Exploring Robotics – Unit C

Sensors

Review – Locomotion and Degrees of Freedom

Locomotion and Manipulations

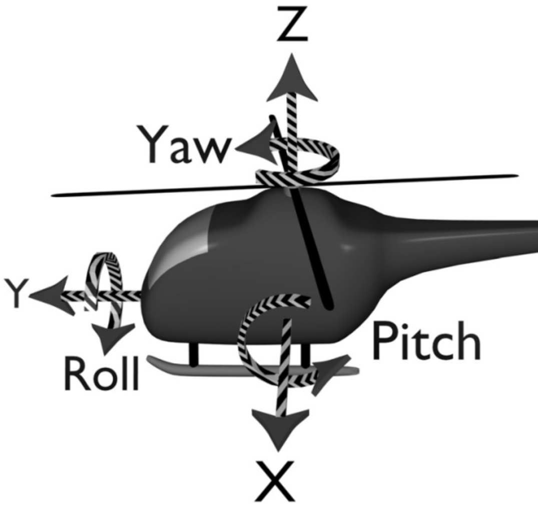
- Choice of effectors and actuators sets the limits on what the robot can do
- Usually categorized as locomotion or manipulation
  - Locomotion: vehicle moving itself
  - Manipulation: An arm moving things
- In both cases can consider the *degrees of freedom* in the design

Degrees of freedom (D.O.F.)

- Definition: How many independent factors needed to specify the motion of the system?
  - The specific number of axes that a rigid body is able to freely move in three-dimensional space
  - For robots: directions of independent motions

Degrees of freedom (D.O.F.)

- For an object in space have:
  - The body can move straight in three dimensions:
    - Without rotation
    - on the ***X, Y*** and ***Z*** axes
    - A.K.A. Translational degrees of freedom
  - Also, it can change orientation between those axes though rotation
    - usually called ***pitch, yaw and roll***
    - ***Rotational degrees of freedom***
  - Total of 6 degrees of freedom

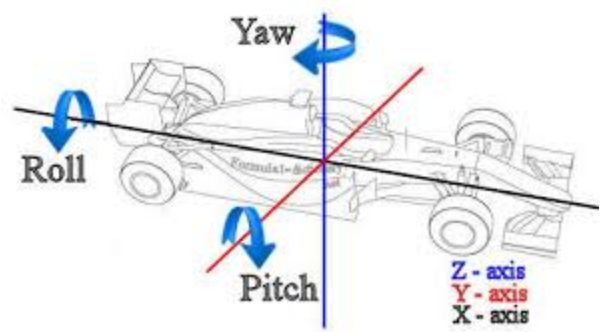


Controllable D.O.F.'s

- If the object can move in each direction of the D.O.F., it is Holonomic
  - All are controllable
- For this, it needs to have an actuator in each direction

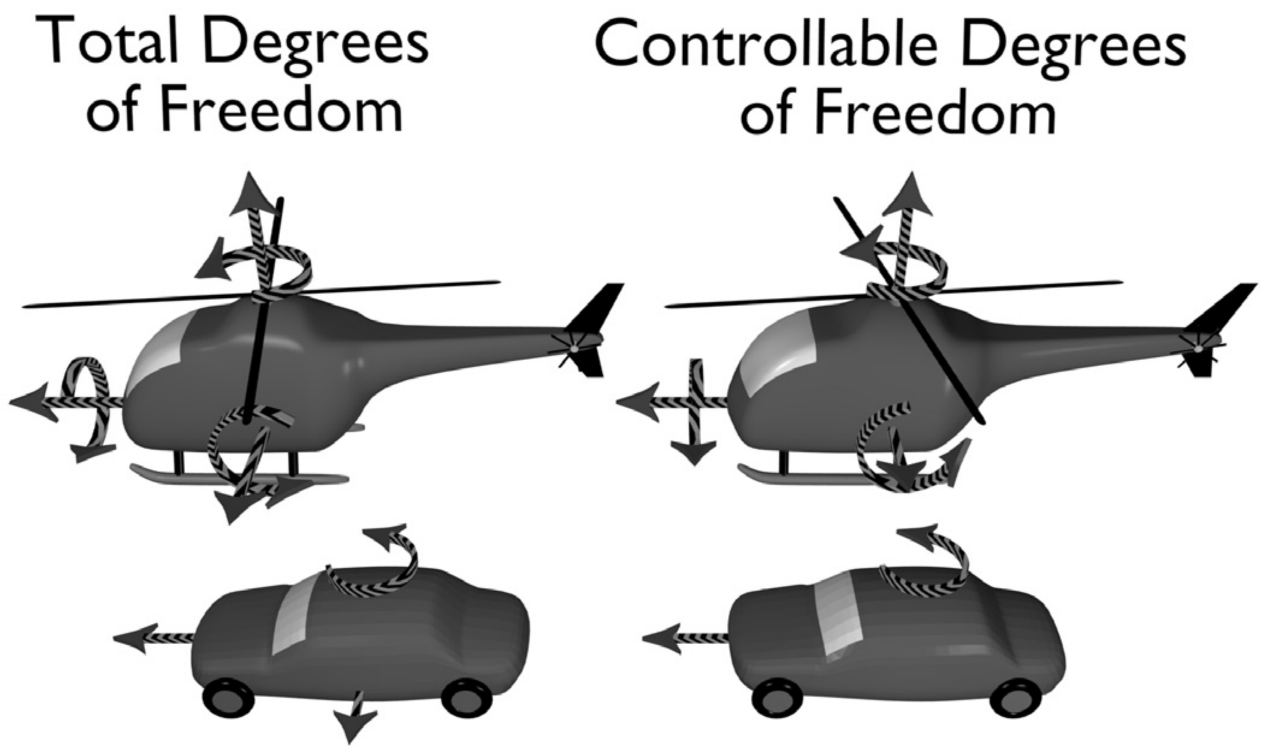
Degrees of freedom (D.O.F.)

- How many D.O.F. to specify movement of a vehicle on a flat surface?
  - Three: X,Y and yaw (turn in x-y dimension)
- How many Controllable D.O.F.'s?
  - In which direction can driver drive the car?
  - X and yaw

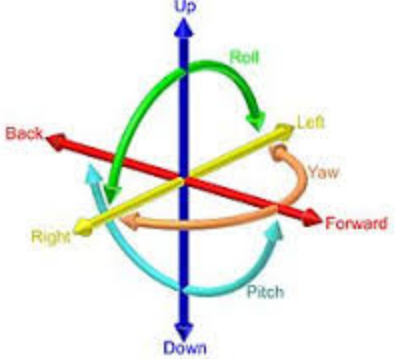


http://www.f6tech.com/our-solution/, http://www.formula1-dictionary.net/motions_of_f1_car.html

Degrees of freedom (D.O.F.)



Robot's Variables Affecting D.O.F.

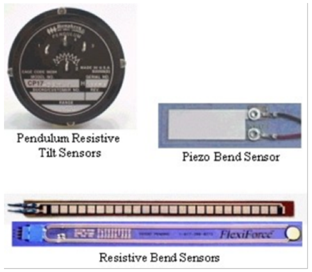


- Number of joints/articulations/moving parts
  - If parts are linked, fewer parameters needed to specify them.
- Number of Individually controlled moving part
  - Need parameters for each to define configuration
  - Often described as 'controllable degrees of freedom'
  - But some may be *redundent*
    - Two movements may be in the same axis

Sensors

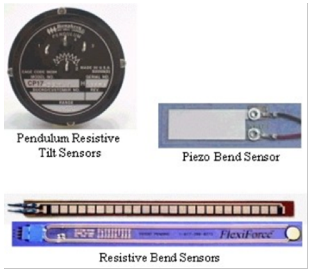
Accelerometer
Gyro
Pendulum Resistive Tilt Sensors
Piezo Bend Sensor
Metal Detector
Digital Infrared Ranging
CDS Cell Resistive Light Sensor
FlexiForce
Resistive Bend Sensors
UV Detector
Limit Switch
Mechanical Tilt Sensors
Touch Switch
Pressure Switch
IR Pin Diode
Side view of Lens
IR Sensor w/lens
Thyristor
Magnetic Sensor
IR Reflection Sensor
IR Amplifier Sensor
IRDA Transceiver
Magnetic Reed Switch
Hall Effect Magnetic Field Sensors

Sensors are for Perception



- Sensors are physical devices that measure physical quantities.
  - Such as light, temperature, pressure
- Perceptual system of a robot includes:
  - Proprioception (internal) system
  - Exteroception (external) system
- Sensors produce uncertainty challenge
  - Sensor noise and errors are inherent in physical measurement

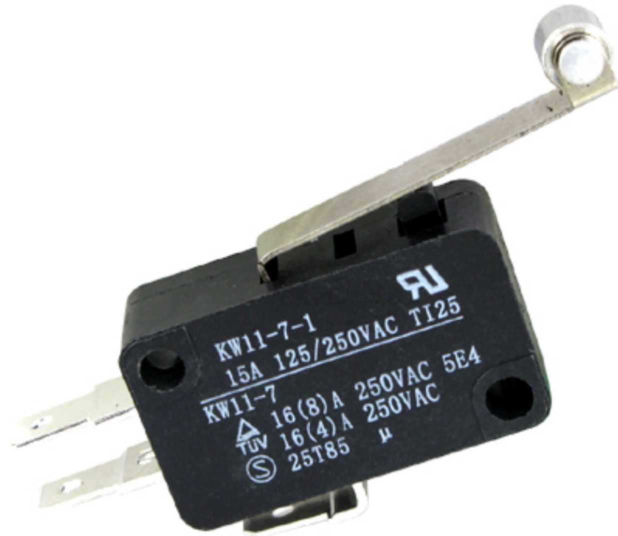
Sensors are for Perception



- Issues with Sensors:
  - Sensors produce signals, not symbols.
- May be continuous or multi-dimensional
- Signal-to-symbol problem:
  - How to form an intelligent response from sensor input when system requires a symbolic input form.
    - Such as a camera waiting for a person to smile (symbol) before taking a photo (response).
- Sensor Fusion: Combining multiple sensors to get better information about the world.

Switches

- Switches measure **current** to detect an open or closed circuit.



Levels of Processing

- **Electronics** (low level): such as measuring voltages
- **Signal processing** (medium level): such as separating voice from noise
- **Computation** (high level): such as recognizing an object from an image

Levels of Processing

- Examples:
  - Bump Sensors (low)
  - Odometer (low)
  - Sonar (medium)
  - Speech (medium)
  - Vision (high)

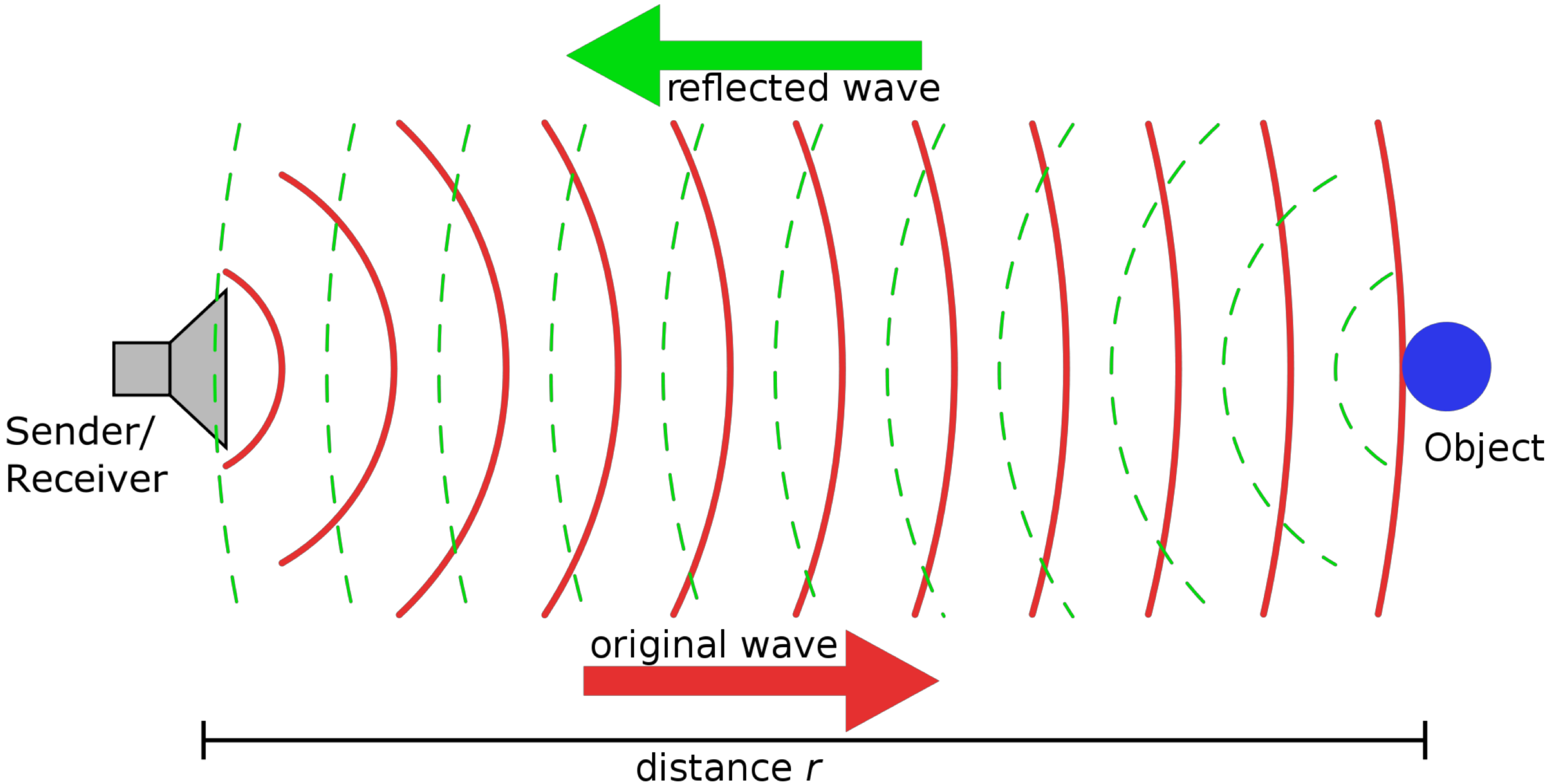
Levels of Processing

- Given the sensor input:
  - Both simple and complex sensors can be used to answer the question:
    What should a robot do? (*action in the world*)
  - Complex sensors can also be used to answer the question:
    What was the world like? (*reconstruction of the world)*

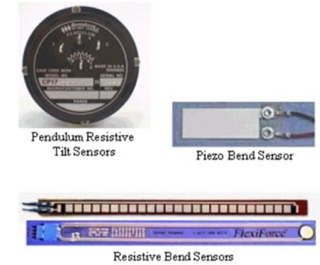
Locating People

- What kind of sensor would you use to locate people in a room?
  - **Camera:** most obvious,
    - but the most complex to process the signal.
  - **Temperature**: locate objects within human body temperature.
  - **Motion Detector:** locate objects moving that are a certain size.
  - **Color Detector**: locate objects of skin color, or human clothes.
  - **Distance**: locate objects that block a previously open area
- The sensors will need to be **calibrated** before use in the robot.

Finding Distance using Sonar



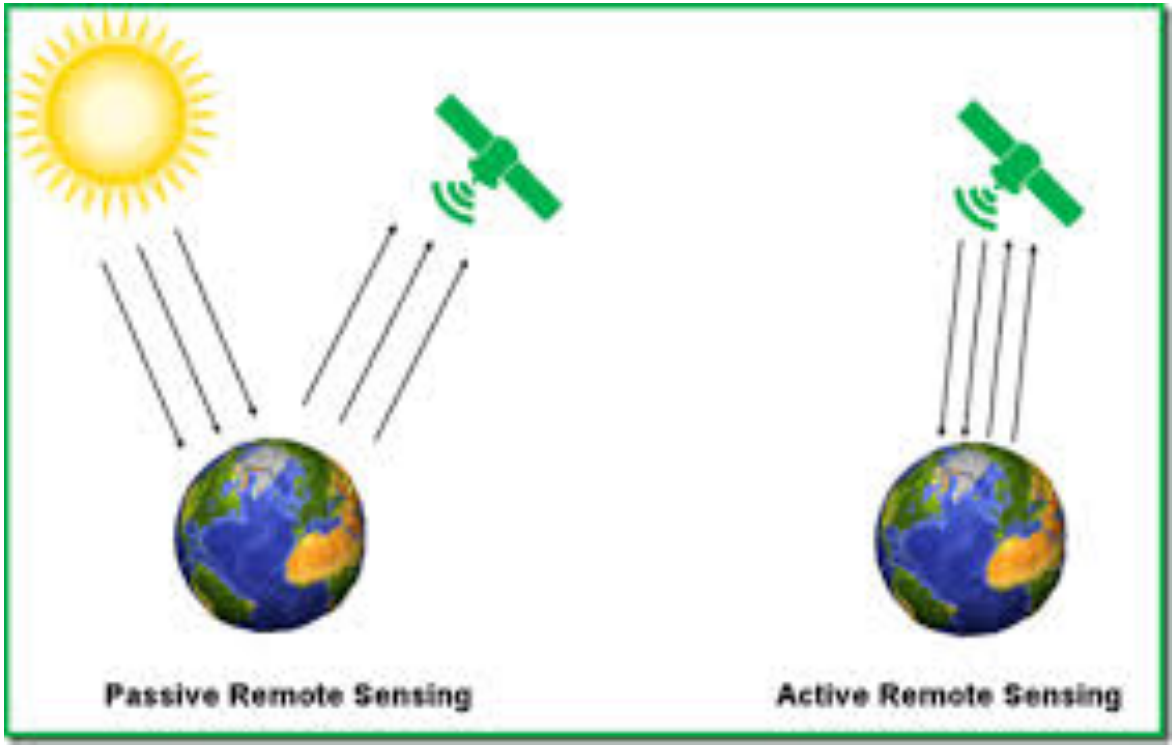
Sensor Types



- **Simple Sensors:** sensors that *don't* require a lot of processing.
- **Passive** vs. **Active** (both simple or complex):
  – **Passive**: measures a physical property only, with a detector
  Ex: switches, resistive light sensors, cameras
  – **Active**: provides own signal/stimulus, with both an emitter and a detector
  Ex: reflectance and break beam, ultrasound and laser.

Passive vs. Active Sensors

- Global satellite system

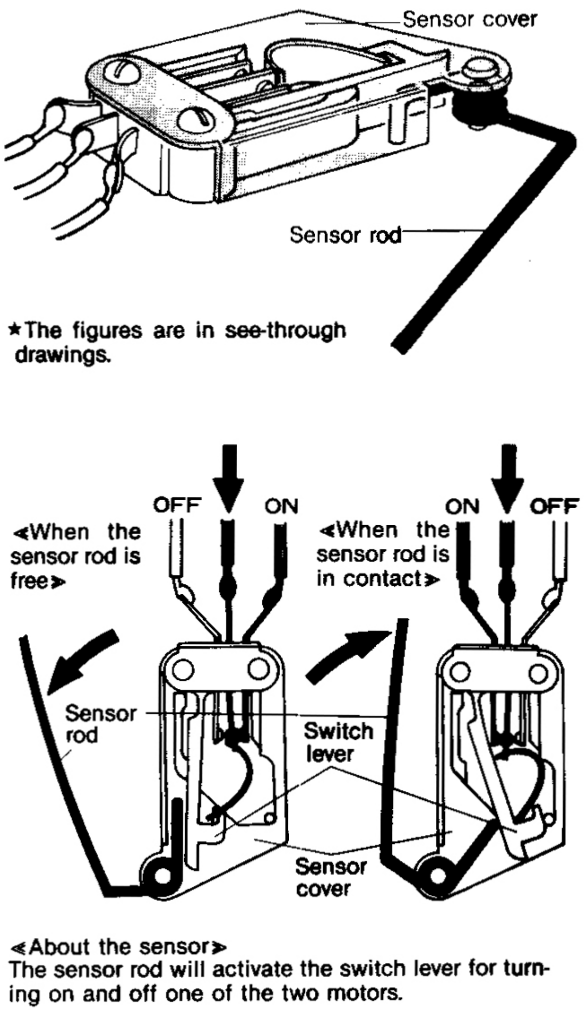


http://grindgis.com/remote-sensing/active-and-passive-remote-sensing

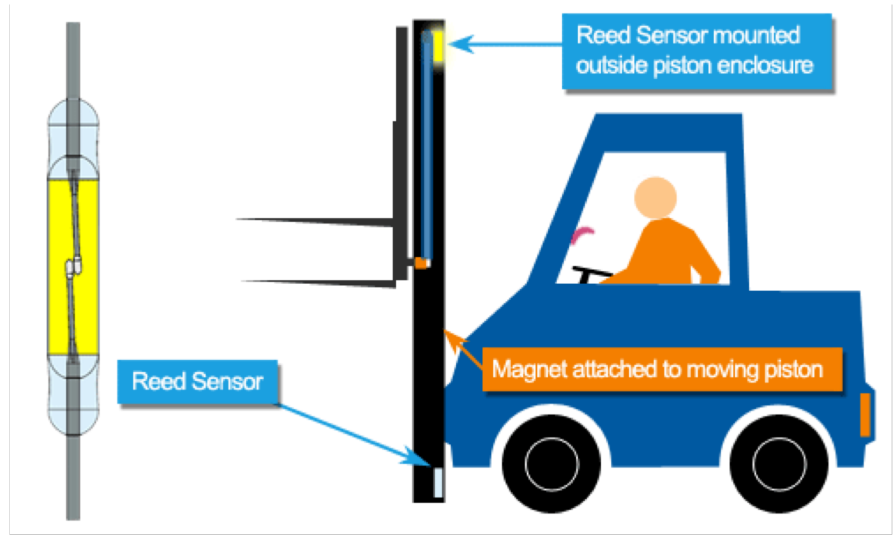
Global satellite system

- Sun constantly emits light energy and is only source of natural light for earth
  - earth’s surface produce natural emissions
- Passive sensors measure this energy or power
    - as a function of physical temperature, roughness and other physical characteristics related to earth
- Active sensors throw their own energy source towards earth
  - Energy reflected from earth’s surface
  - Measured by active sensors

Sensor Types (cont.)



Contact Sensor



Limit sensor

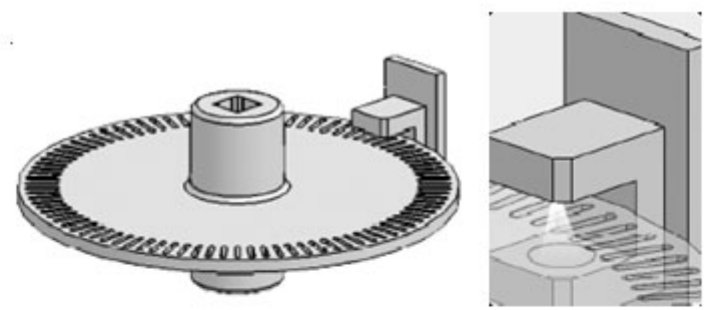


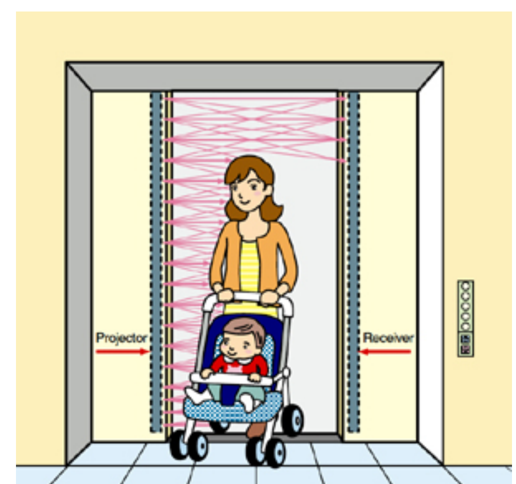
Figure 2. Optical shaft encoder disk

Shaft encoder sensor

Light Sensors

- **Photocells** convert light intensity to resistance in the circuit
  - Work even with invisible light (such as infrared)
  - Could be used for measuring intensity, differential intensity or break in continuity
- **Reflectance** sensors: active sensors with emitter and detector ***side by side***

- **Break beam sensors**: emitter and detector **face each other**



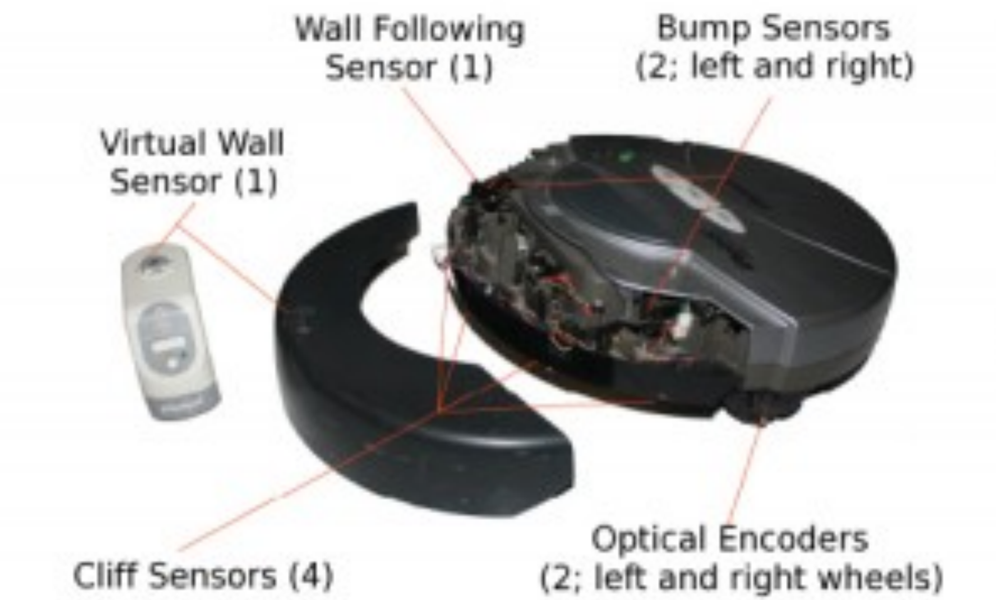
- **Calibration** is used to *reduce noise*

iRobot ROOMBA

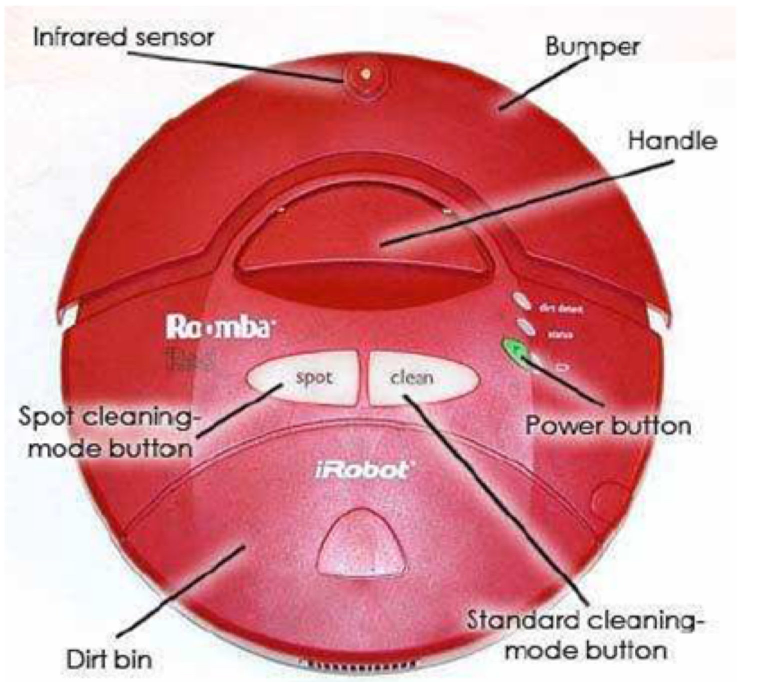
- The Roomba vacuums your floors and rugs at the press of a button, helping to maintain a cleaner home.
  - Self-navigation around corners and doors.
    - Combines input from smart sensors
    - Requires minimal human input
    - System Includes virtual wall units
      - Sends infra-red signals that cause robot to turn

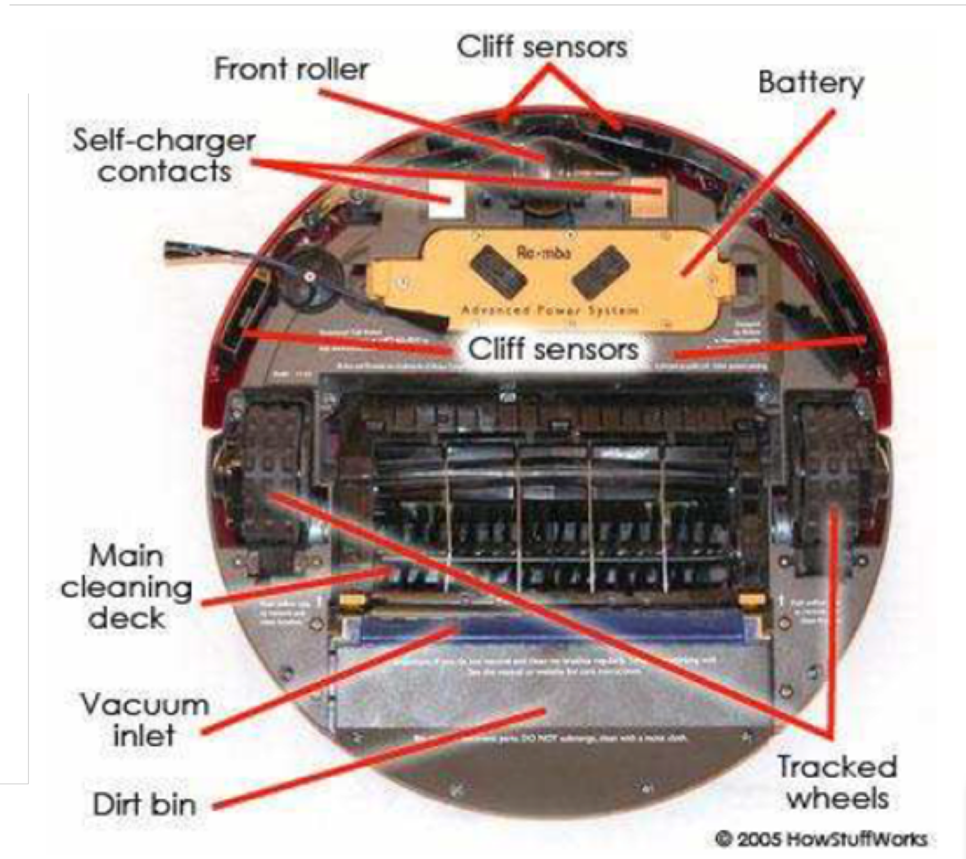
How Roomba works

- The Roomba (sage) contains 10 sensors



Top and bottom views





Roomba Sensors

- The Roomba avoid steps by using **cliff sensors.**
  - Constantly send out infrared signals
    - Normally immediately bounce back
    - If approaching a cliff, the signals all of a sudden get lost.
- **Wall sensor** is located on the right side of the bumper
  - Lets Roomba follow very closely along walls and furniture without touching them.
- **Object sensors** activated when Roomba touches an obstacle
  - It then performs the sequential actions of backing up, rotating and moving forward until it finds a clear path

Roomba Sensors

- A **piezoelectric sensor** used to detect dirt
  - Crystal that generates electrical impulses when touched
  - causing the robot to retrace its steps, clean a little slower and more thoroughly second time around
- Newer versions use **infrared cameras** to create a \`picture' of the room
  - Result in efficient, less random cleaning paths

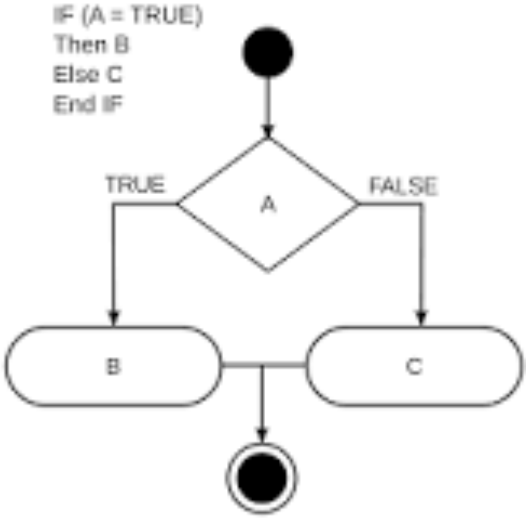
Decision Making

- Sensory inputs will make the robot a little more intelligent
  - such as the value of the light sensor,
- We need a **decision-making** mechanism
  - To enable robots to react to their environment **autonomously** (without a human touching it).
- How can we do that?
  - Conditional Execution

https://www.changedlivesnewjourneys.com/decision-making-after-brain-injury/

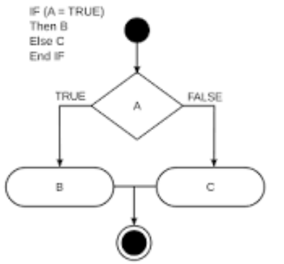
Conditional Execution

- **Conditional execution** used in decision-making
  - in the programming environment.
  - Widely used in programming languages
  - Common example: **If–then(–else)**



https://en.wikipedia.org/wiki/Conditional_(computer_programming)

Conditional Execution



- Basic structure of **if-then else construct**:

  If (boolean condition) Then

      (consequent)

  Else

      (alternative)

  End If

Conditional Execution

- In MindStorms, implemented by **Conditional Constructs (if-then-else)**
  - allows programs to behave differently based on different values of sensor inputs.

NXT Touch Sensor

The NXT Touch sensor's configuration panel is shown in Figure 9-1.

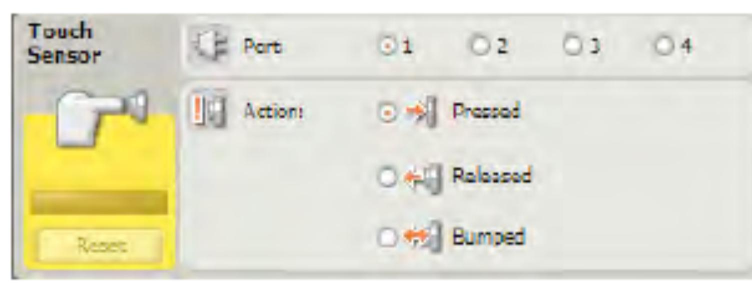


Figure 9-1. The NXT Touch sensor's configuration panel

Lab Time!

- Let’s work with the robot!