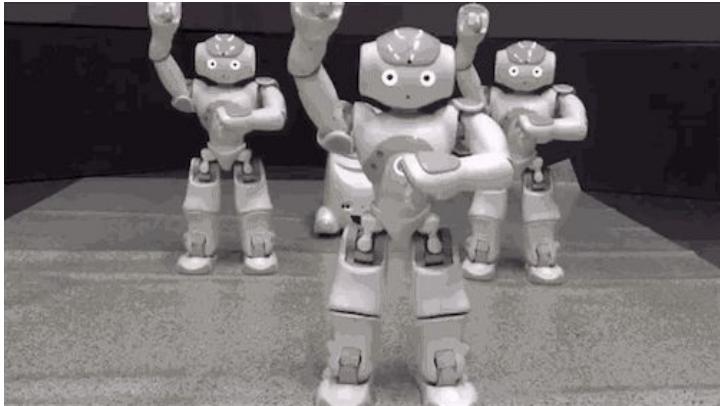
3D (dirty, dangerous and demeaning)



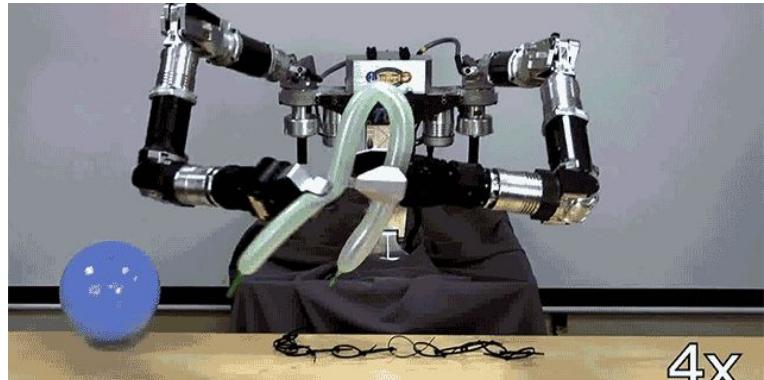
MILITARY



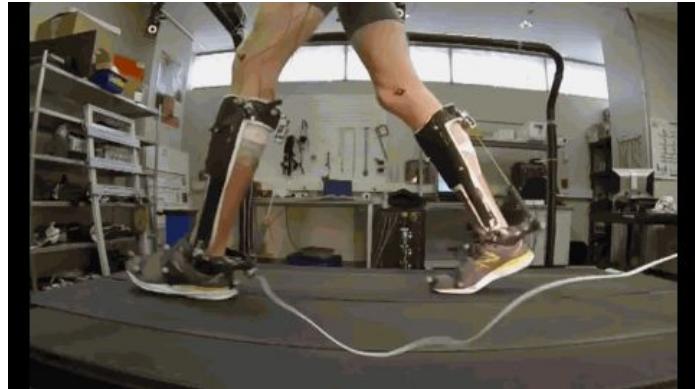
EDUCATIONAL



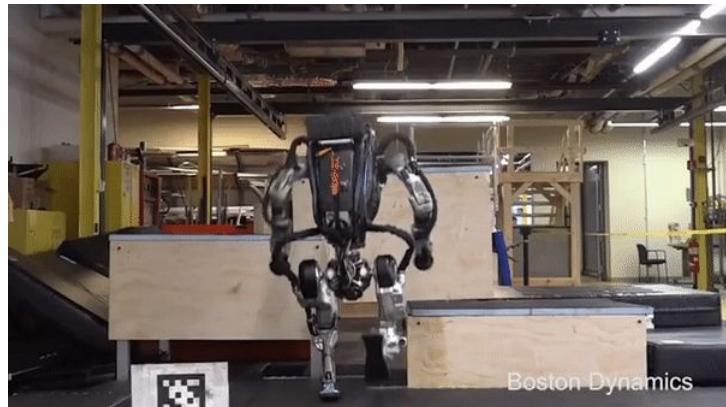
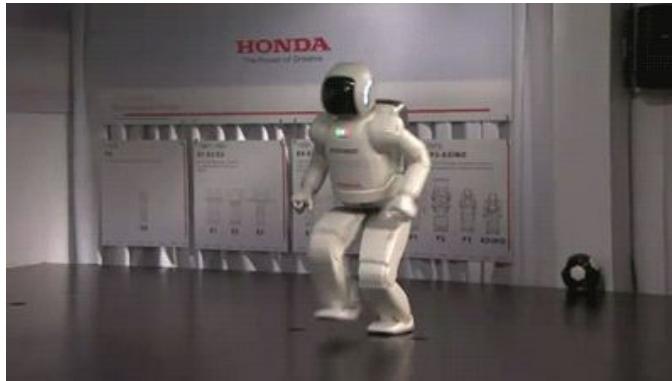
FOR ENTERTAINMENT



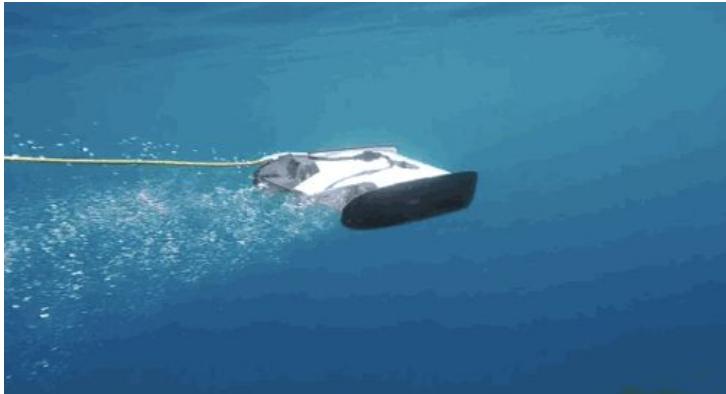
EXOSKELETONS



ANTHROPOMORPHIC



MARINE



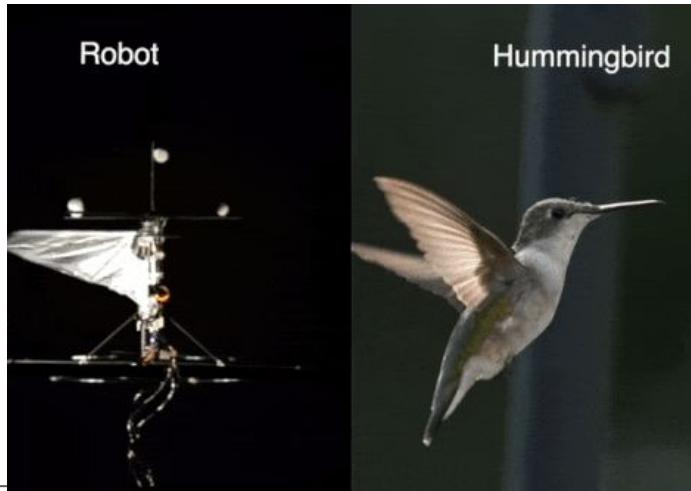
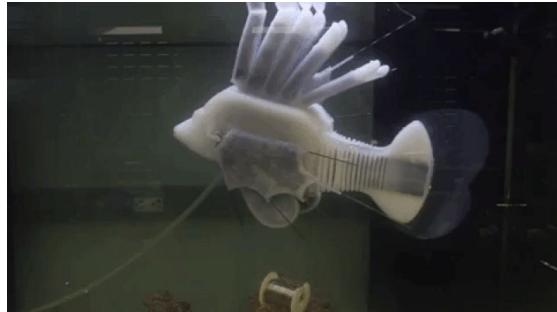
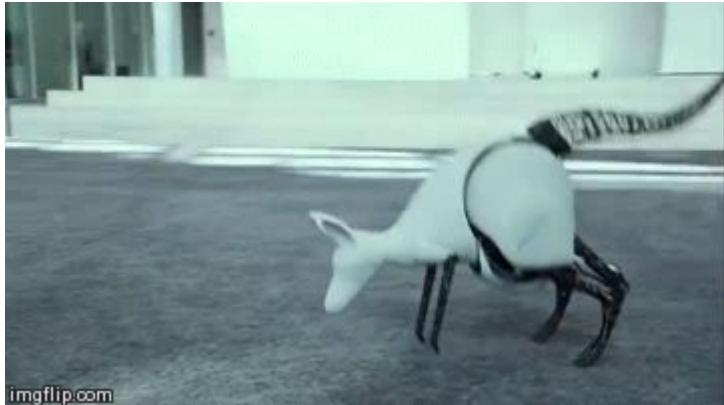
TELEPRESENCE



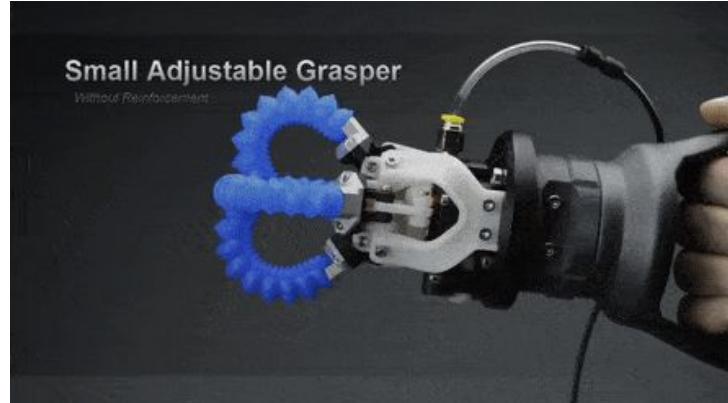
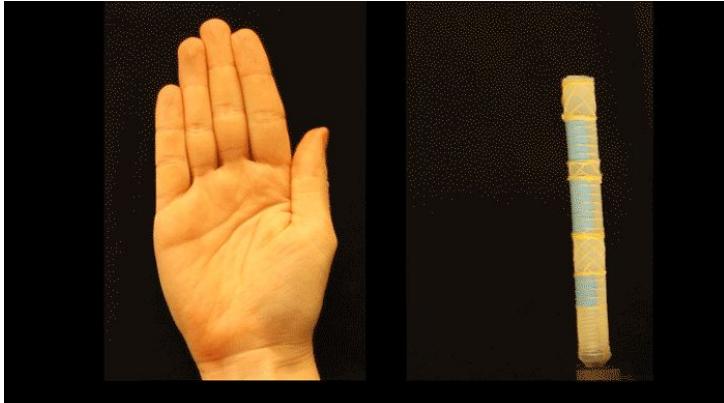
AUTONOMOUS CARS



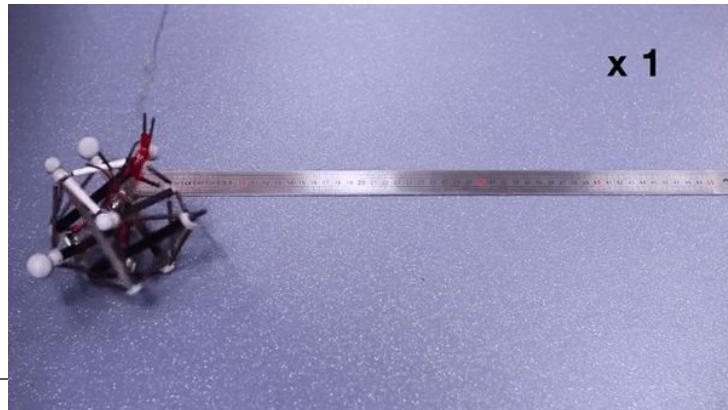
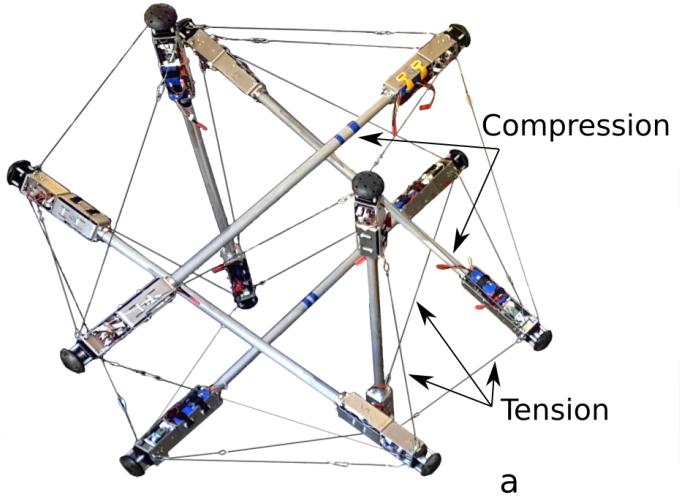
BIOINSPIRED



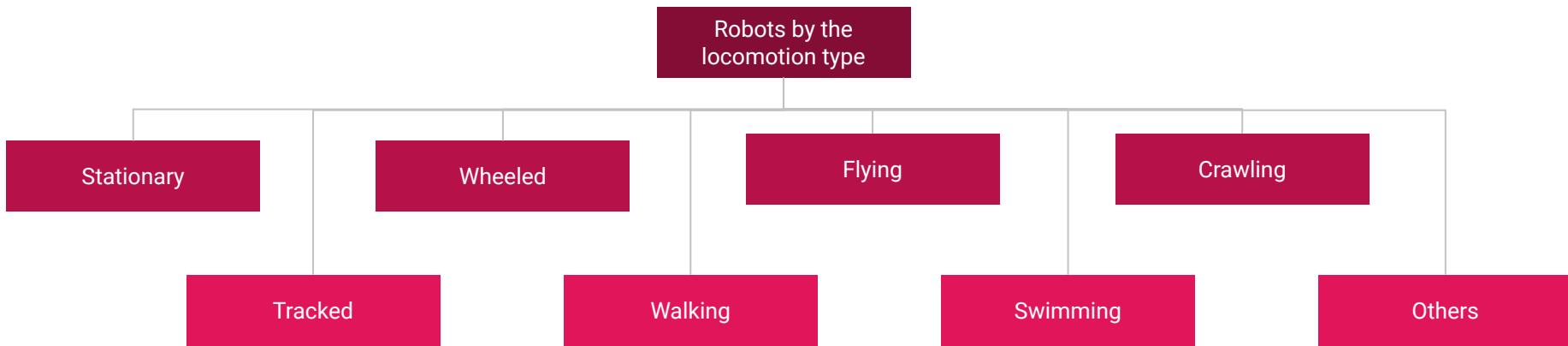
SOFT



TENSEGRITY



ROBOTS BY THE TYPE OF LOCOMOTION (MOVEMENT)



ROBOTS BY THE TYPE OF LOCOMOTION (MOVEMENT)



Robots by the
locomotion type



Stationary

Wheeled

Flying

Crawling

Tracked

Walking

Swimming

Others



Mobile (wheeled) robots

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04

MOBILE (WHEELED) ROBOTS

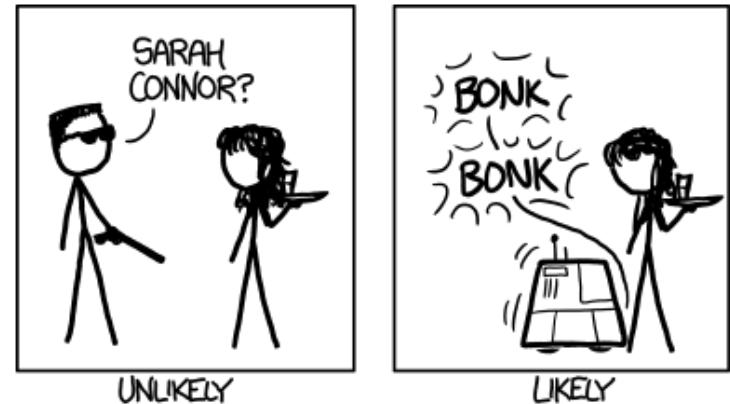


MOBILE (WHEELED) ROBOTS



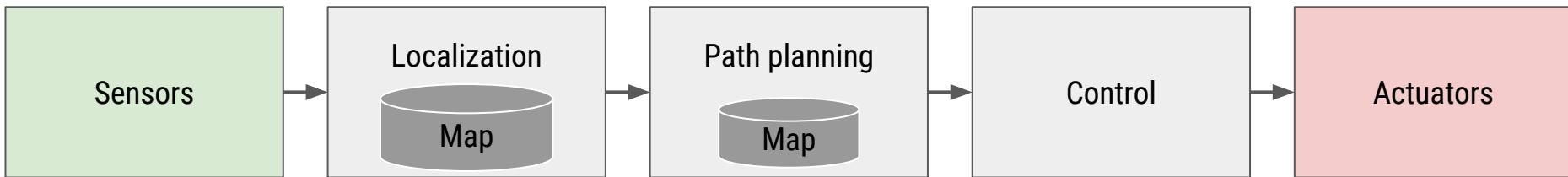
WHY MOBILE ROBOTS?

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

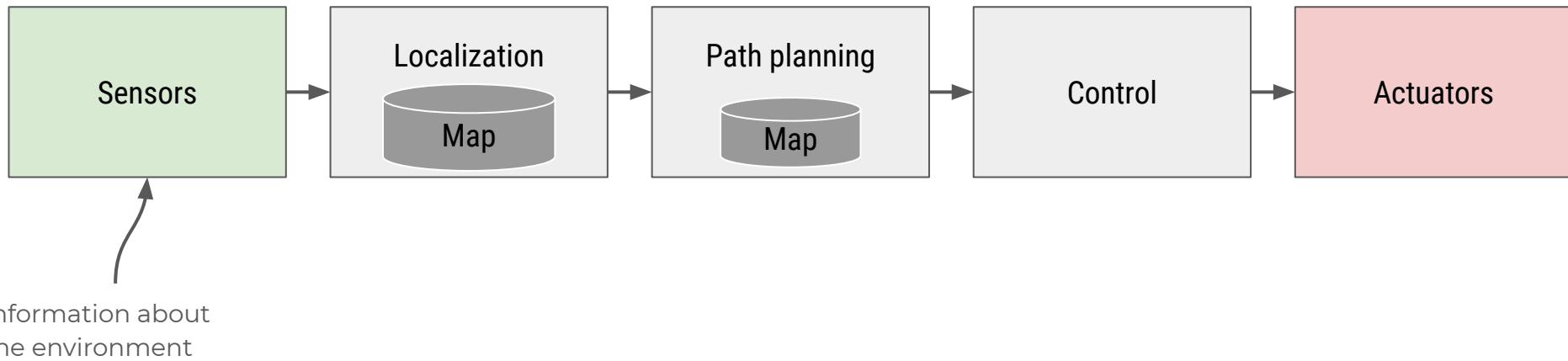


All of this makes mobile robots one of the most common family of robots used in real applications.

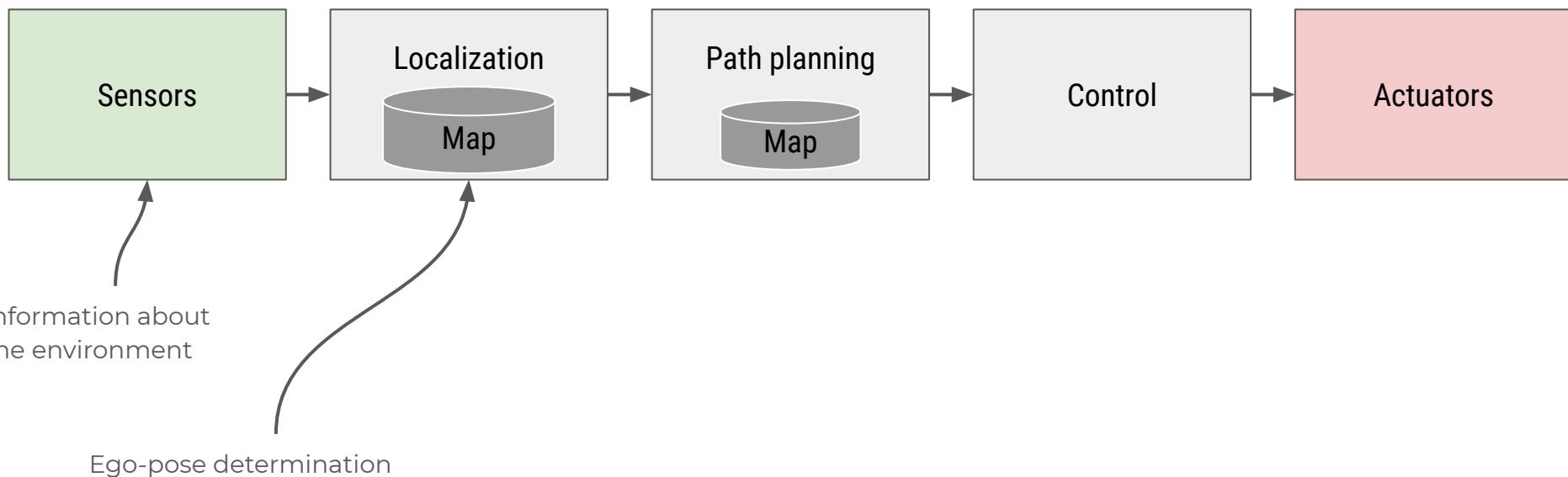
(SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



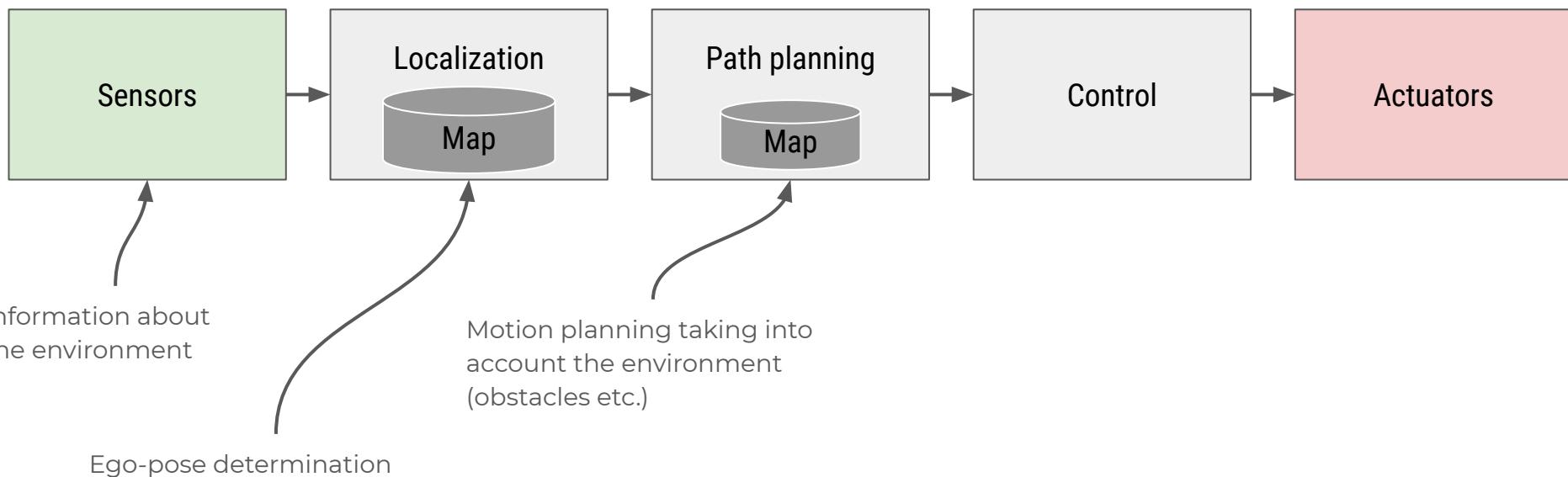
(SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



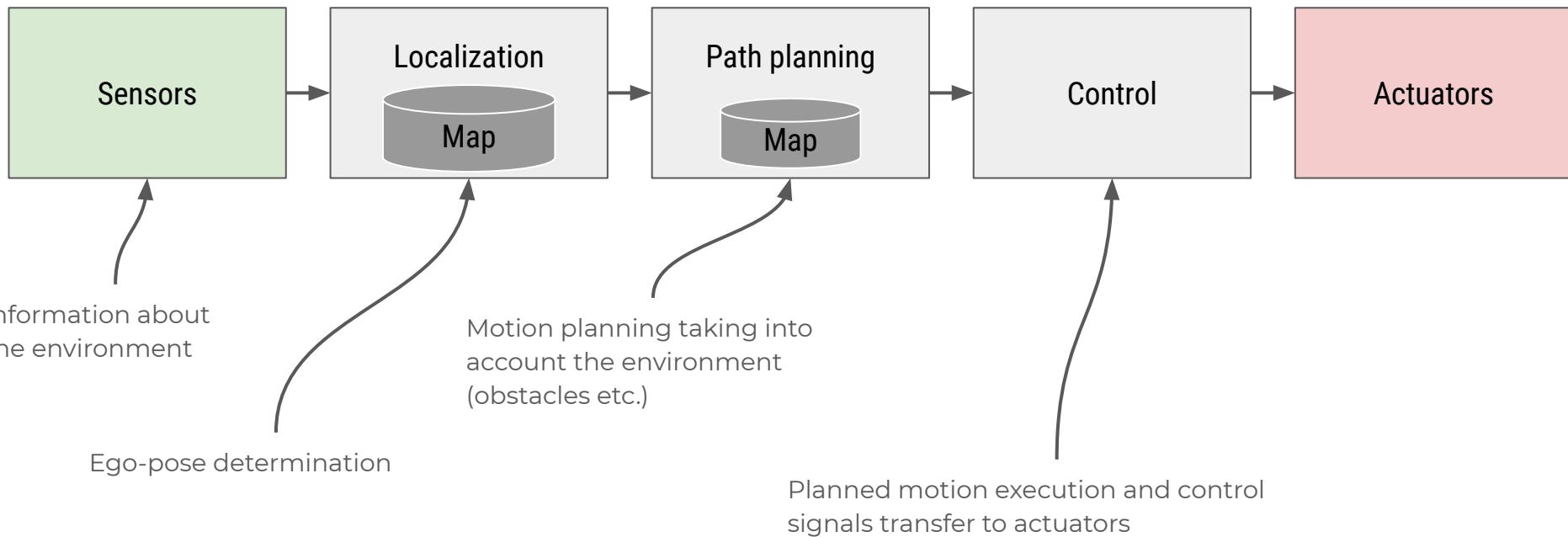
(SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



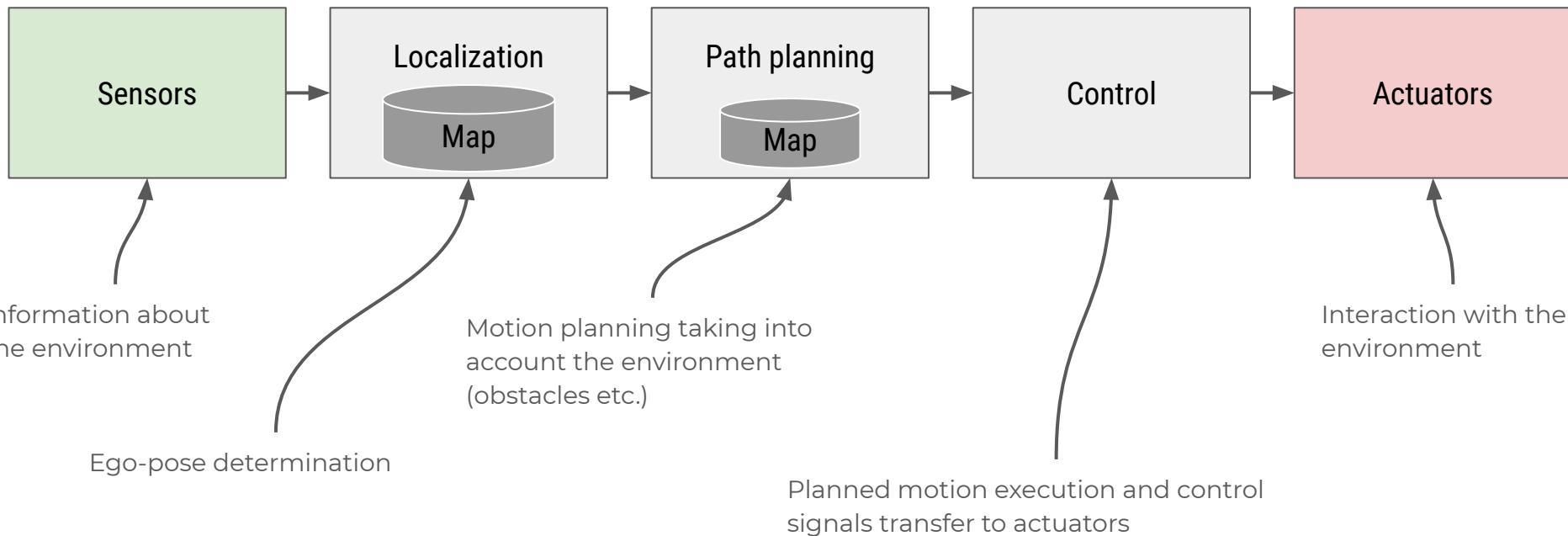
(SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT

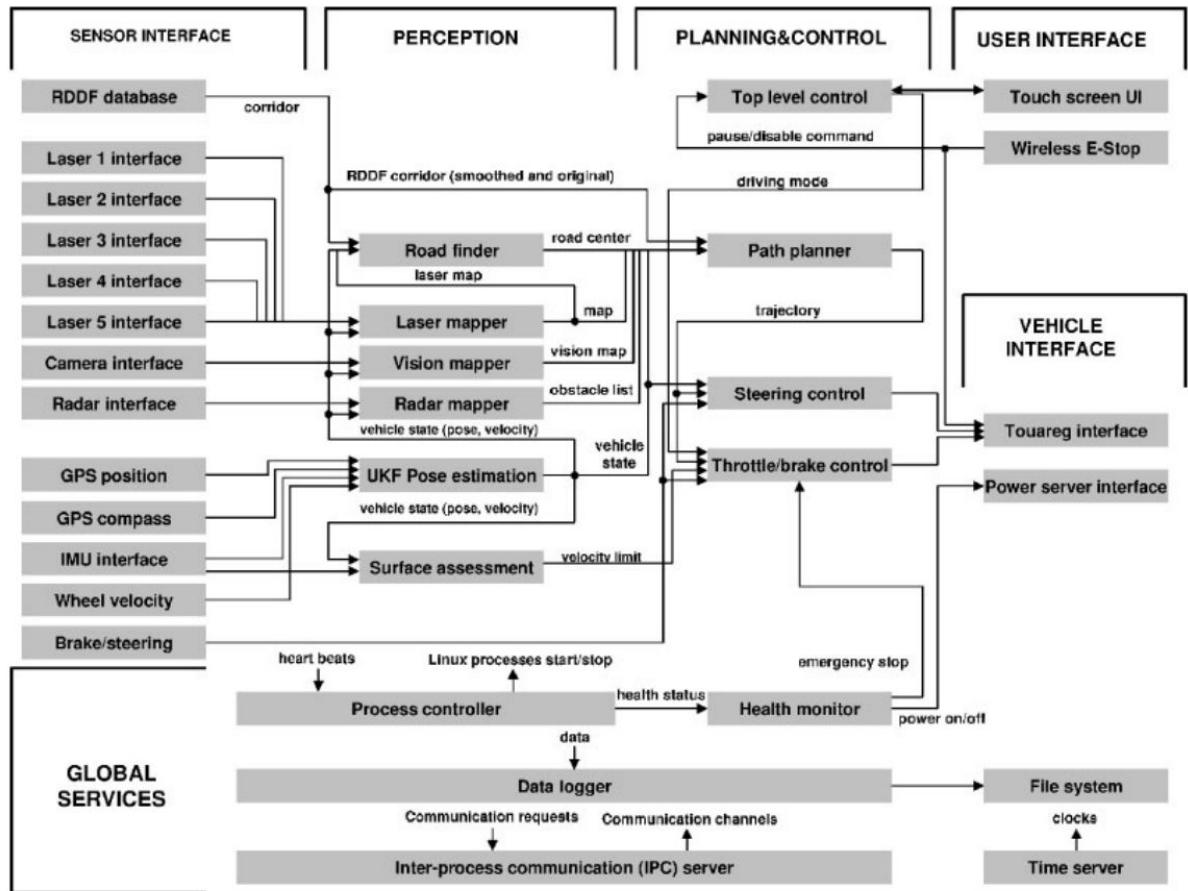


(SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



(SIMPLIFIED) CONTROL SCHEME OF MODERN MOBILE ROBOT



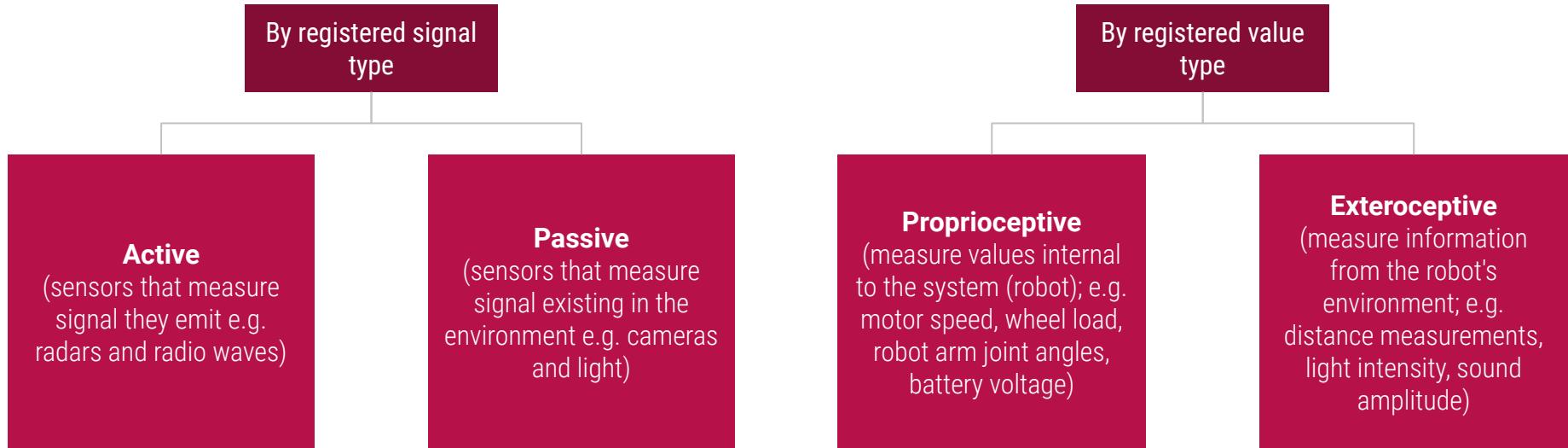


Robotic sensors

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05

SENSORS TYPES



SENSORS TYPES

Proprioceptive

- ❑ Endoders
- ❑ 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

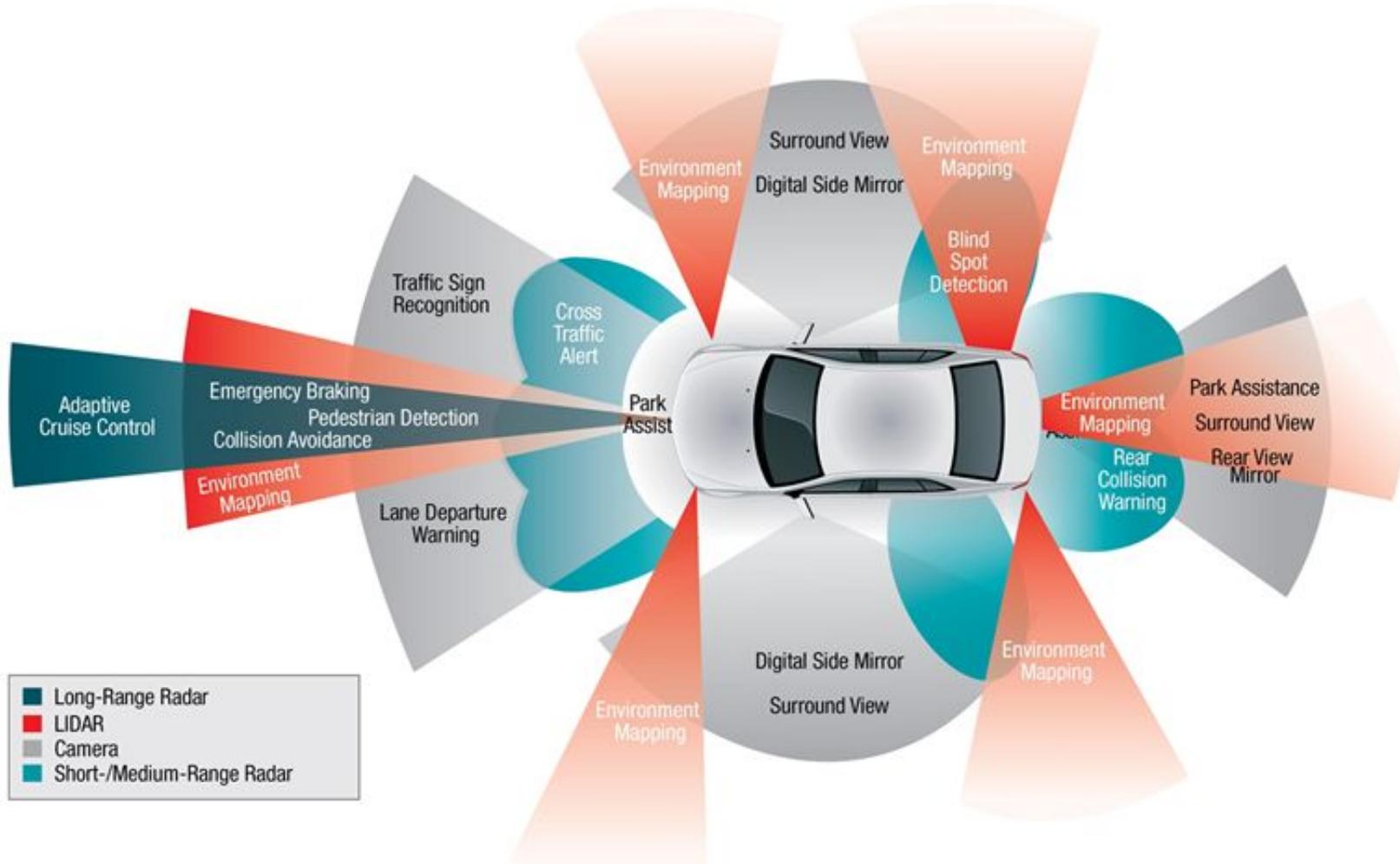
Proprioceptive

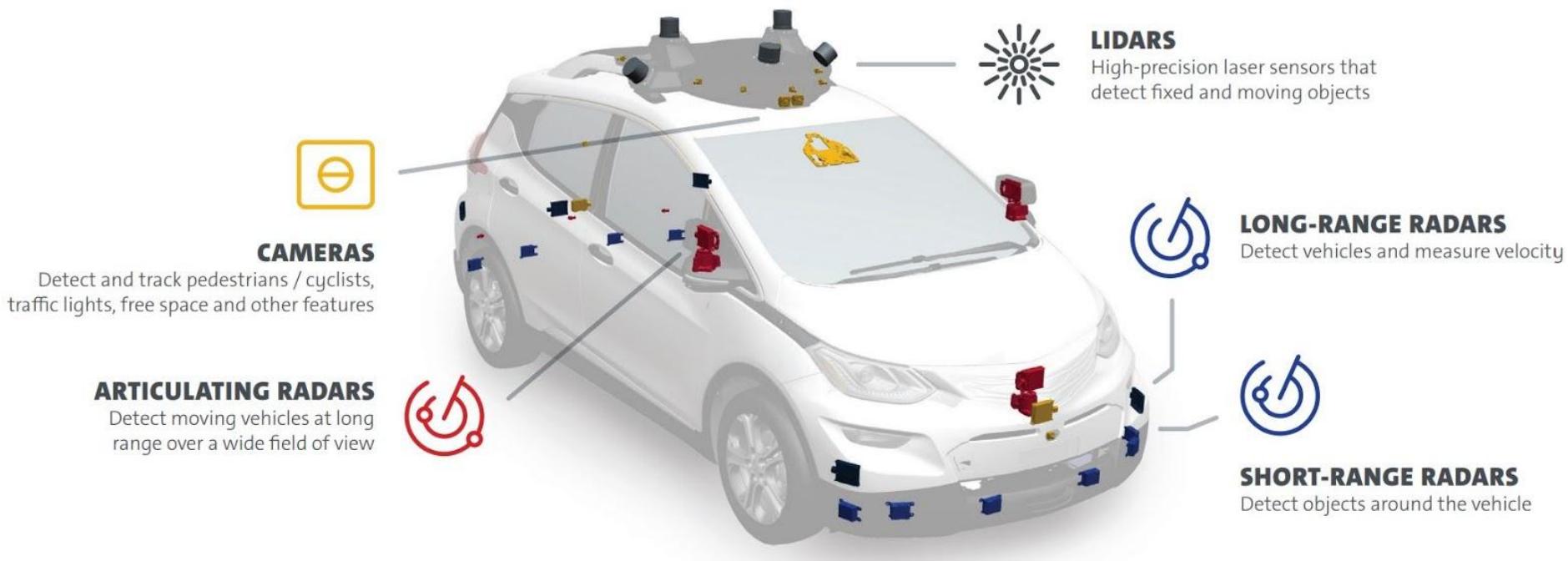
- Endoders
- Inertial measurement systems (IMU, VRU, AHRS)
 - Accelerometers
 - Gyroscopes
 - Magnetometers
 - Altimeters

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

Exteroceptive

- Light Detection and Ranging (LIDARs)
- Sound Navigation and Ranging (SONARs)
- Infrared distance/proximity sensors
- Cameras
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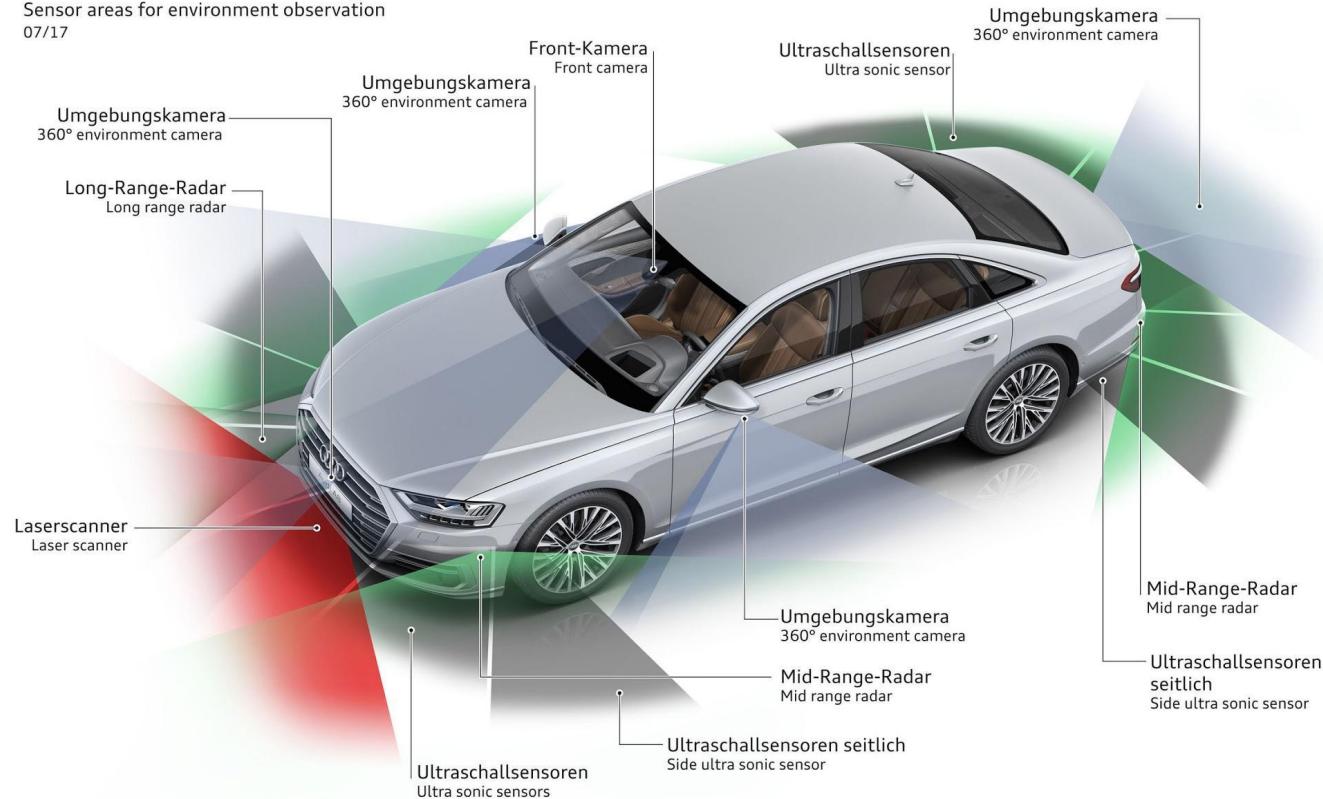






Audi A8

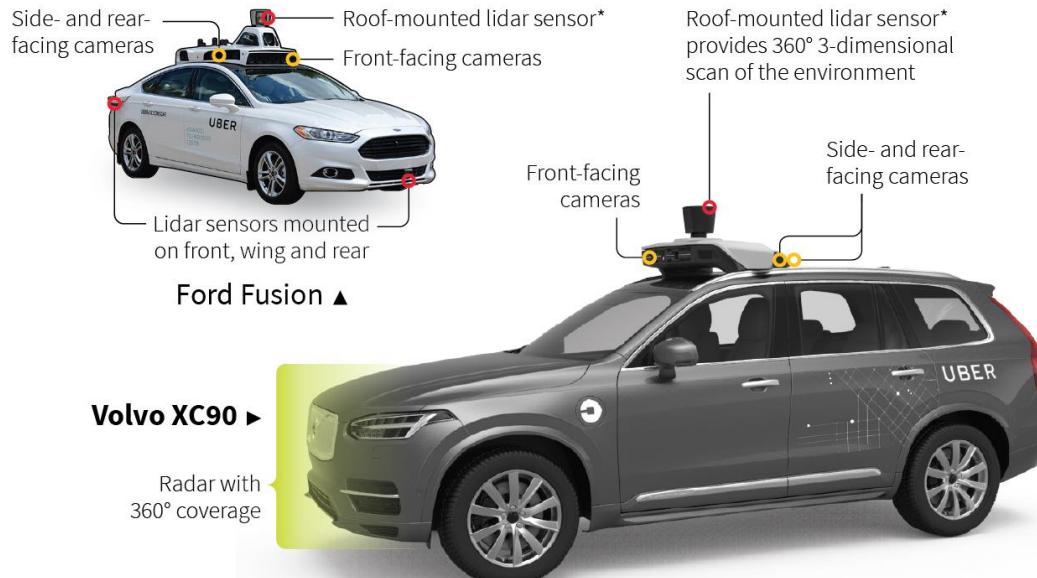
Sensorfelder der Umfeldüberwachung
Sensor areas for environment observation
07/17



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



Source: Uber

Images: Über

W Foo 28/03/2018

* Lidar uses laser light pulses to detect obstacles



12 different types of sensors



SENSORS TYPES

Proprioceptive

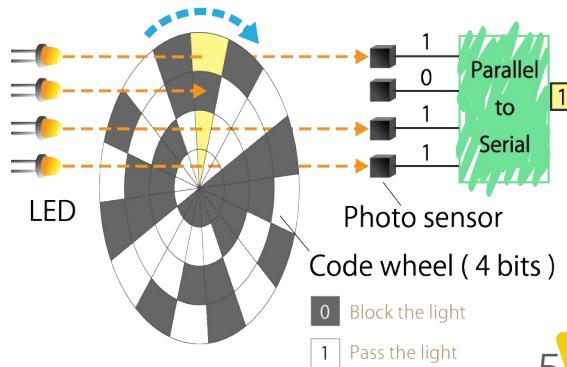
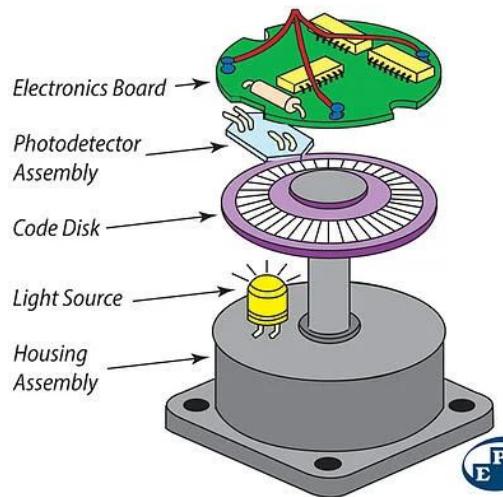
- ❑ Endoders
- ❑ Inertial measurement systems (IMU, VRU, AHRS)
 - ❑ Accelerometers
 - ❑ Gyroscopes
 - ❑ Magnetometers
 - ❑ Altimeters

Exteroceptive

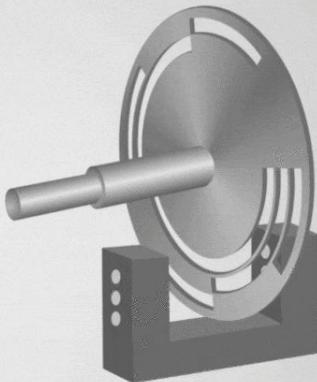
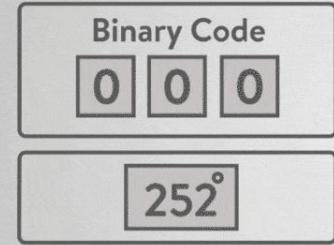
- ❑ Light Detection and Ranging (LIDARs)
- ❑ Sound Navigation and Ranging (SONARs)
- ❑ Infrared distance/proximity sensors
- ❑ Cameras
 - ❑ Mono-
 - ❑ Stereo-
 - ❑ RGB-D (based on different principles)
 - ❑ Infrared (IR)
 - ❑ Multispectral
- ❑ Radio Detection and Ranging (RADARs)
- ❑ Global Navigation 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

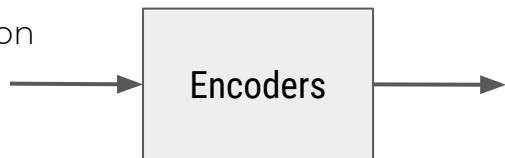


Absolute Encoder

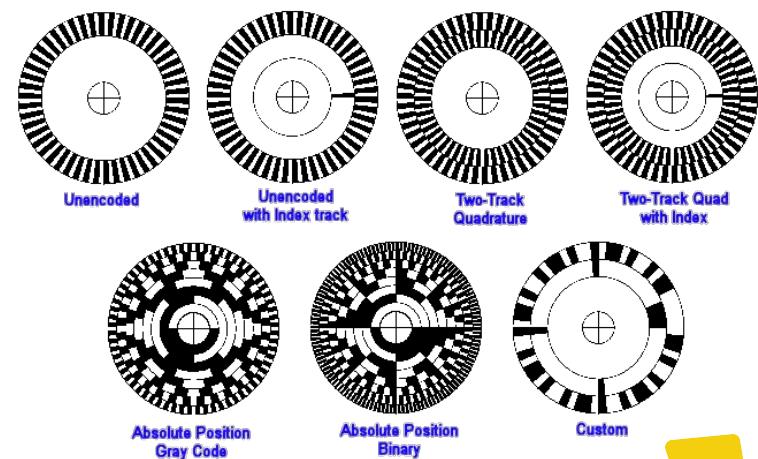


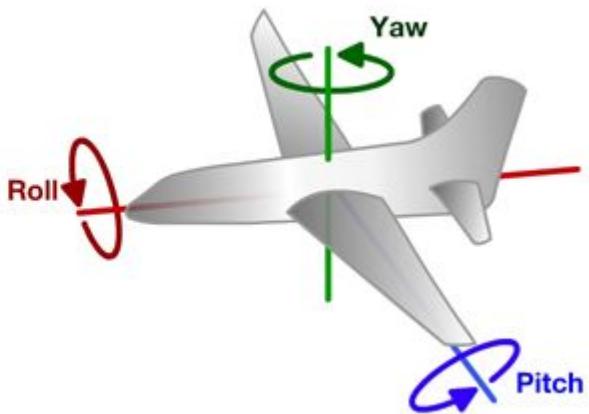
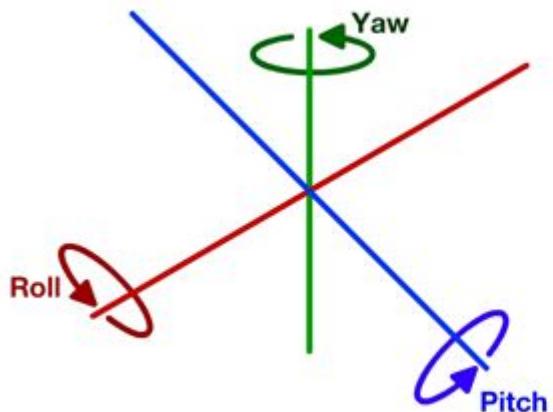
REALPARS

Motor shaft rotation angle



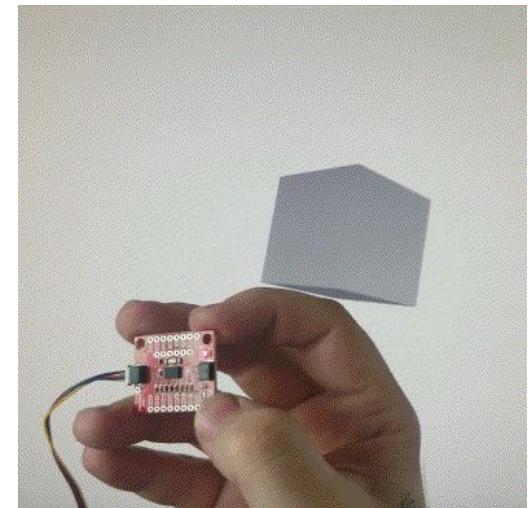
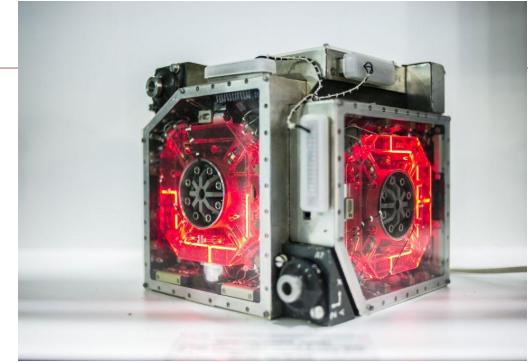
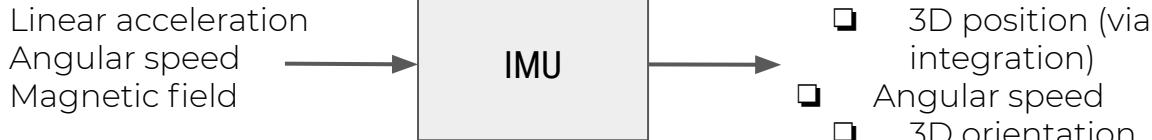
- Speed
- Distance
- Acceleration
- Yaw angle
(for steering wheel)





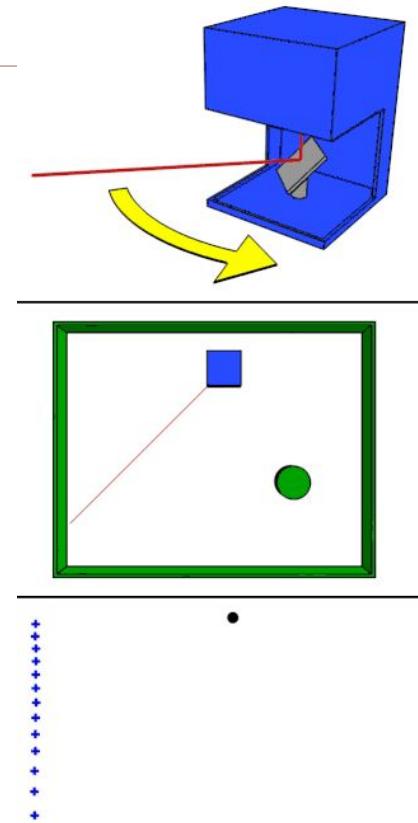
INERTIAL MEASUREMENT SYSTEMS (IMU, VRU, AHRS)

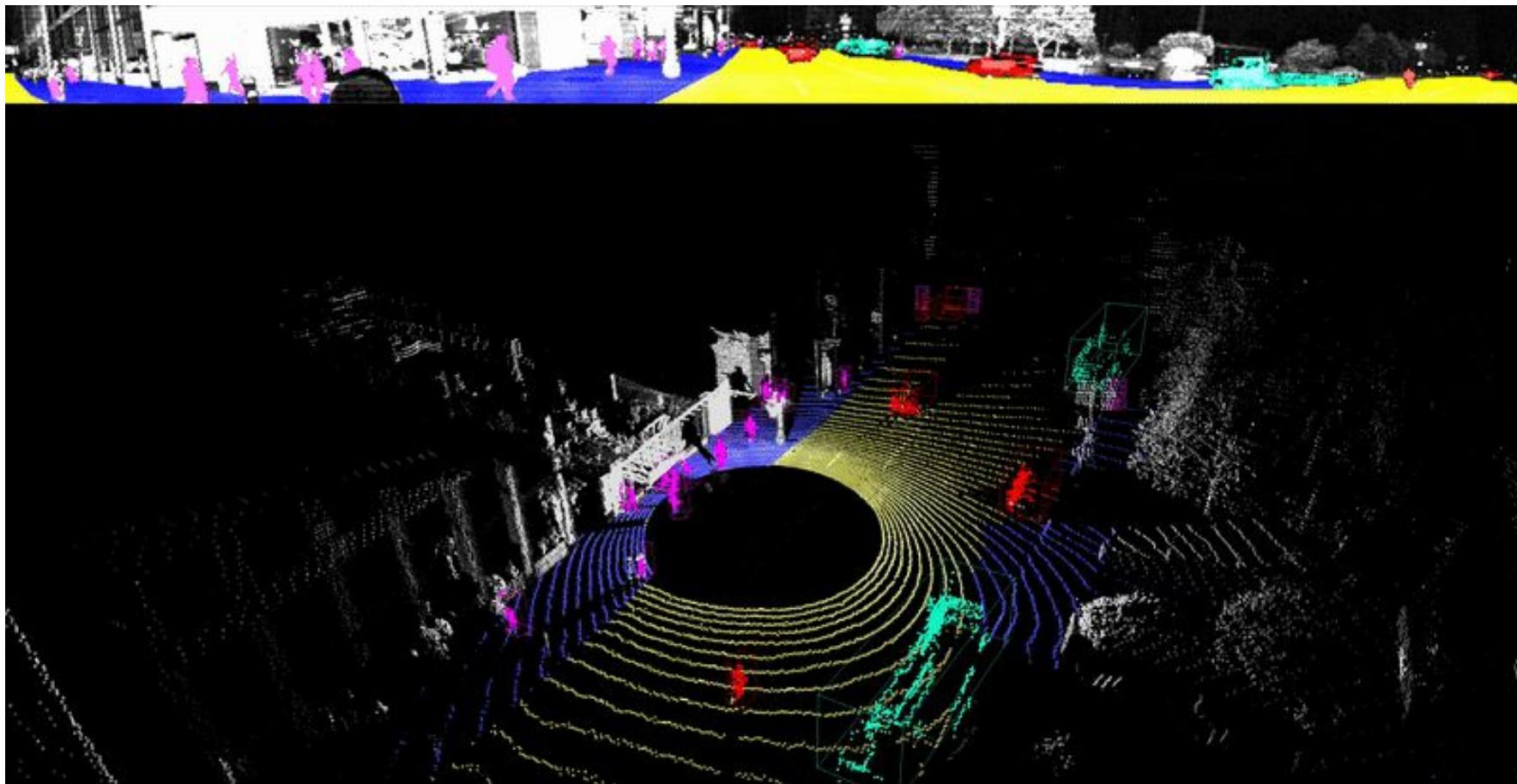
- ❑ Inertial measurement systems (IMU, VRU, AHRS)
 - ❑ Accelerometers
 - ❑ Gyroscopes
 - ❑ Magnetometers
 - ❑ Altimeters



LIGHT DETECTION AND RANGING (LIDARs)

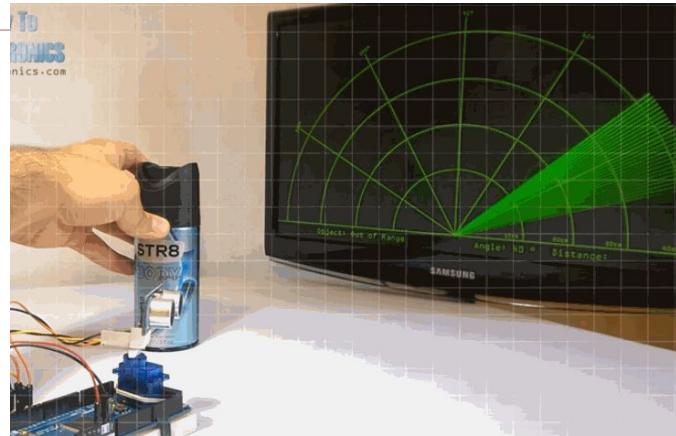
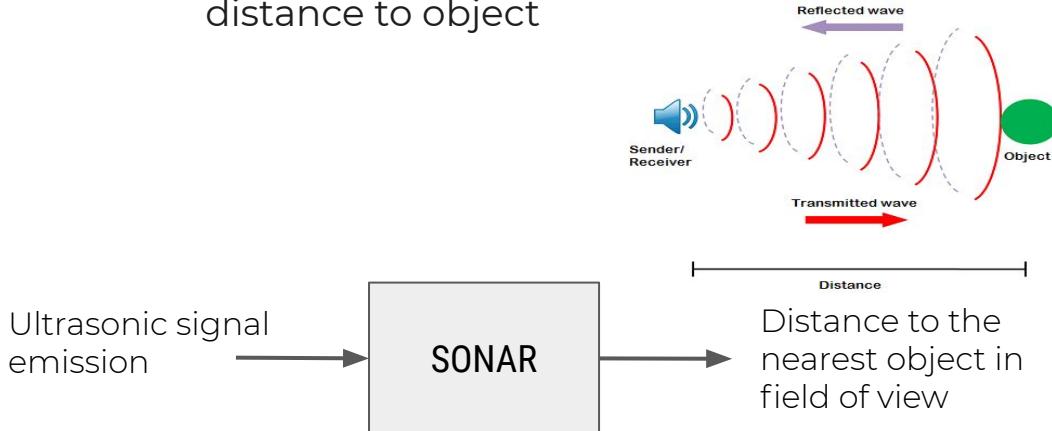
- ❑ **LIDAR** (Light Detection and Ranging or Laser Induced Direction and Range System) — detection, identification and ranging by using light source
- ❑ Operating principle:
 - ❑ The directional beam of the light signal source is reflected from the targets, returns to the source and is captured by the 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





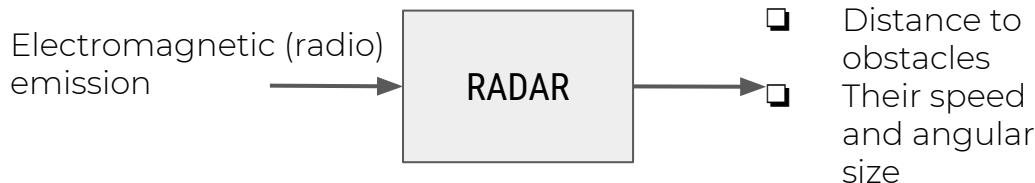
ULTRASONIC SENSORS (SONARs)

- ❑ **Sonar** (sound navigation ranging) — is an instrument that measures the distance to an object using ultrasonic sound waves.
- ❑ Operating principle:
 - ❑ Emits an ultrasonic signal
 - ❑ Measures 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.

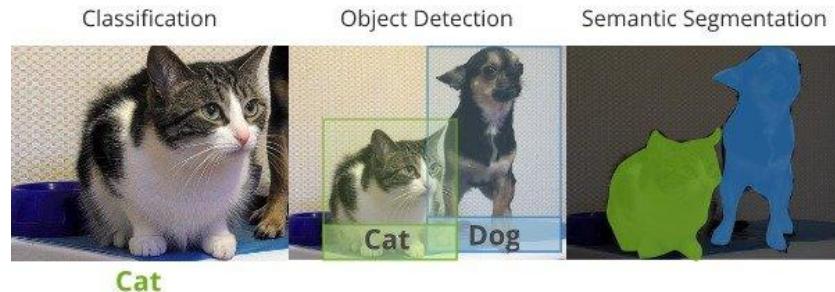
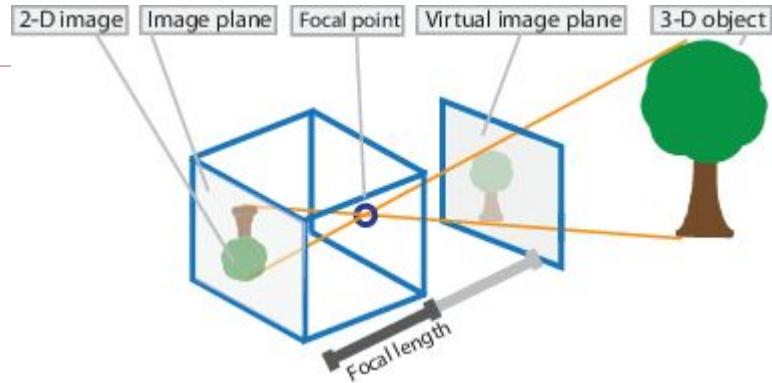
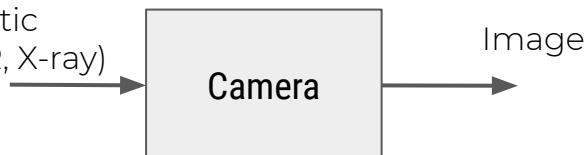


CAMERAS

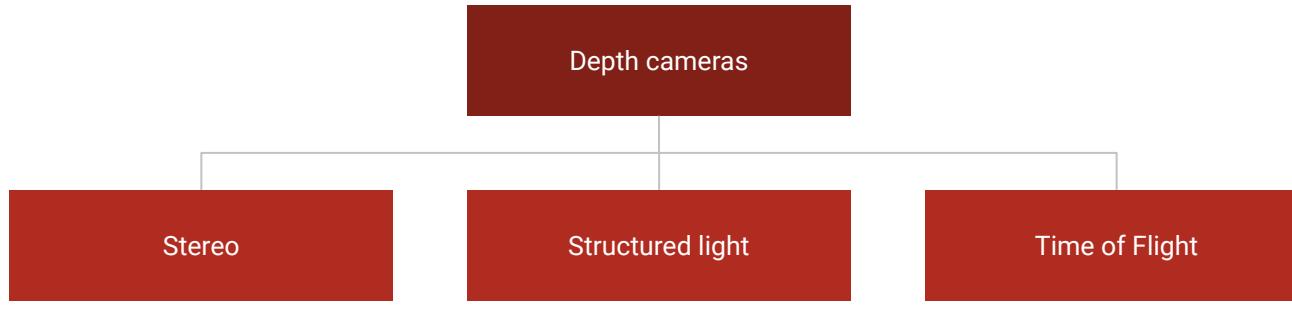
- ❑ **Camera** — projective sensor. Projects a 3D world onto a 2D plane.

- ❑ Operating principle:

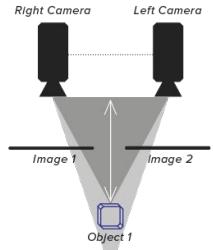
- ❑ Matrix pixels register light reflected from objects (attenuation of radiation in the case of X-rays)
- ❑ The number of photons hitting a pixel is converted into an electrical signal



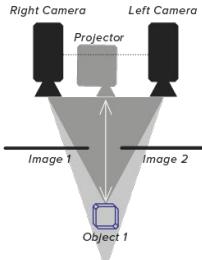
DEPTH CAMERAS



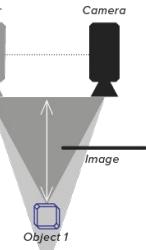
PASSIVE STEREO



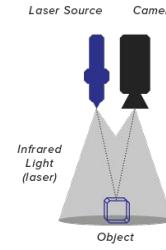
ACTIVE STEREO



STRUCTURED LIGHT



TIME OF FLIGHT



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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