

# EXPLORE ROBOTICS – CISC 1003

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# EXPLORING ROBOTICS

## – UNIT C

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Sensors

# REVIEW – LOCOMOTION AND DEGREES OF FREEDOM

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# Locomotion and Manipulations

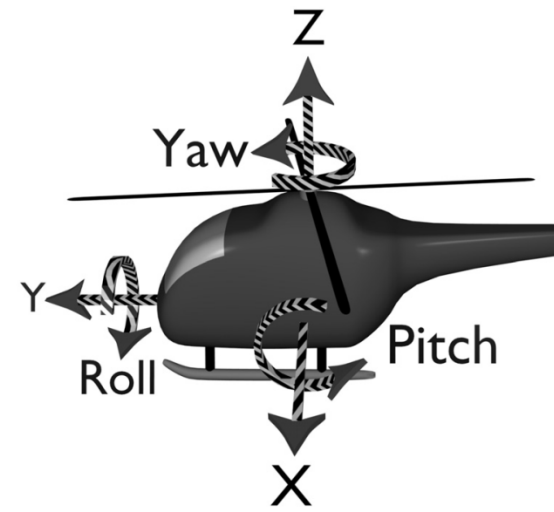
- Choice of effectors and actuators sets the limits on what the robot can do
- Usually categorized as locomotion or manipulation
  - Locomotion: vehicle moving itself
  - Manipulation: An arm moving things
- In both cases can consider the *degrees of freedom* in the design

# 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

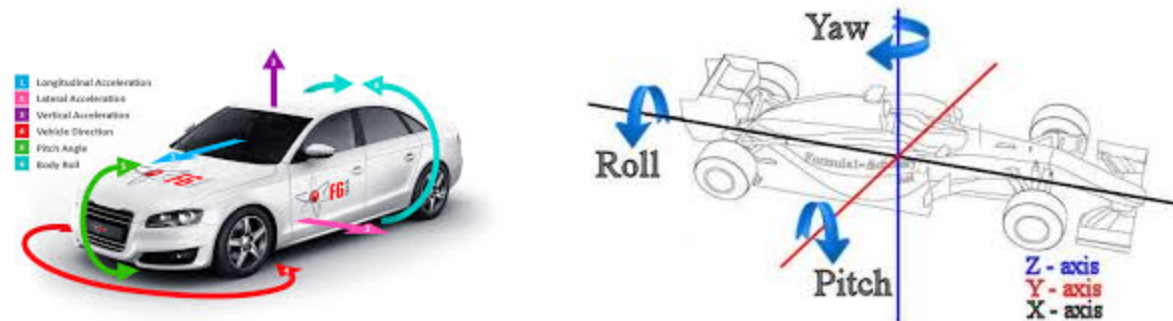


# Controllable D.O.F.'s

- 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.)

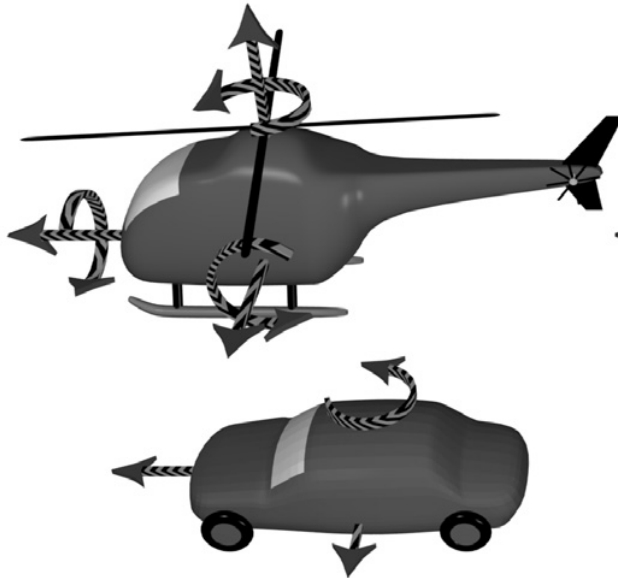
- How many D.O.F. to specify movement of a vehicle on a flat surface?
  - Three: X,Y and yaw (turn in x-y dimension)
- How many Controllable D.O.F.'s?
  - In which direction can driver drive the car?
  - X and yaw



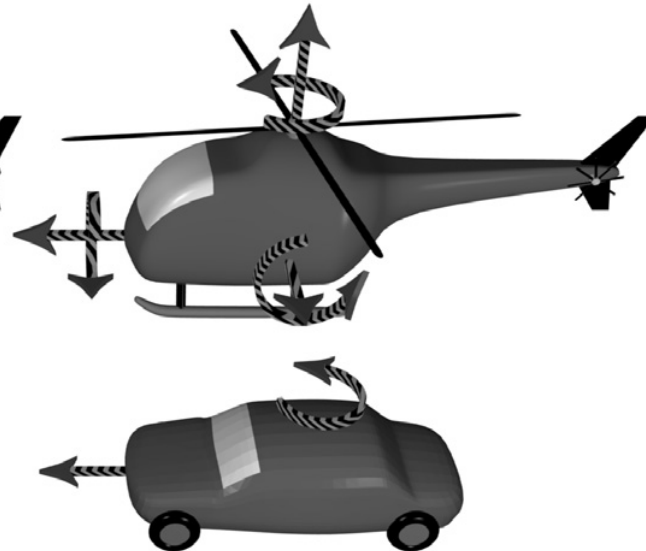


# Degrees of freedom (D.O.F.)

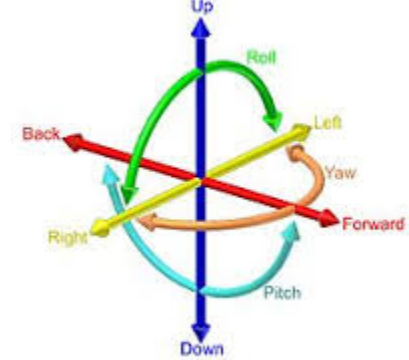
Total Degrees  
of Freedom



Controllable Degrees  
of Freedom



# 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 *redundant*
    - Two movements may be in the same axis

# Sensors



Accelerometer



Gyro



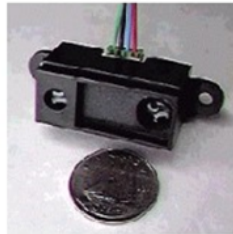
Pendulum Resistive Tilt Sensors



Piezo Bend Sensor



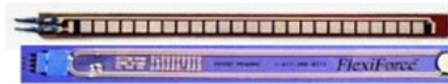
Metal Detector



Digital Infrared Ranging



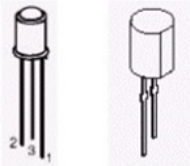
CDS Cell Resistive Light Sensor



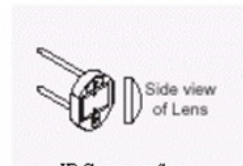
Resistive Bend Sensors



UV Detector



IR Pin Diode



IR Sensor w/lens



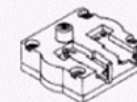
Limit Switch



Mechanical Tilt Sensors



Touch Switch



Pressure Switch



IR Reflection Sensor



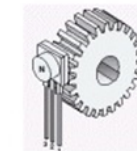
IR Amplifier Sensor



Thyristor



Magnetic Sensor



Hall Effect Magnetic Field Sensors



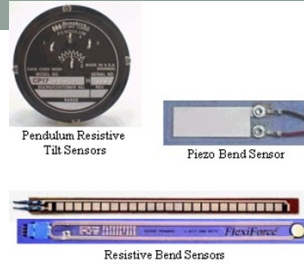
IRDA Transceiver



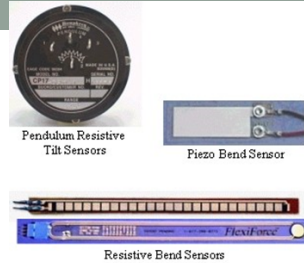
Magnetic Reed Switch

# 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



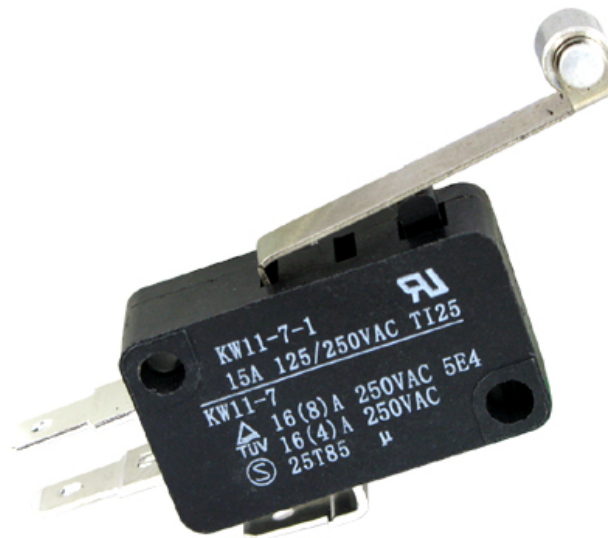
# Sensors are for Perception



- 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)



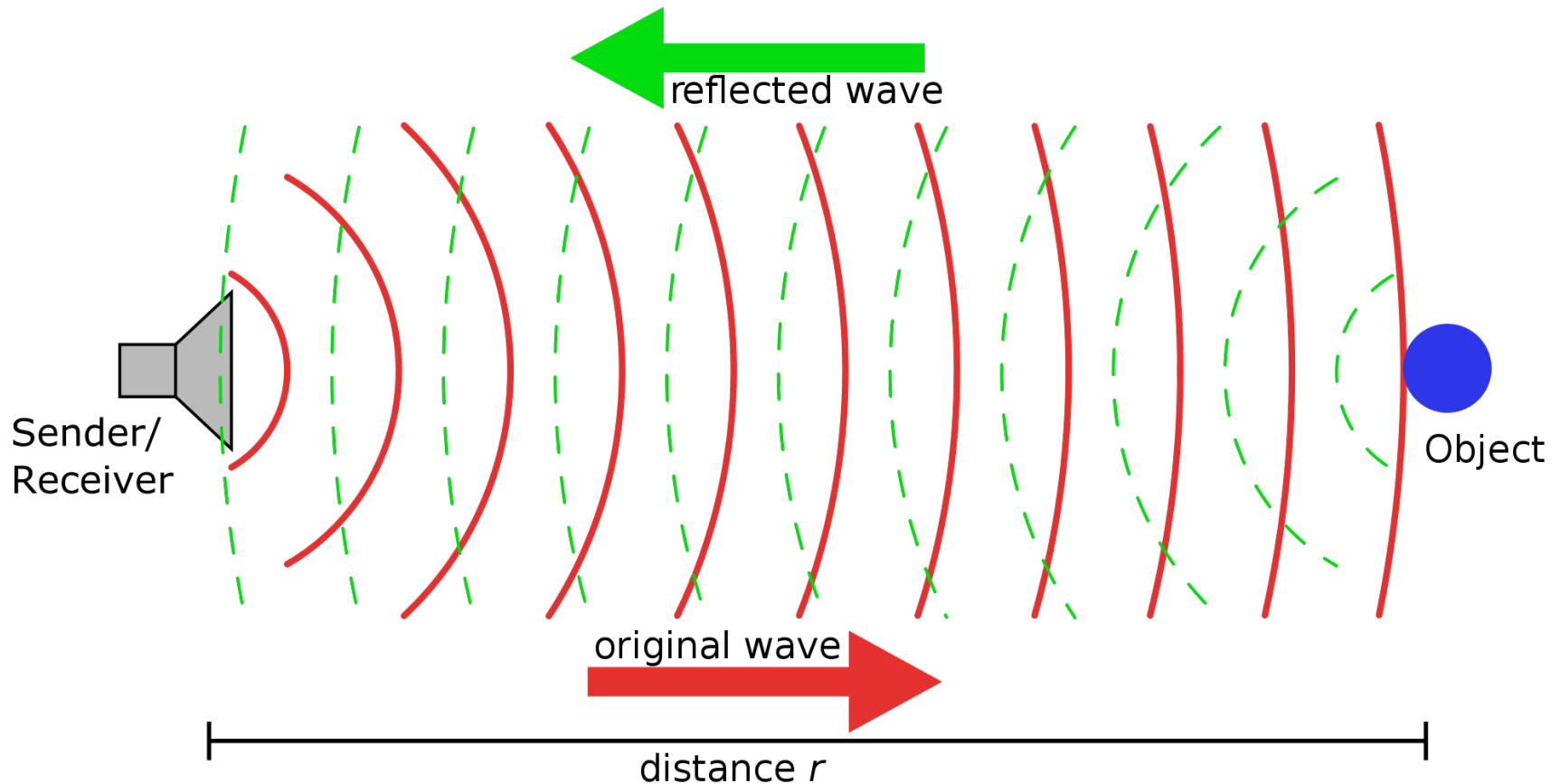
# Levels of Processing

- 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*)**

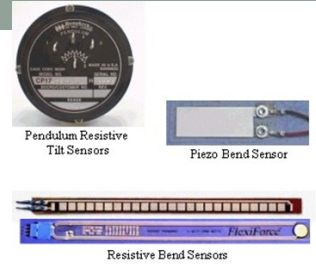
# Locating People

- 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



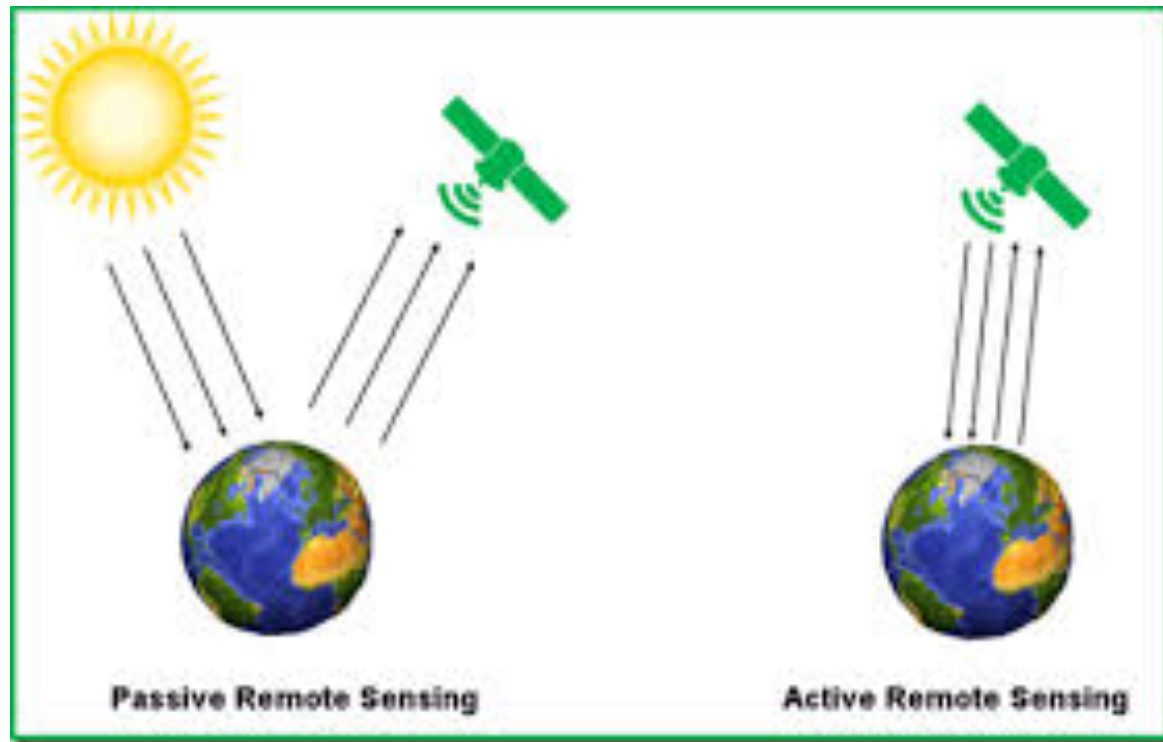
# Sensor Types



- **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

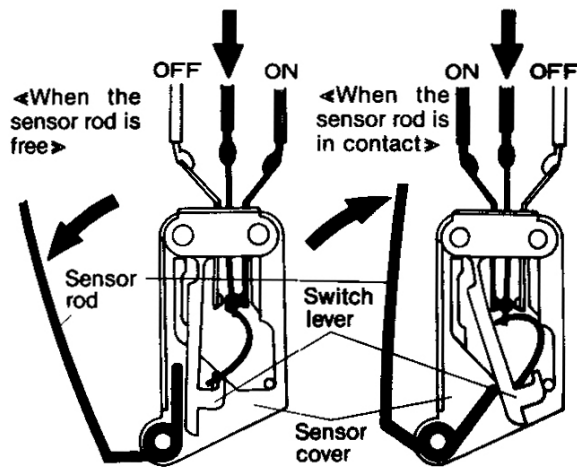
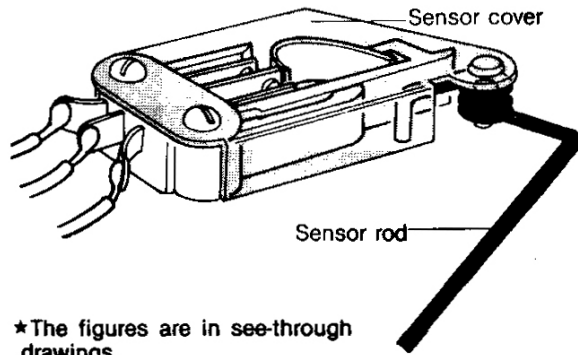
- Global satellite system



# Global satellite system

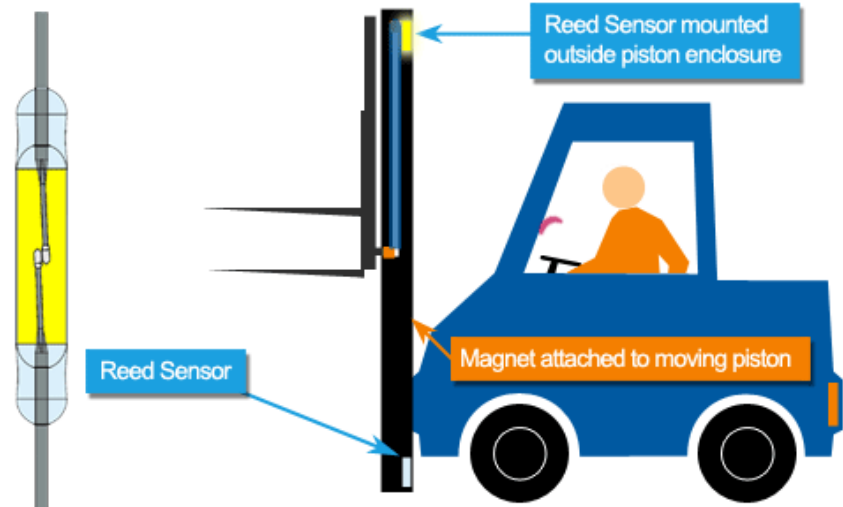
- Sun constantly emits light energy and is only source of natural light for earth
  - earth's surface produce natural emissions
- Passive sensors measure this energy or power
  - as a function of physical temperature, roughness and other physical characteristics related to earth
- Active sensors throw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

# Sensor Types (cont.)



«About the sensor»  
The sensor rod will activate the switch lever for turning on and off one of the two motors.

**Contact Sensor**



**Limit sensor**

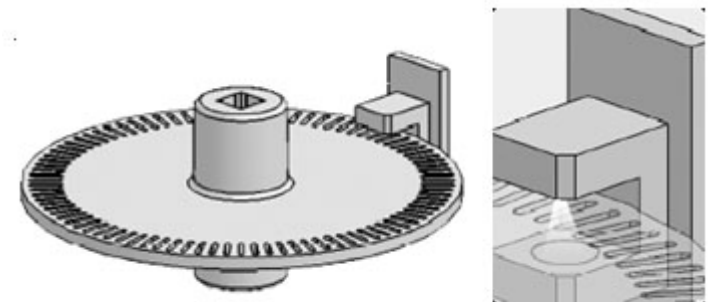
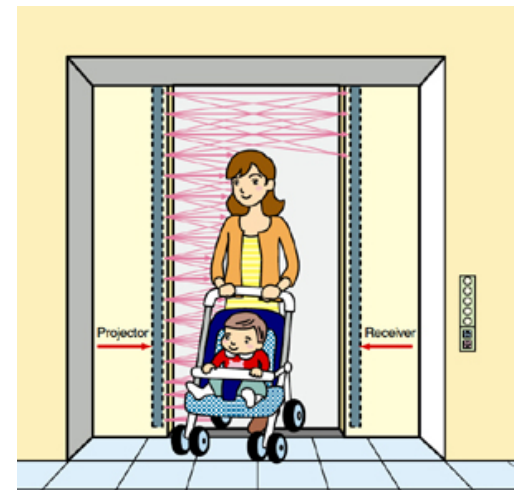


Figure 2. Optical shaft encoder disk

**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*





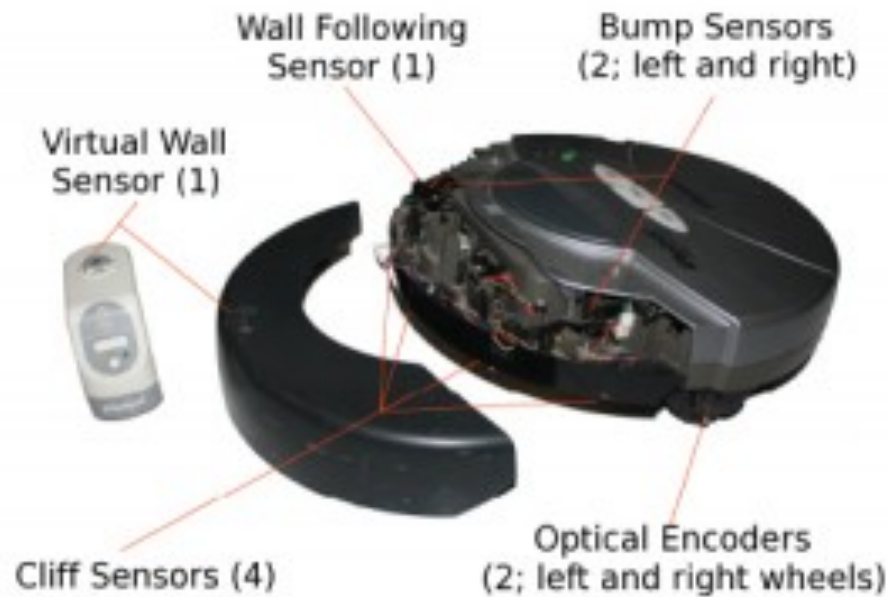
# iRobot ROOMBA

- 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

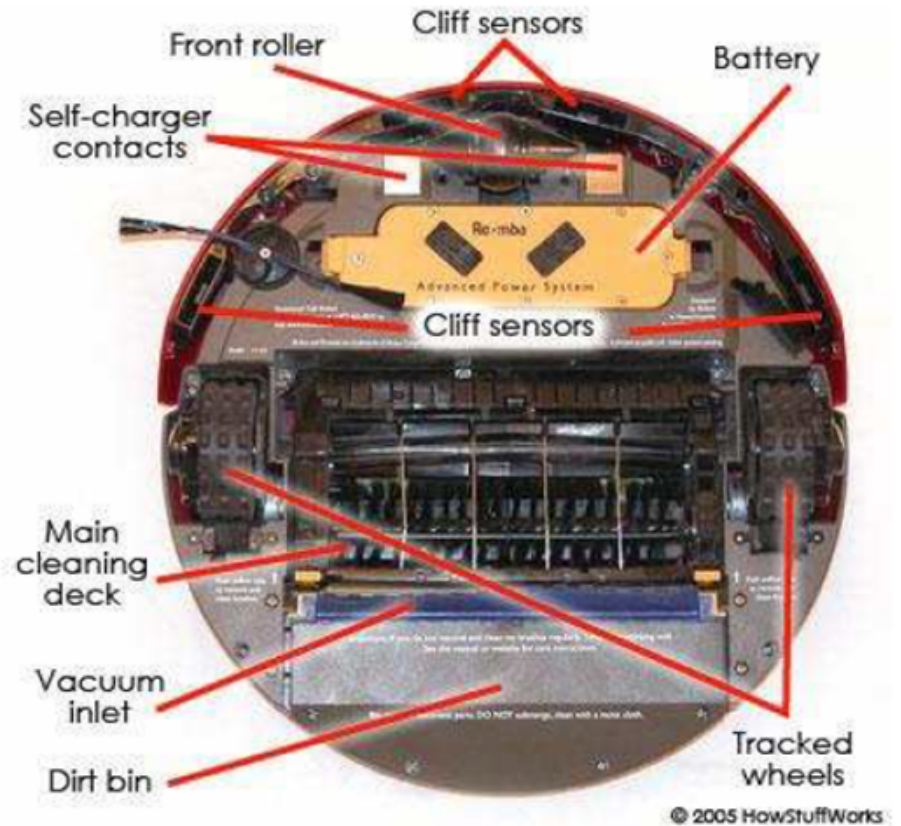
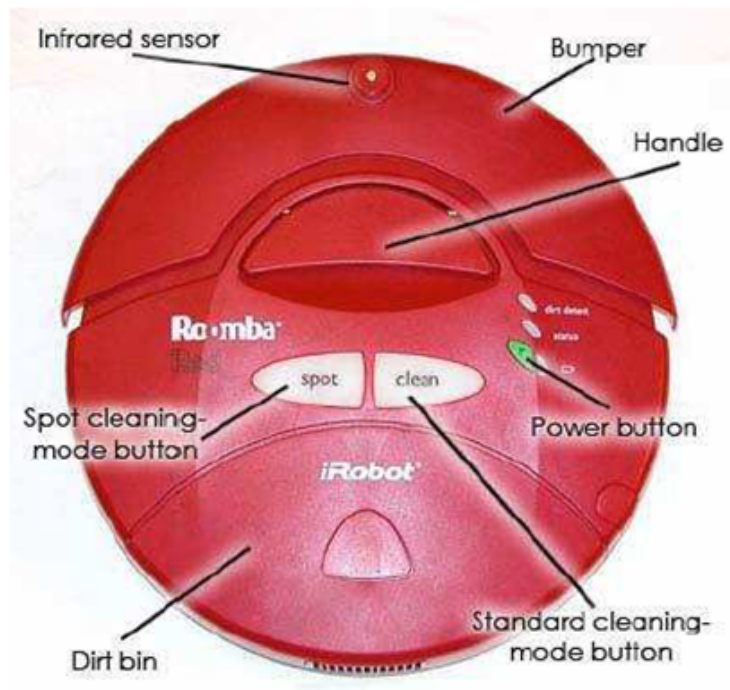


# How Roomba works

- 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

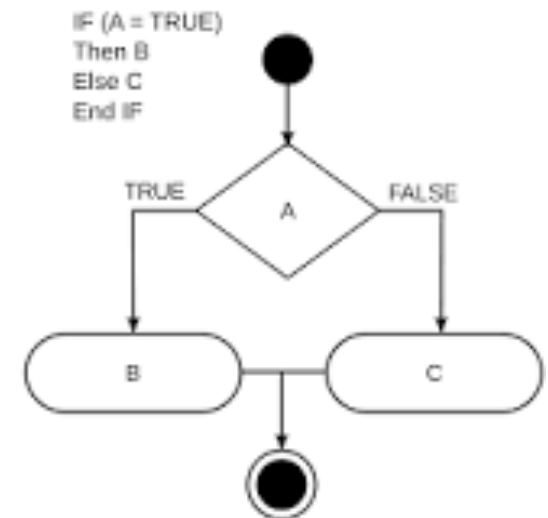
# Decision Making



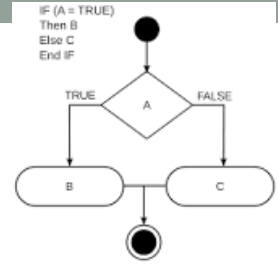
- Sensory inputs will make the robot a little more intelligent
  - such as the value of the light sensor,
- We need a **decision-making** mechanism
  - To enable robots to react to their environment **autonomously** (without a human touching it).
- How can we do that?
  - Conditional Execution

# Conditional Execution

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



# 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.

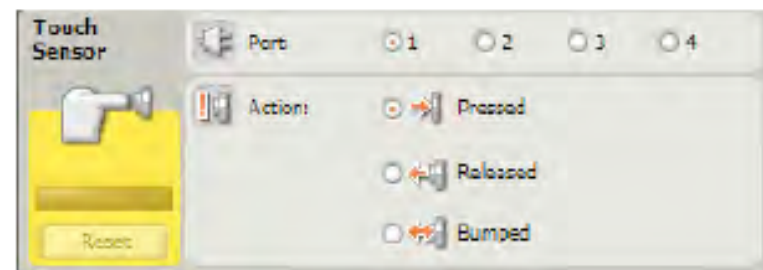


Figure 9-1. The NXT Touch sensor's configuration panel

# LAB

- Let's start working with robots!

