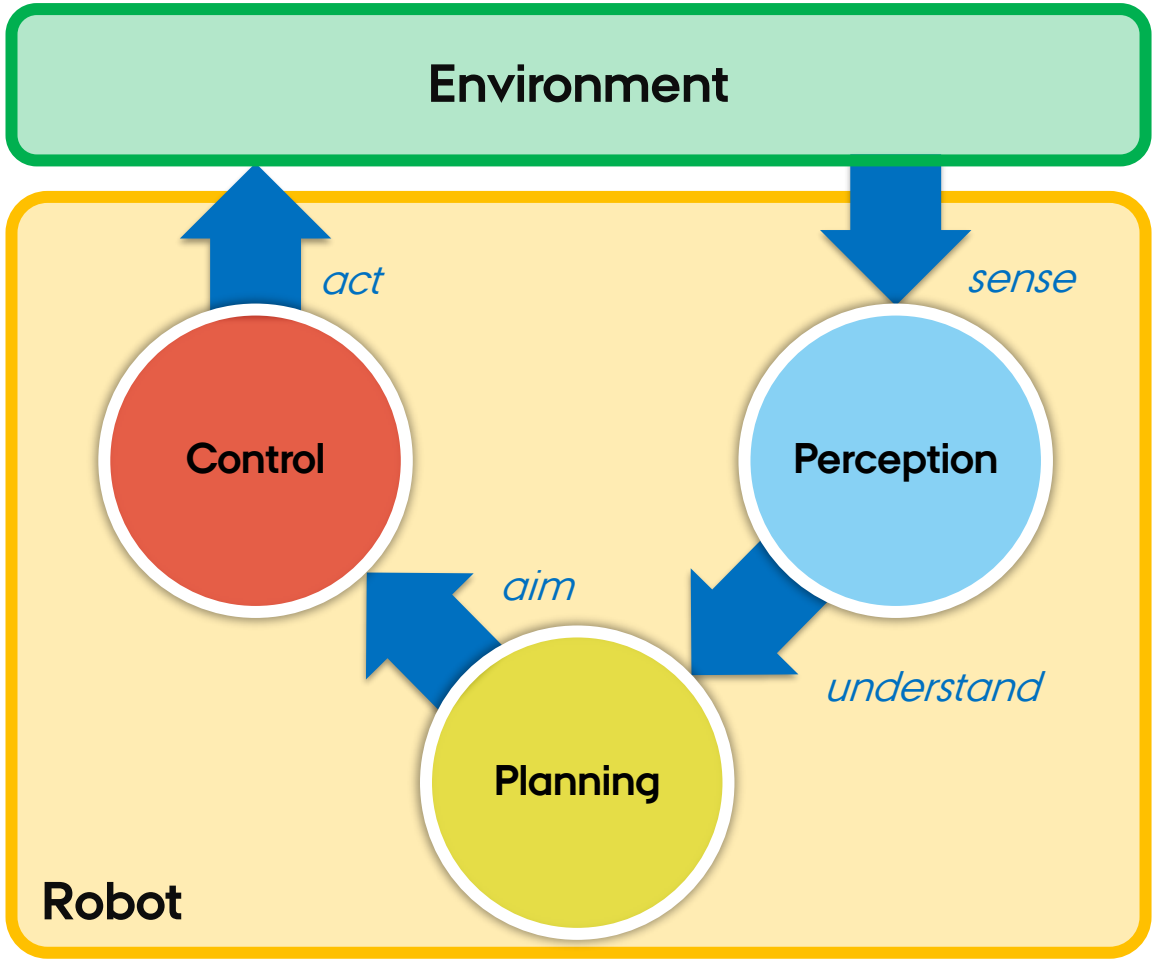
ROBOT SENSORS

AARHUS
UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER
ENGINEERING

ANDRIY SARABAKHA
ASSISTANT PROFESSOR (TENURE TRACK)

ROBOT NAVIGATION PARADIGM

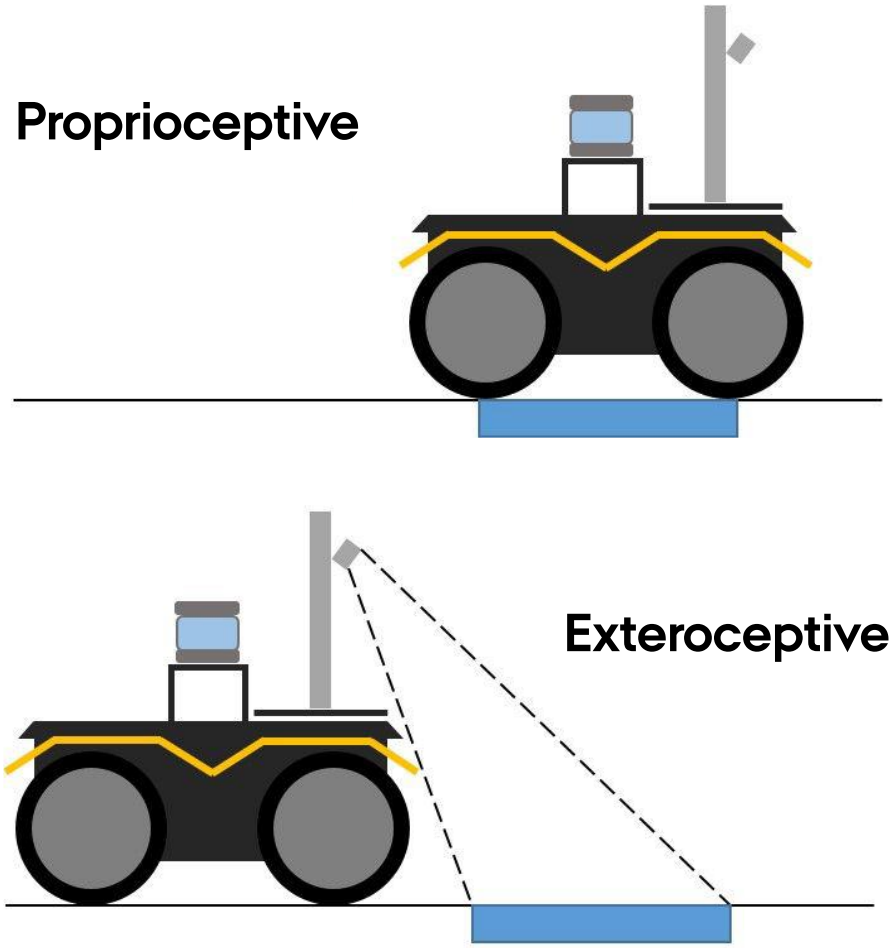


SENSOR TYPES

https://www.frontiersin.org/articles/10.3389/fnbot.2020.576846/full

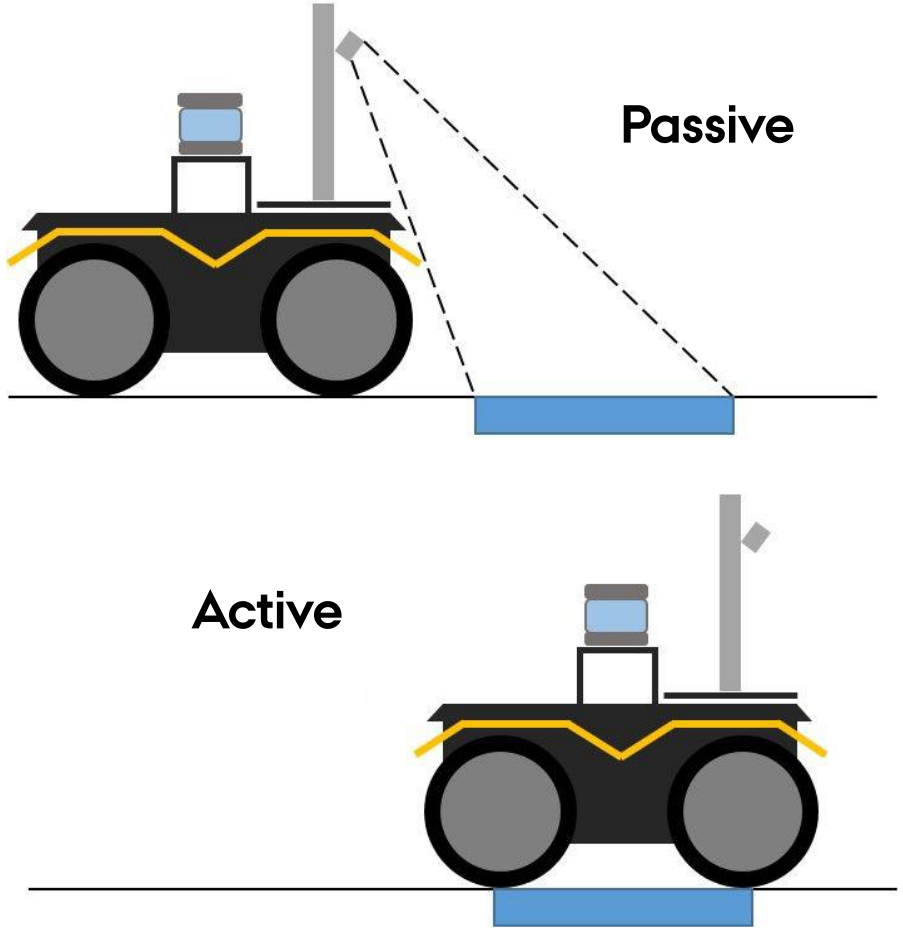
PROPRIOCEPTIVE AND EXTEROCEPTIVE SENSORS

- **Proprioceptive sensors**
  - Internal information to the robot
  - Examples:
    - Encoders: position
    - Gyroscopes: angular rate
    - Voltmeter: battery percentage
- **Exteroceptive sensors**
  - External information from the environment
  - Examples:
    - Camera: images
    - LiDAR: distance
    - Compass: heading



PASSIVE AND ACTIVE SENSORS

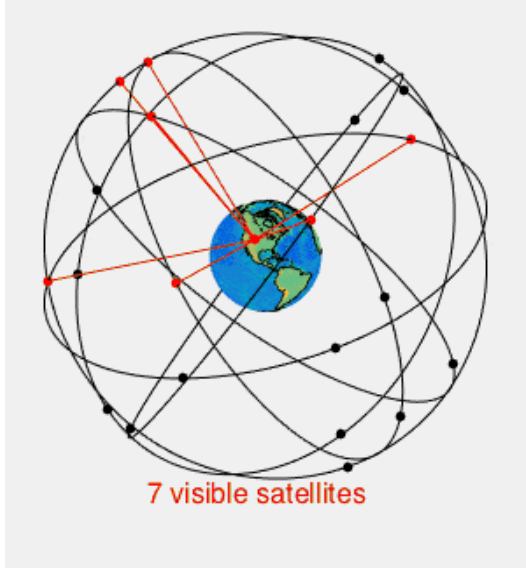
- **Passive sensors**
  - Use energy from the environment
  - Examples:
    - Camera: images
    - Compass: heading
    - GPS: position
- **Active sensors**
  - Emit energy into environment
  - Examples:
    - Encoders (magnetic): position
    - LiDAR: distance
    - Radar: distance

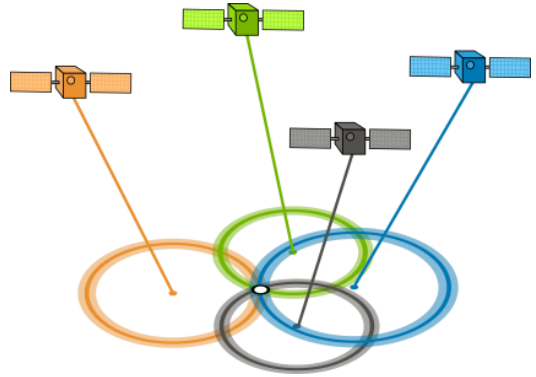


COMMON SENSORS ON MOBILE ROBOTS

GNSS

- **Global navigation satellite system (GNSS)** is a satellite navigation system that uses satellites to provide autonomous geopositioning
- **Global positioning system (GPS)**, the GNSS owned by the USA, provides geolocation and time information to a GPS receiver anywhere on the Earth where there is an unobstructed line of sight
- GPS has a constellation of 38 satellites
- At least four satellites are required to estimate the position
- Applications: positioning and time information
- Advantages: global coverage
- Disadvantages: signal blockage



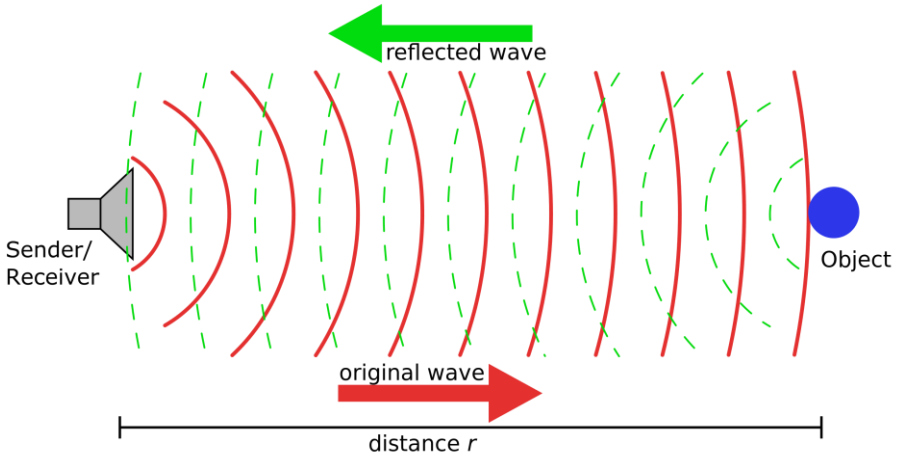


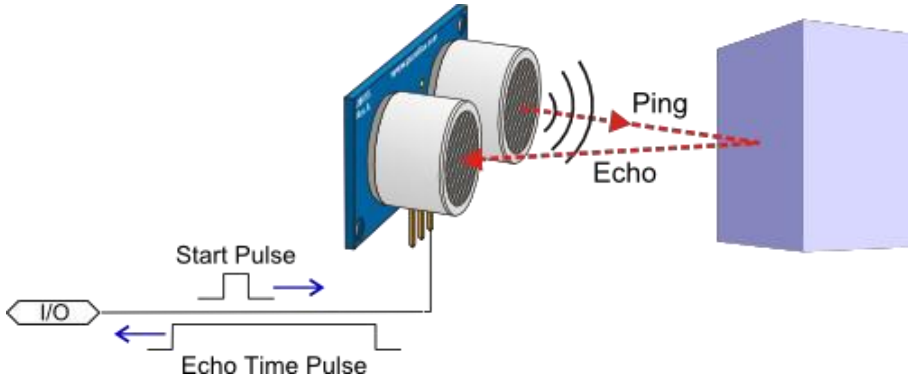
RADAR

- **Radar** is a radiolocation system that uses radio waves to determine the distance (range), to the surrounding objects
- A radio pulse is generated by a piezoelectric emitter, reflected by an object on its path, and sensed by a piezo-electric receiver
- Based on the speed of sound v and the elapsed time from emission to reception Δt, the distance d between the sensor and the object is

$$d = \frac{v \cdot \Delta t}{2}$$

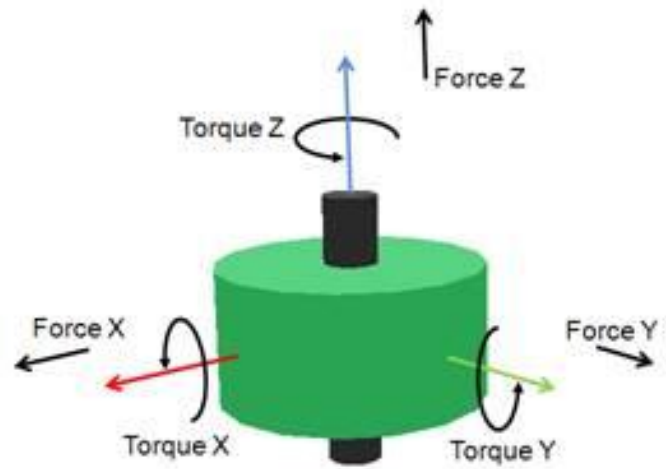
- Applications: distance measurement
- Advantages: long-range detection
- Disadvantages: limited resolution





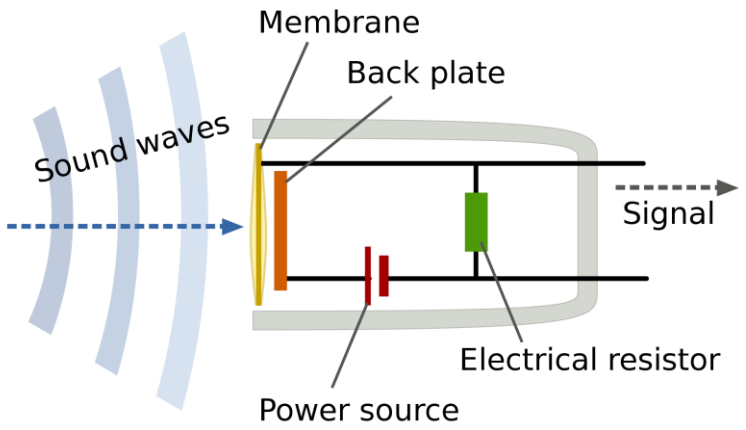
FORCE-TORQUE SENSOR

- **Force-torque sensors** measure the forces and moments exerted on the robot
- Force-torque sensor provides three forces along X-, Y- and Z-axis, and three torques around X-, Y- and Z-axis
- Applications: tactile control
- Advantages: precision
- Disadvantages: cost, complexity, need interaction

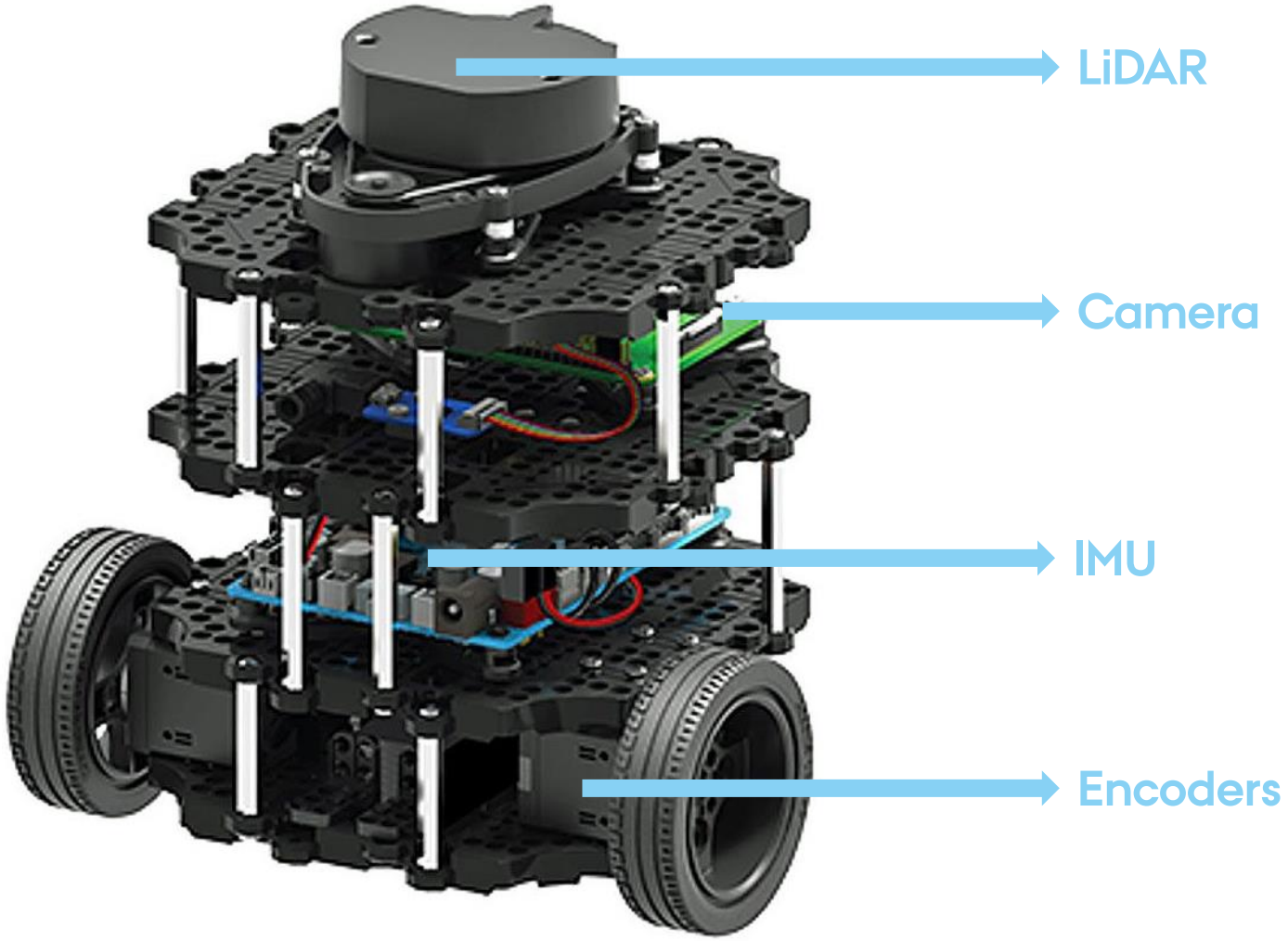


MICROPHONE

- A **microphone** is a transducer that converts sound into an electrical signal
- Applications: voice commands
- Advantages: versatility
- Disadvantages: noise sensitivity



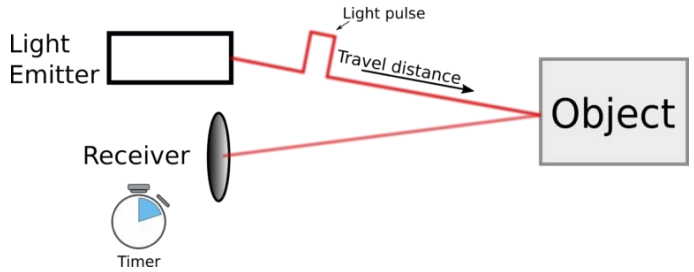
SENSORS ON TURTLEBOT3

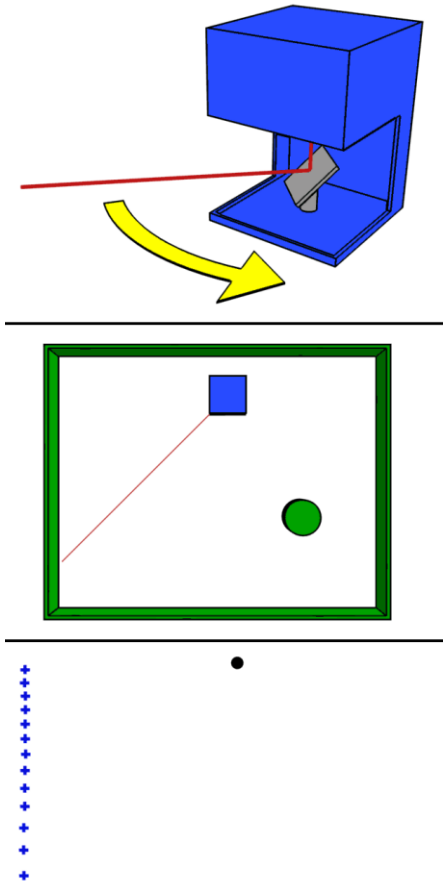


LIDAR

- **Lidar** (an acronym of "*light detection and ranging*") is a method for determining ranges by targeting an object a laser and measuring the time for the reflected light to return to the receiver
- Based on the speed of light c and the elapsed time from emission to reception Δt, the distance d between the sensor and the object is

$$d = \frac{c \cdot \Delta t}{2}$$

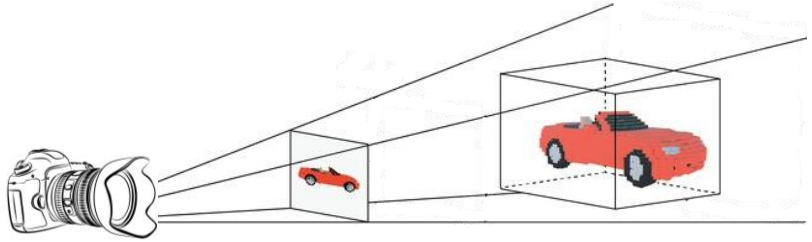




- Applications: distance measurements
- Advantages: high accuracy
- Disadvantages: cost

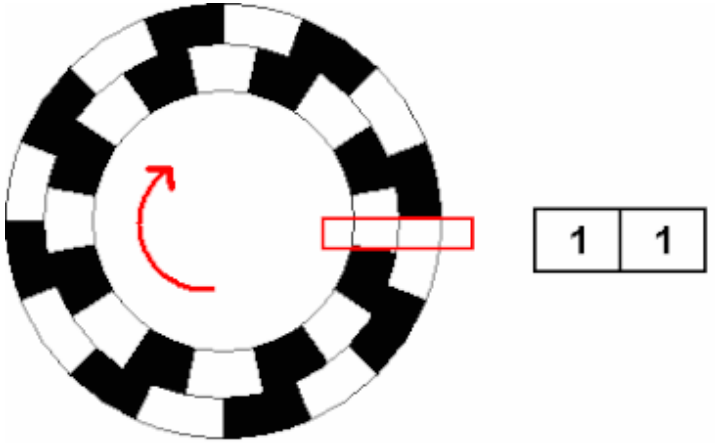
CAMERA

- **Camera** is an instrument used to capture images and/or videos
- Camera projects 3D world into a 2D image
- Colored images are represented by three channels corresponding to red, green and blue colors
- Each channel is represented by a 2D matrix which stores the intensity of each pixel
- Applications: capture visual information
- Advantages: versatility
- Disadvantages: privacy concerns, light sensitive



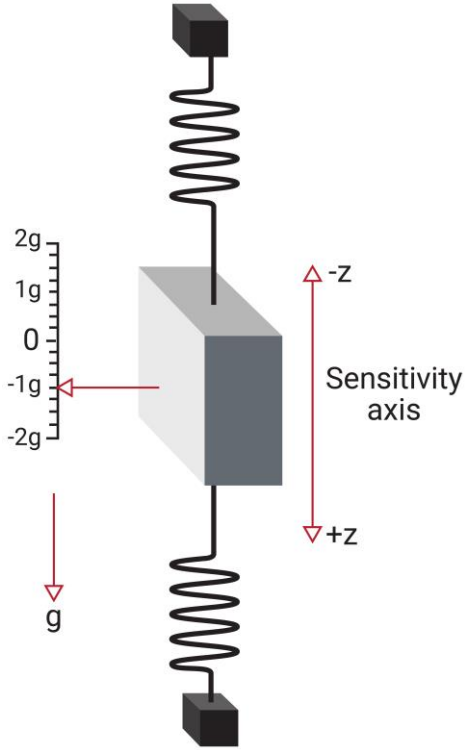
ENCODER

- Wheel **encoder** is an electro-mechanical device that measures the angular position of the wheel
- Wheel encoder consists of a wheel with evenly spaced slots around its circumference and a sensor that detects the position of the slots as the wheel rotates
- Applications: displacement estimation
- Advantages: low cost
- Disadvantages: sensitivity to wheel slip



ACCELEROMETER

- **Accelerometer** is a device that measures the proper acceleration of an object
- When an accelerometer is subjected to a linear acceleration along the sensitivity axis, the acceleration causes the mass to shift to one side, with the amount of deflection proportional to the acceleration
- Applications: acceleration measurements
- Advantages: compact size
- Disadvantages: noise sensitive

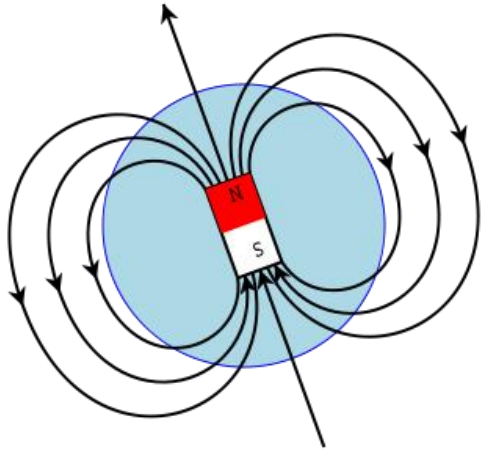


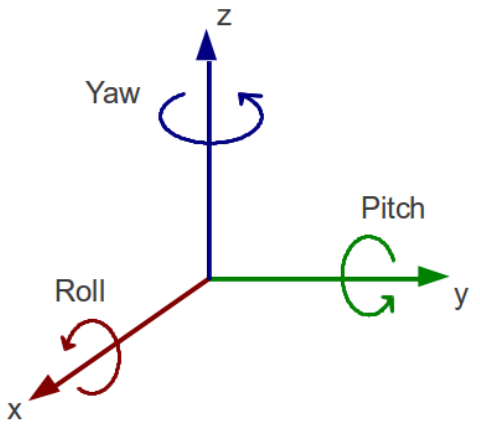
GYROSCOPE

- **Gyroscope** is a device used for measuring angular rate
- Gyroscopes use the theory of the Coriolis effect
- Due to the angular momentum, the gyroscope will maintain its position around the axis of rotation
- Applications: angular rate sensing
- Advantages: fast response time
- Disadvantages: drift

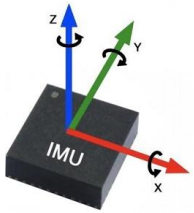
MAGNETOMETER

- **Magnetometer** is a device that measures magnetic field
- When a magnet inside the magnetometer is crossed by a magnetic field, it generates electric current proportional to the strength of the magnetic field
- Applications: orientation measurements
- Advantages: sensitive detection
- Disadvantages: susceptibility to interference

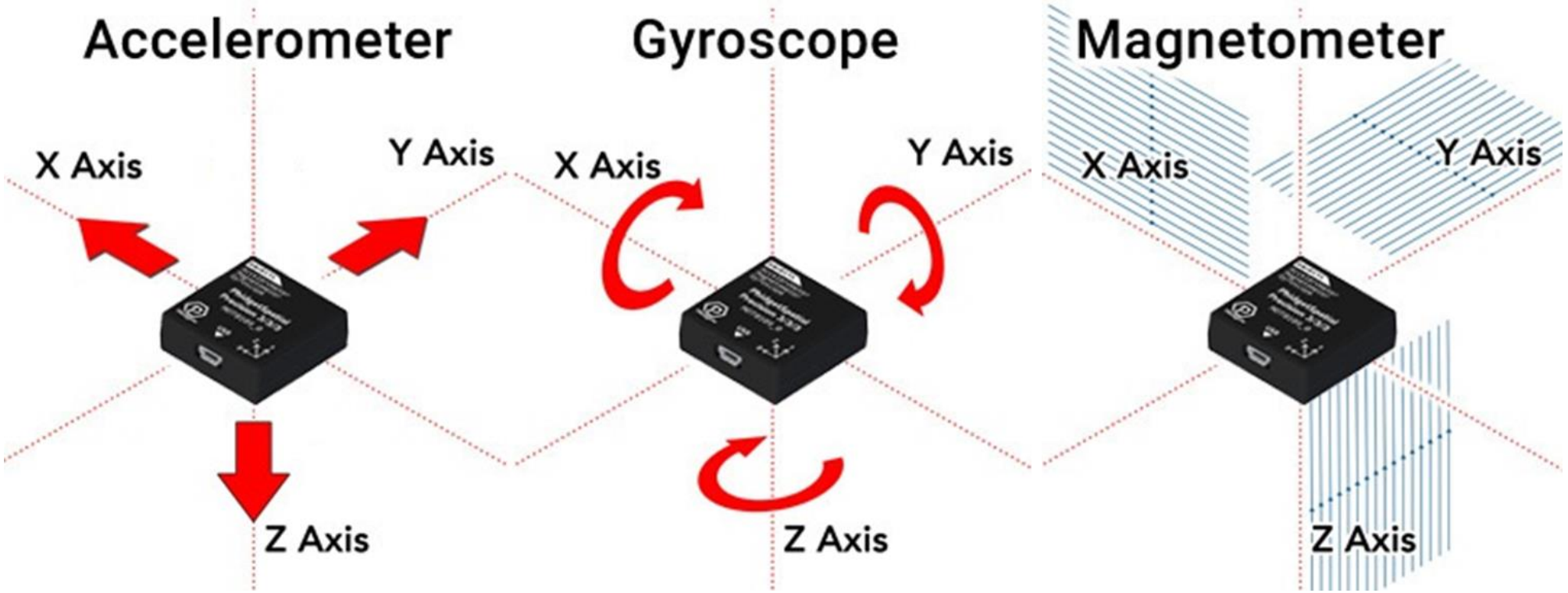




IMU (INERTIAL MEASUREMENT UNIT)

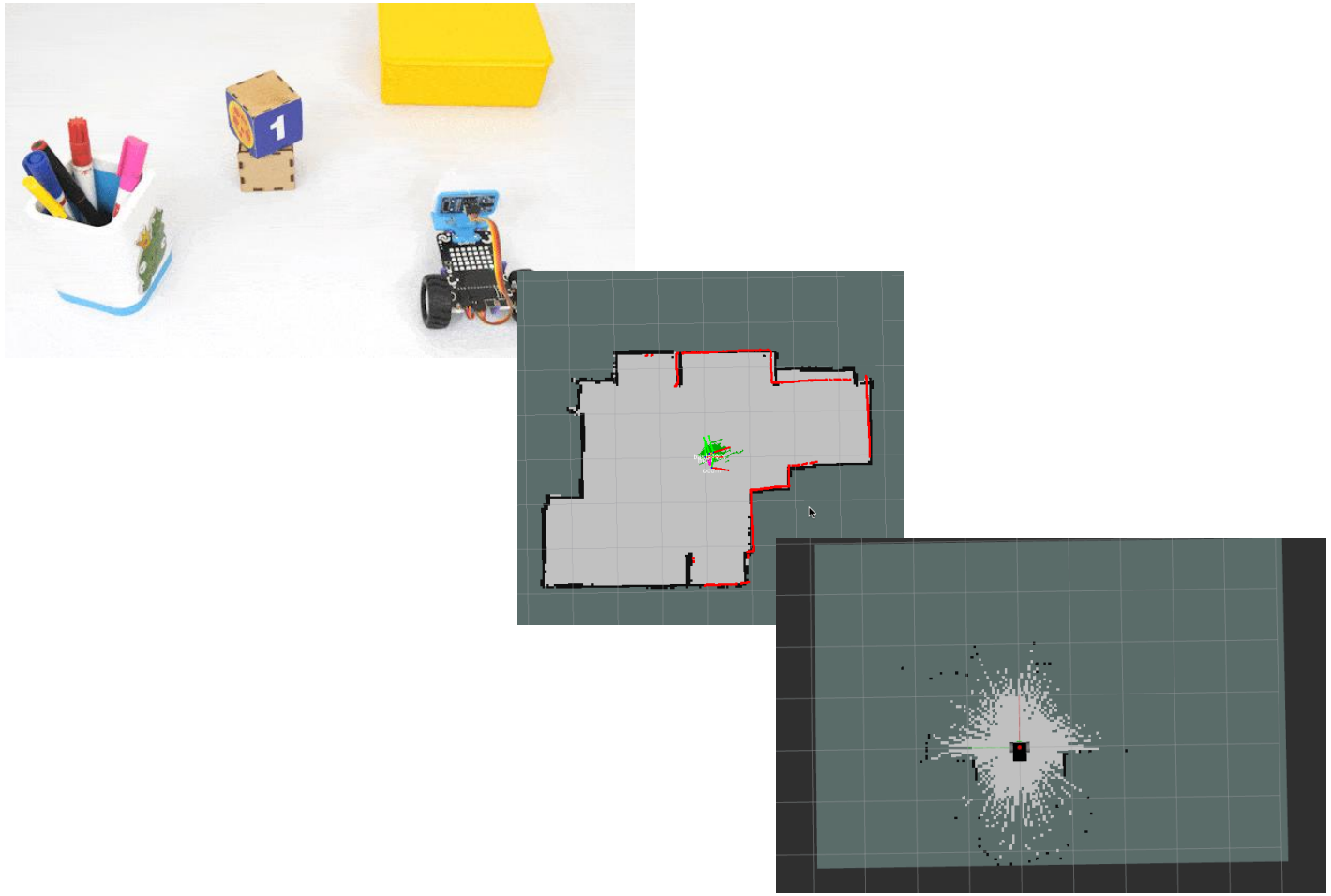


- **Inertial measurement unit** (IMU) combines **3 accelerometers**, **3 gyroscopes** and **3 magnetometers**.



APPLICATIONS

- Obstacle Avoidance
- Robot Localization
- Environment Mapping



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