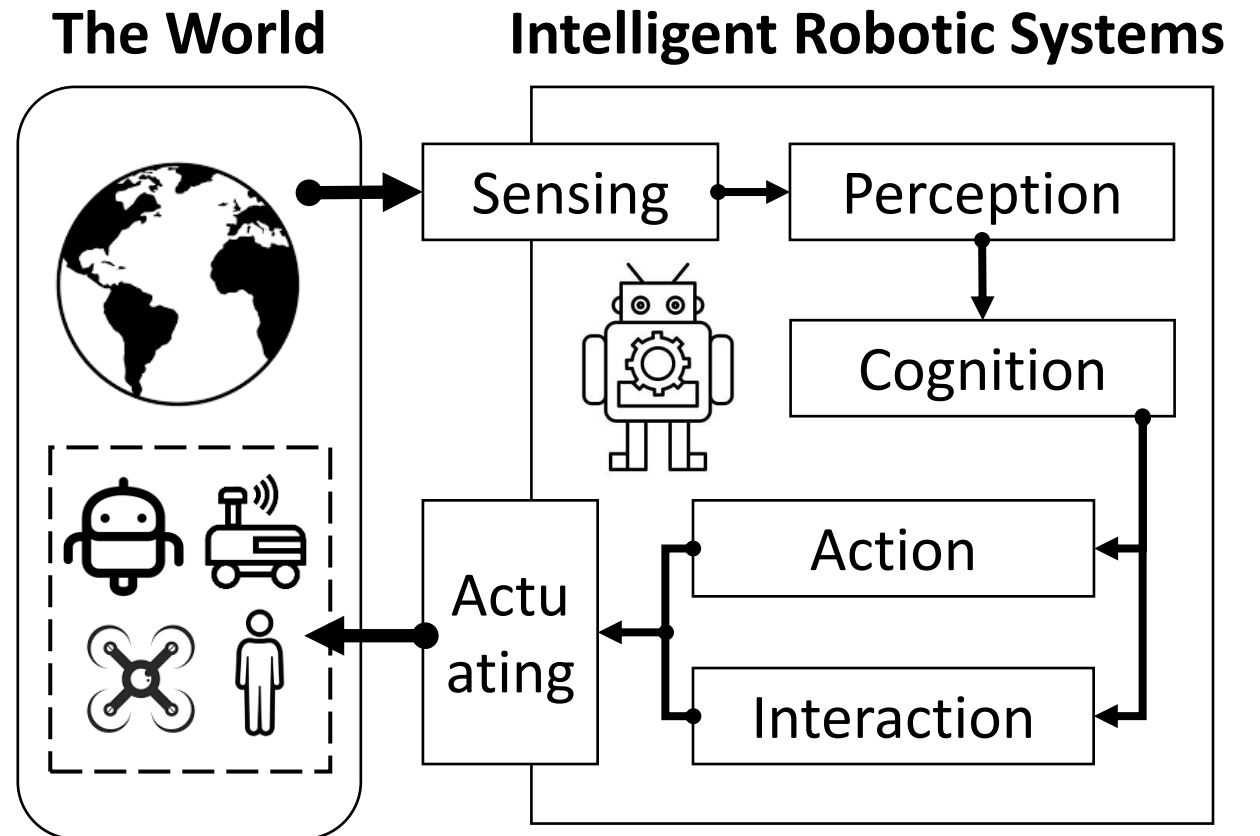


# COMPSCI-603: Robotics

## Sensing and Actuating

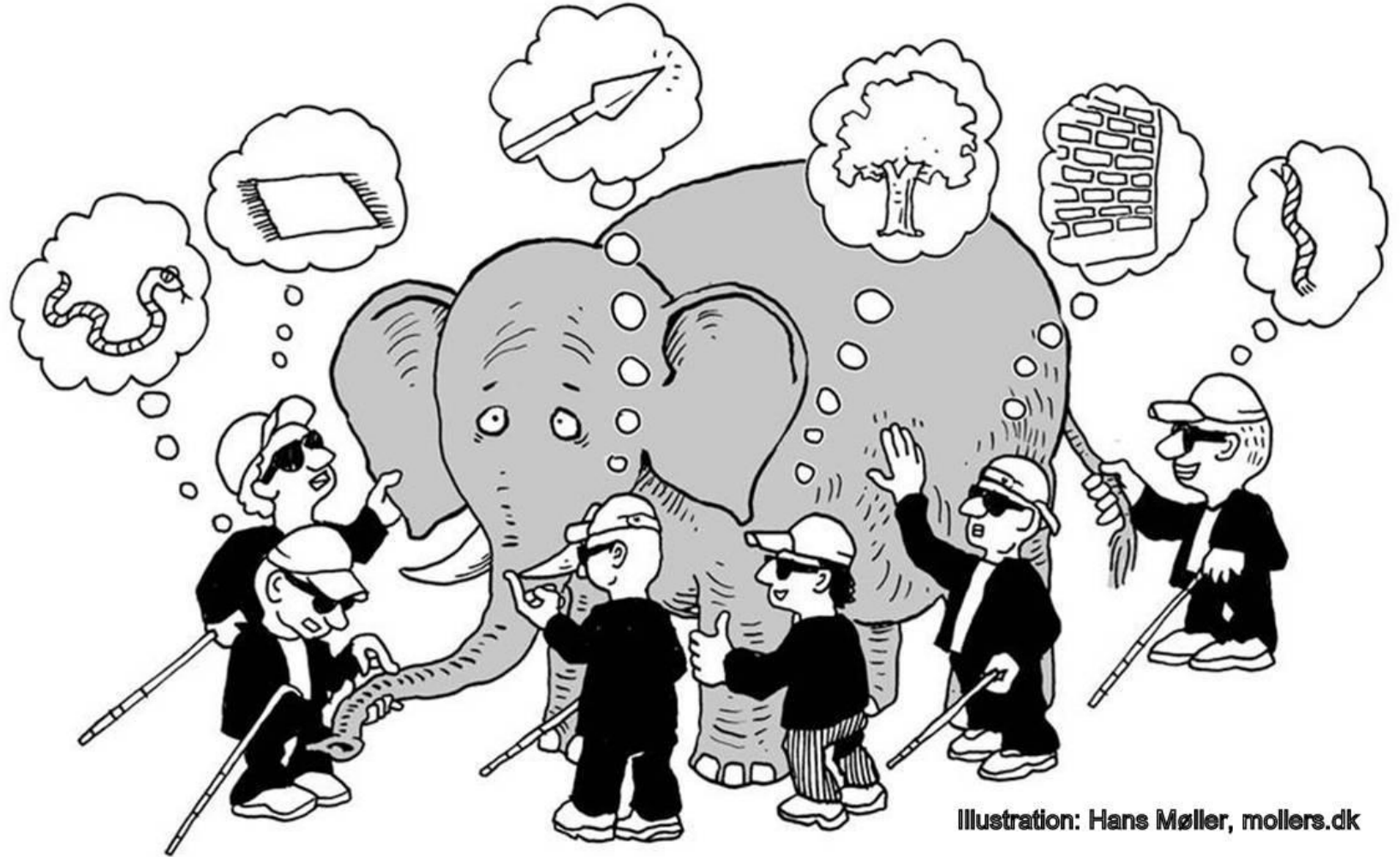
(Brief Overview)

# Course Overview



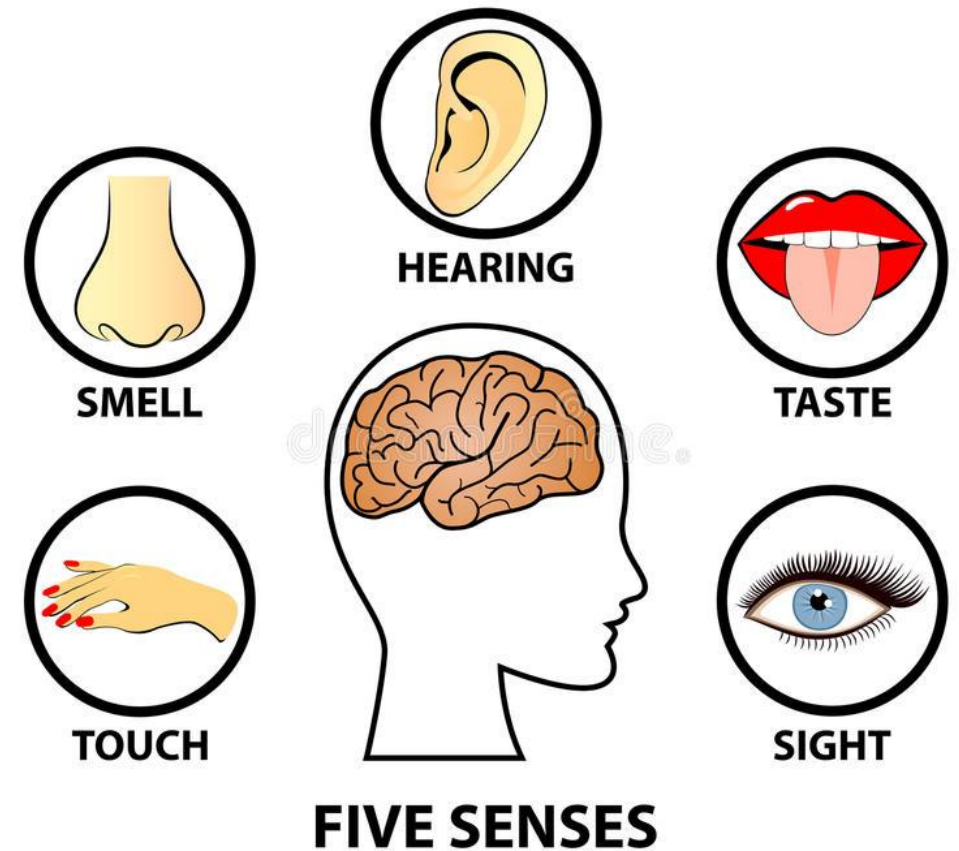
# Robot Sensing

- What is the purpose of sensing for robots?



# Sensors

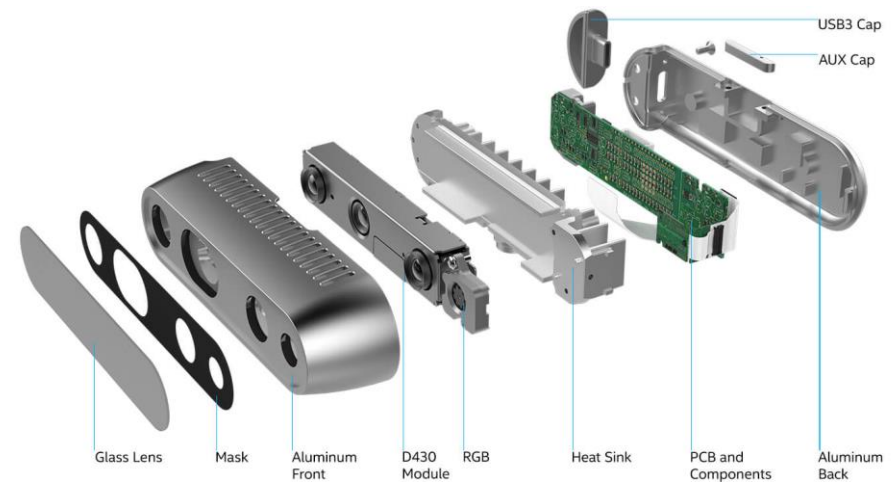
- Sensors are electronic devices that measure physical quantities.
- Sensors are a necessary physical component of the *perception* system of a robot.
- Sensors do not provide state, but measurement or observation
- Examples:
  - Contact: switch
  - Distance: radar
  - Location: GPS



Reference: Roland Siegwart, Illah Reza Nourbakhsh and Davide Scaramuzza. "Introduction to Autonomous Mobile Robots", Chapter 4, MIT Press, 2011.

# Sensor Types

- From the perspective of energy emission:
  - Passive: receive energy only.
    - Vision → Camera
    - Hearing → Microphone
  - Active: emit energy and measure its response.
    - Radar, sonar
    - LiDAR
    - Structured light
    - Touch





# Sensor Types

- From the perspective of information sources:
  - Proprioceptive sensors: measure values internally to the robot, e.g., for robot state estimation.
    - Battery status
    - Motor rotation
    - CPU temperature
  - Exteroceptive sensors: obtain observations of the external environment, e.g., for situational awareness.
    - Distance
    - Visual images
    - Thermal readings

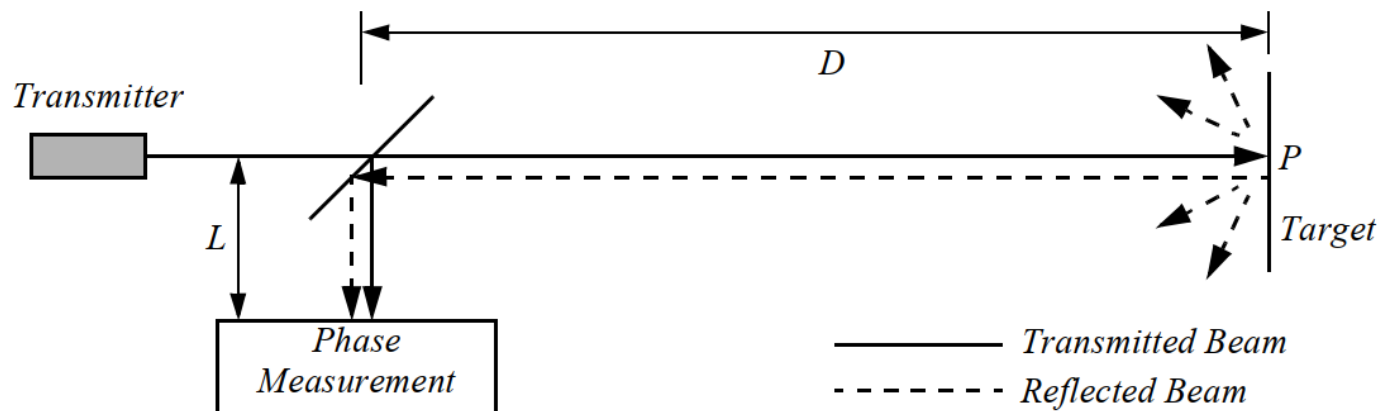
# Common Proprioceptive Sensors

- Odometry sensor (to estimate change in position over time): motor/wheel encoders.
  - Inertial sensor (to estimate velocity): gyroscope, accelerometer.
  - Heading sensor: compass.
  - Tilting angle sensor: inclinometer.
- 
- Inertial measurement unit (IMU): an electronic device that uses a combination of accelerometers, gyroscopes, and sometimes magnetometers to measure orientation in space.

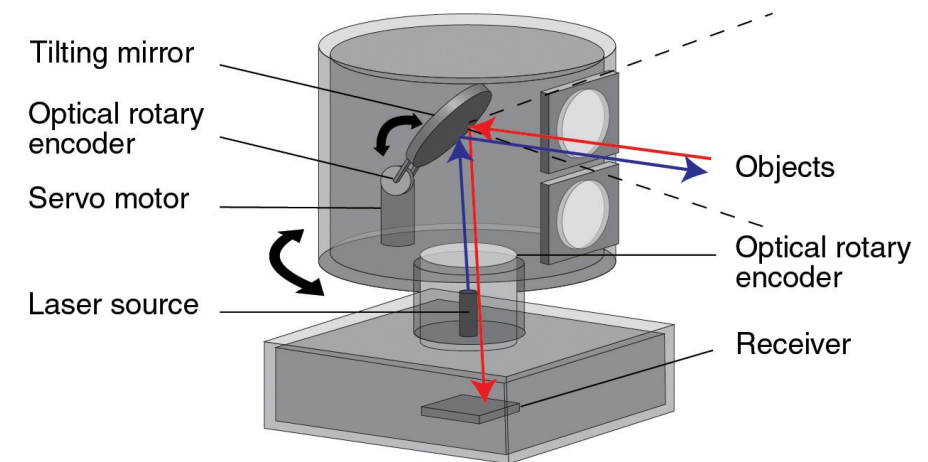
# Common Exteroceptive Sensors

- Laser range sensor
  - Measures large range distance, so called range sensors.
  - Uses propagation speed of electromagnetic waves.
  - Thus, is also called Light Detection And Ranging (LiDAR).

$$\text{Distance} = (\text{Speed of Light} \times \text{Time of Flight}) / 2$$



RPLiDAR





demo.rviz\* - RViz

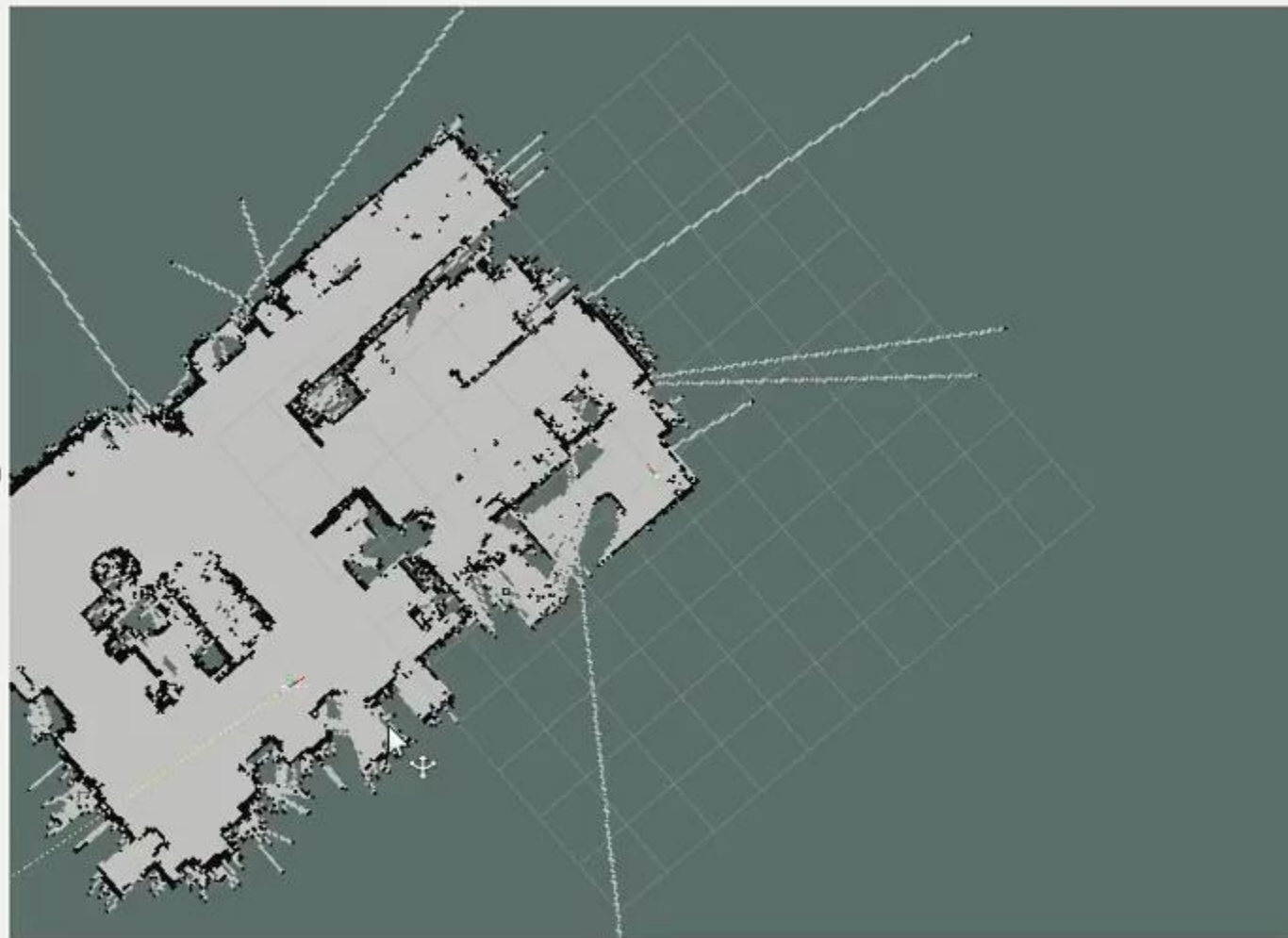
File Panels Help

Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Nav Goal Publish Point

**Displays**

- Global Options
  - Fixed Frame: map
  - Background ...: 48; 48; 48
  - Frame Rate: 30
- Global Status
  - Fixed Frame: OK
  - Grid: ☒
  - Image: ☒
    - Status: Ok
    - Image Topic: /camera/rgb/image...

Add Remove Rename



**Views**

Type: Orbit (rviz) Zero

Current View	Orbit (rviz)
Near Clip ...	0.01
Target Fra...	<Fixed Frame>
Distance	18.0931
Yaw	2.4354
Pitch	1.5698
Focal Point	0; 0; 0

Save Remove Rename

Time

ROS Time: 1457281976.48 ROS Elapsed: 476.41 Wall Time: 1457281976.52 Wall Elapsed: 476.41

☐ Experimental

Reset Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel: Zoom. Shift: More options.

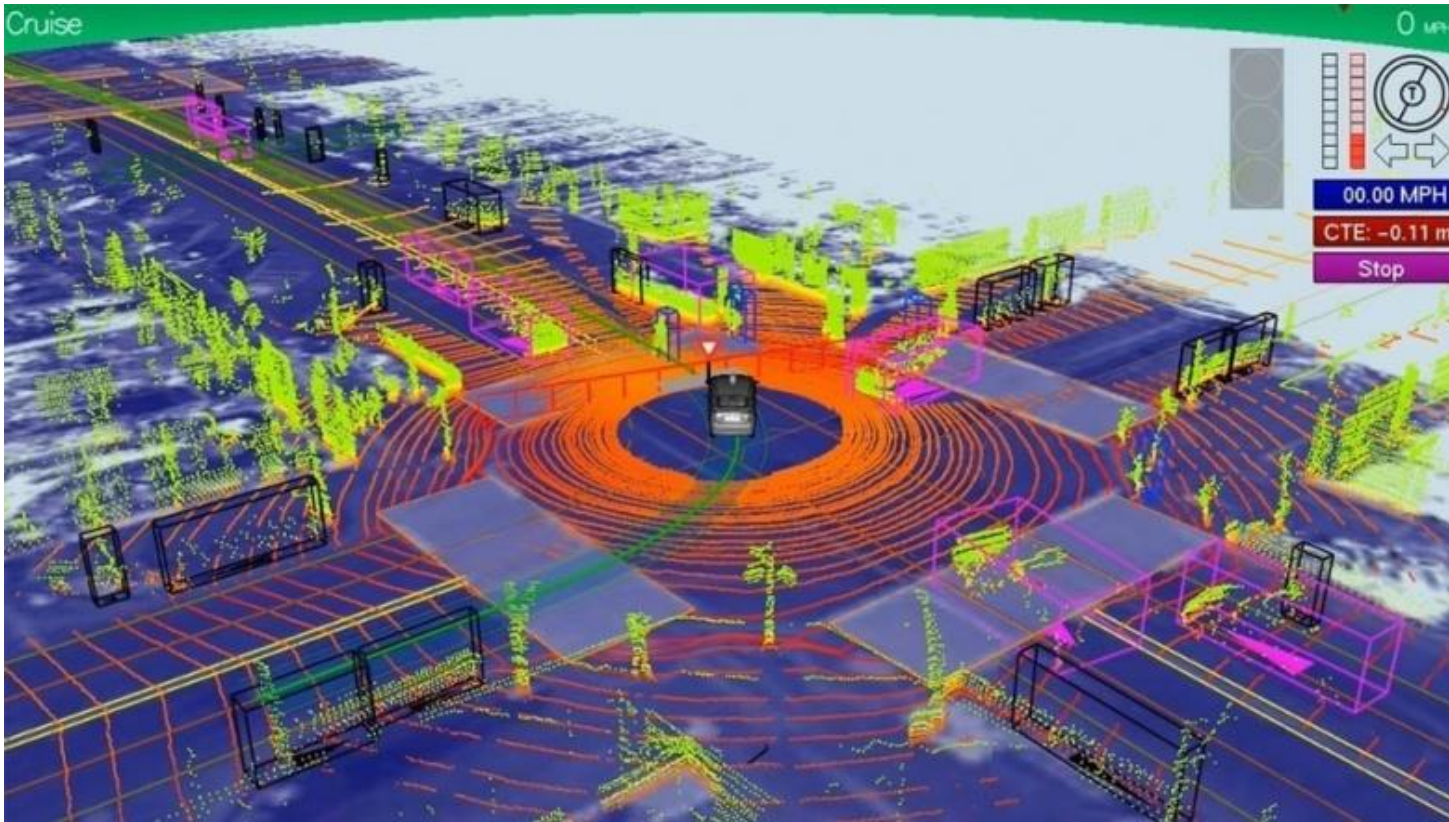
30 fps

demo@demo-ThinkP... demo.rviz\* - RViz

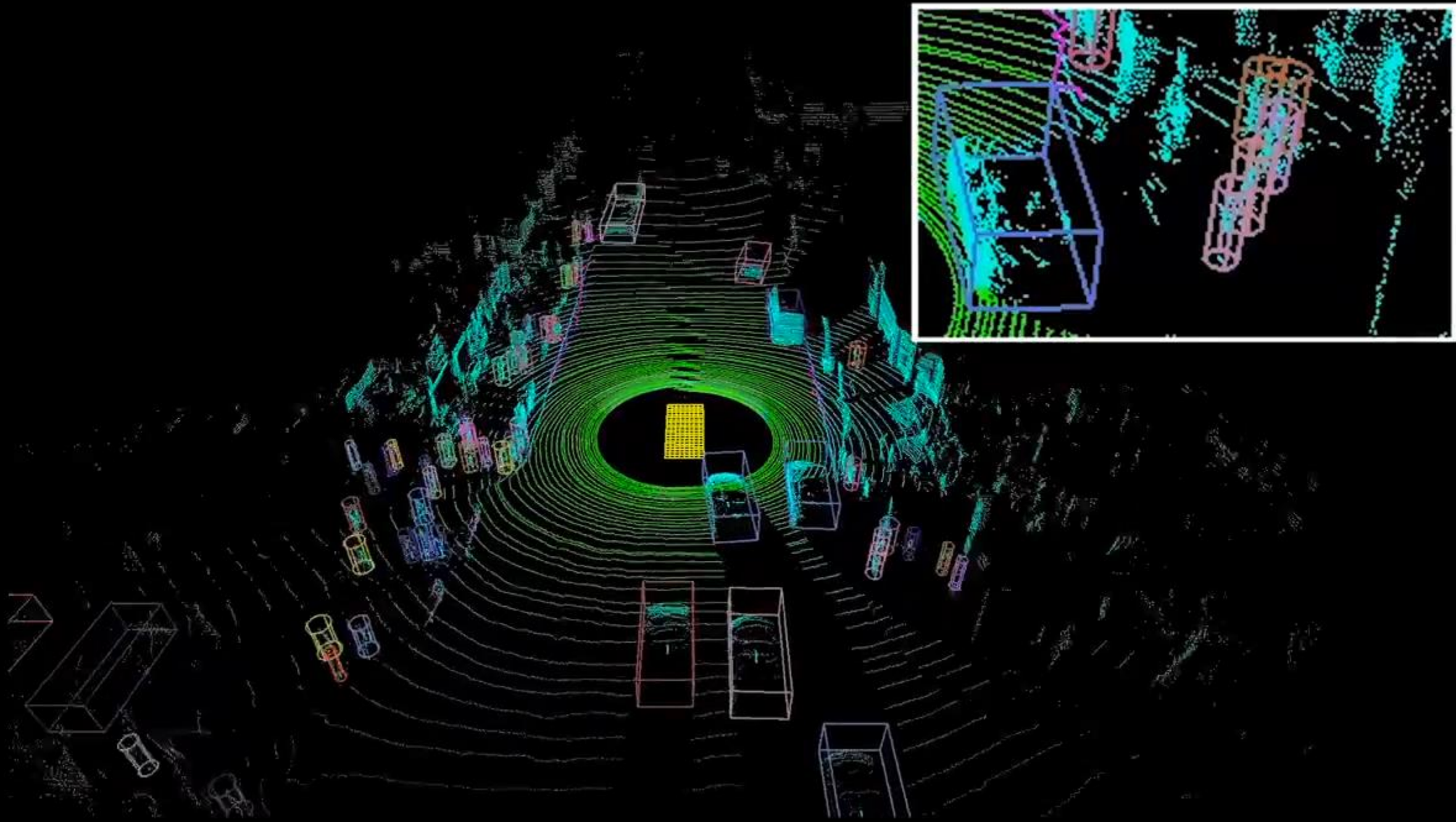
2D SLAM using PRLiDAR: <https://www.youtube.com/watch?v=iVndhBqpp-0>

# Common Exteroceptive Sensors

- 3D LiDAR: use multiple laser beams to expand the vertical field of view.

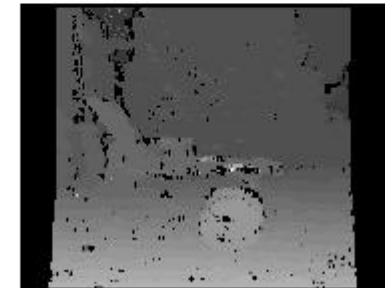
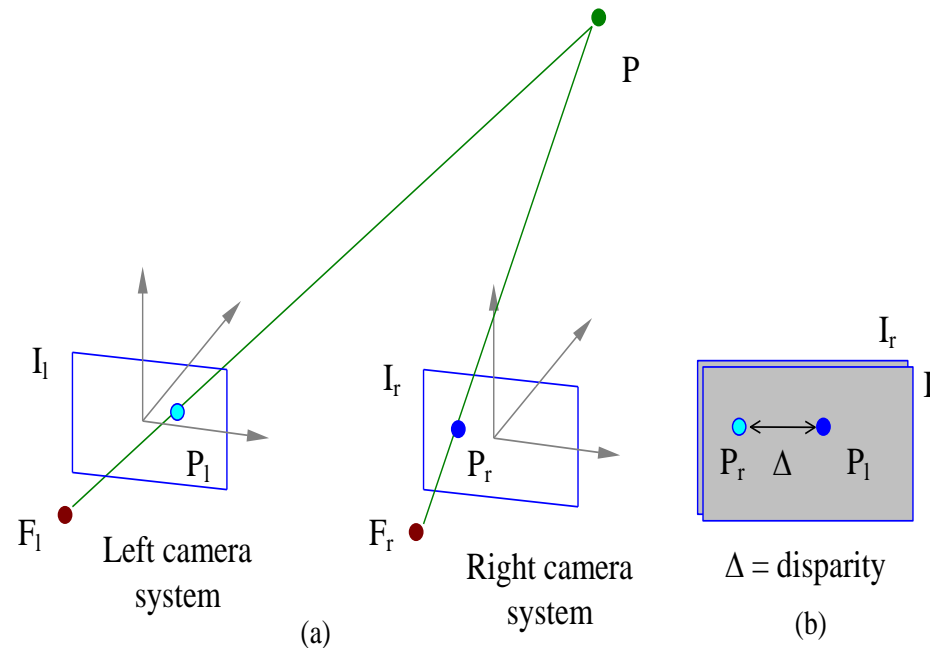






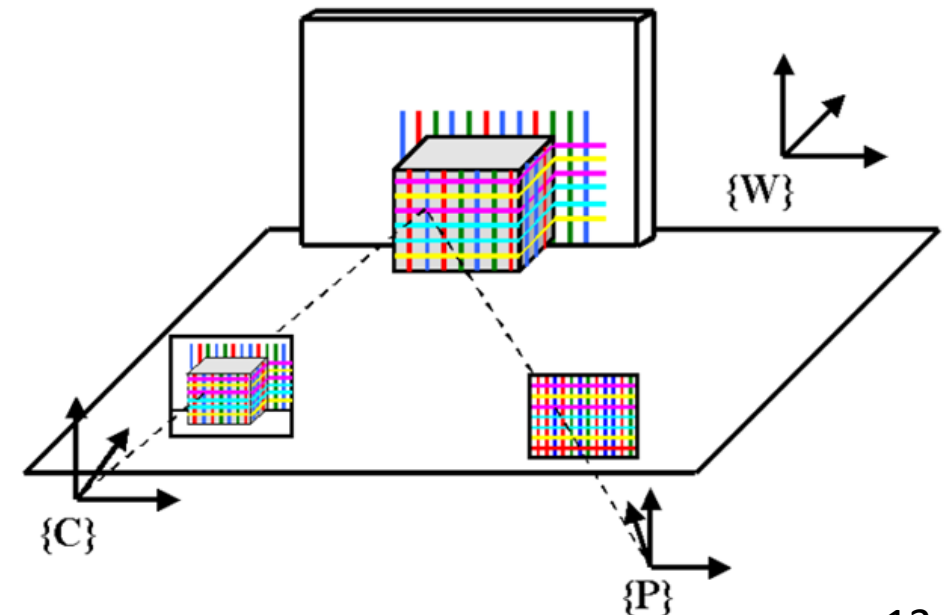
# Common Exteroceptive Sensors

- Stereo camera: two (or more) cameras looking at the same scene from different perspectives provide a mean for determining three-dimensional shape and position.



# Common Exteroceptive Sensors

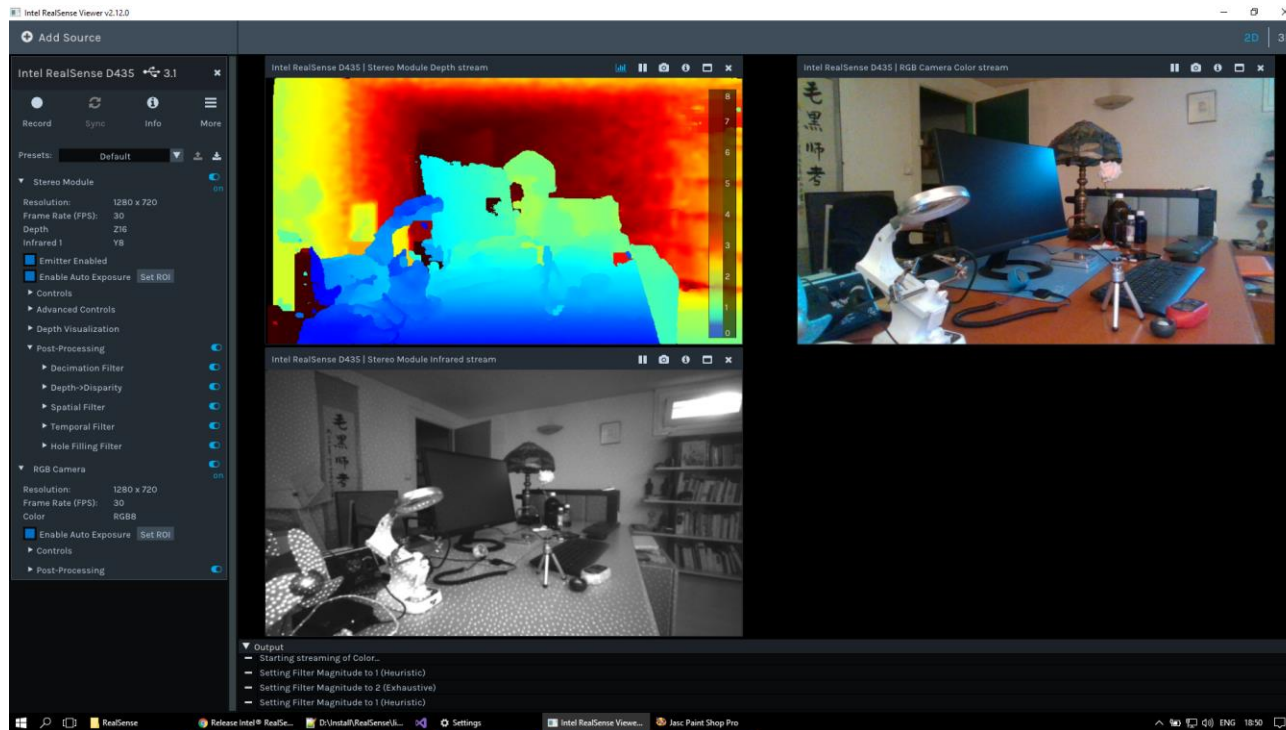
- Structured light sensor (color-depth sensors):
  - Projects a known pattern onto the scene.
  - Measures the similarity of sensed and projected patterns to find correspondence.
  - Uses triangulation to estimate distance.



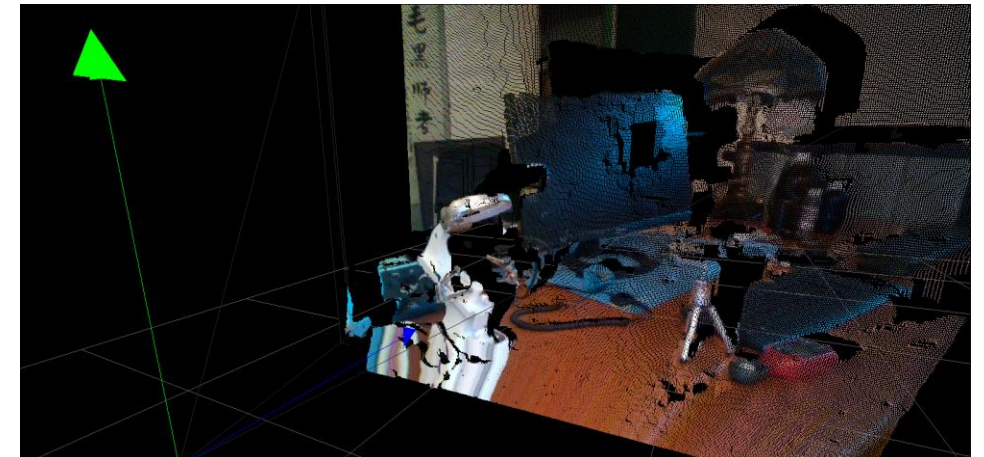
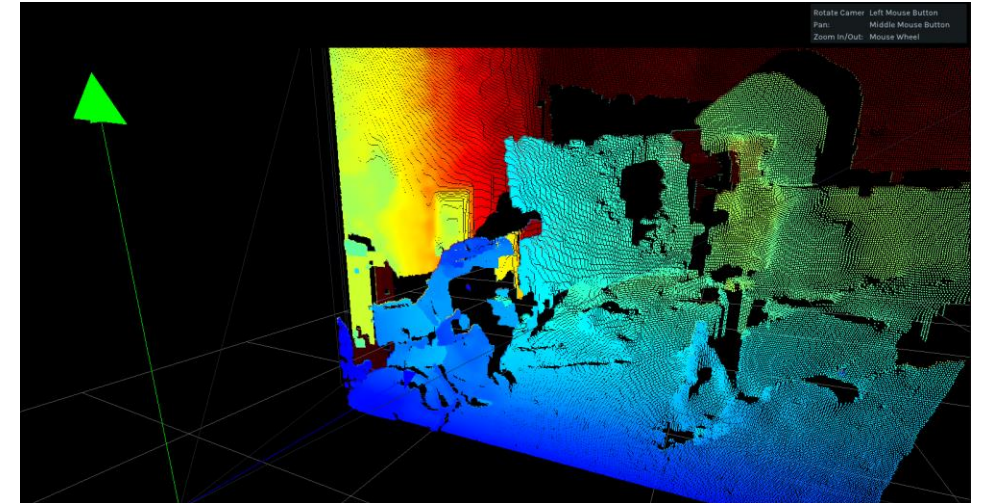


# Common Exteroceptive Sensors

- Structured light sensor:
  - <https://github.com/IntelRealSense/librealsense/releases>













































Reference: "Intel RealSense D435 review" by Maurice's Musings.









Actuating	Flying	Swimming	4+ Legged	2 Legged	4+ Wheeled	2 Wheeled	Arms	Head
Defense								
Industry								
Security								
Medical								
Transport		Yole Developpment Report, “Sensors for drones and robots: market opportunities and technology revolution,” 2016						
Commercial								
Consumer								

# Actuating: Mobile Robots



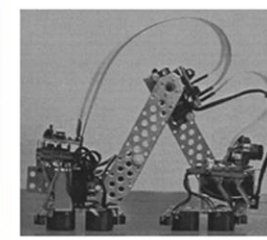
Delta Extreme



ACM-III



ACM-R3



Inch Worm



RobuRoc



Soryu 4



Slug Crawler



Talon

Tracked

Articulated Body

Hybrid  
(Articulated Body)

Hybrid  
(Legged)

Legged

Legged

Bridging

Conforming

Jumping Over

Wheeled



Segway RMP440



Atlas J8 XTR



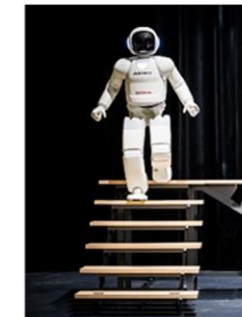
Tri-Star Wheel



PackBot



Curiosity



Asimo



Genghis



Big Dog



RHex

Chun Fan Goh, Akshay Hinduja, Divish Ajmani, Robin Song, Lei Zhang, and Kenji Shimada.  
"Designing a mobility solution for fully autonomous welding of double-hull blocks."  
Journal of Mechanisms and Robotics 11, no. 4.  
2019.



# Actuating: Soft Robots

iSprawl



Soft gripper



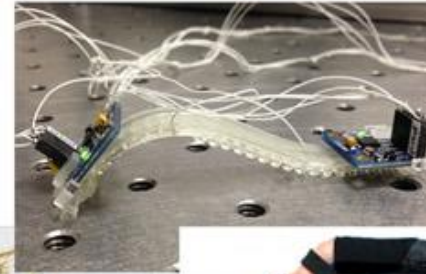
OCTOPUS



Universal gripper



Tuft Softworm



Inflatable robotic arm



X-RHex



Soft robotic fish



PoseiDrone



Origami robot



Rehabilitation glove



Octobot

Mostly stiff  
Few selectively compliant elements

Entirely soft

Cecilia Laschi, Barbara Mazzolai, and Matteo Cianchetti. "Soft robotics: Technologies and systems pushing the boundaries of robot abilities." Science robotics 1, no. 1. 2016.

# Real-World Robots

- Autonomous driving

## HOW UBER'S FIRST SELF-DRIVING CAR WORKS

Top mounted **LiDAR** beams 1.4 million laser points per second to create a 3D map of the car's surroundings.

A **colored camera** puts LiDAR map into color so the car can see traffic light changes.

There are **20 cameras** looking for braking vehicles, pedestrians, and other obstacles.

**Antennae** on the roof rack let the car position itself via GPS.

**LiDAR modules** on the front, rear, and sides help detect obstacles in blind spots.

A **cooling system** in the car makes sure everything runs without overheating.



SOURCE: Uber

BUSINESS INSIDER

## The self-driving car's sensors

*Just like a person has five senses, Google's self-driving car has a variety of gadgets that detect nearby objects so it can avoid them.*

**Global Positioning System software**  
Helps car determine its location.

**Position sensor**  
Located in the wheel hub, this sensor helps determine car's location from wheel rotations.

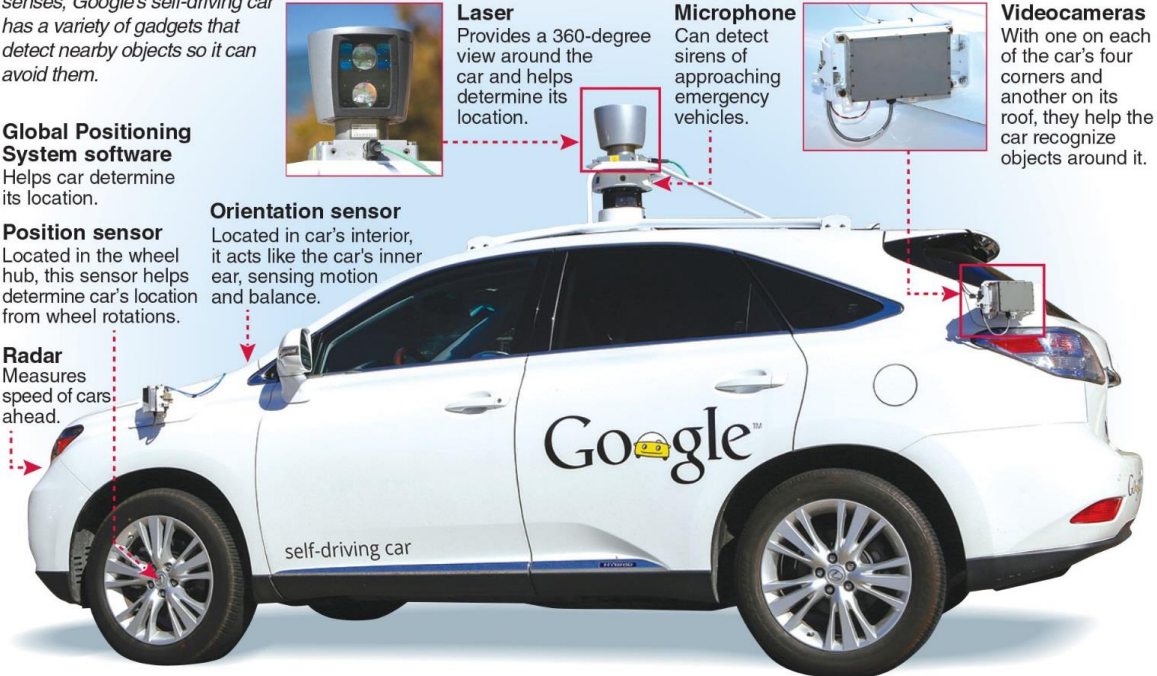
**Radar**  
Measures speed of cars ahead.

**Orientation sensor**  
Located in car's interior, it acts like the car's inner ear, sensing motion and balance.

**Laser**  
Provides a 360-degree view around the car and helps determine its location.

**Microphone**  
Can detect sirens of approaching emergency vehicles.

**Videocameras**  
With one on each of the car's four corners and another on its roof, they help the car recognize objects around it.



### How the car operates

- 1 Any object the vehicle's sensors spot is interpreted by software to determine if it's a pedestrian, cyclist, vehicle or something else.
- 2 Using what it's learned from previous driving, the software makes predictions about what objects will do next.
- 3 The software analyzes the information to decide whether it is safe to accelerate, turn or hit the brakes.



### How the car sees the world

This computerized image is what Google researchers monitoring sensor data see as they ride in the vehicle.

- Other vehicle
- Pedestrian
- Cyclist
- Objects that warrant caution
- A crosswalk, indicating the car needs to stop
- A traffic signal, warning of upcoming railroad tracks
- Path where Google's car intends to go

Source: Google  
Graphic: Tribune News Service



# Real-World Robots

- Mars Rover

