

# Exploring Robotics

## Unit D Sensing and Decision Making



## Sensors

- Convert a physical property into an electronic or digital signal
  - Ex. Touch sensor (switch – close/open – electric current)
- Two types of sensors
  - Exteroceptive: obtain external information around the robot (e.g. light levels, sound)
  - Proprioceptive: monitor the robot's internal state (e.g. wheel positions, joint angles of arms)
- Sensors provide signals, not symbols, which typically need to be processed to be useful to the robots

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## Different Types of Sensors

Property being Sensed	Type of Sensor
contact	bump, switch
distance	ultrasound, radar, infra red (IR)
light level	photo cell, camera
sound level	microphone
smell	chemical
temperature	thermal
inclination	gyroscope
rotation	encoder
pressure	pressure gauge
altitude	altimeter

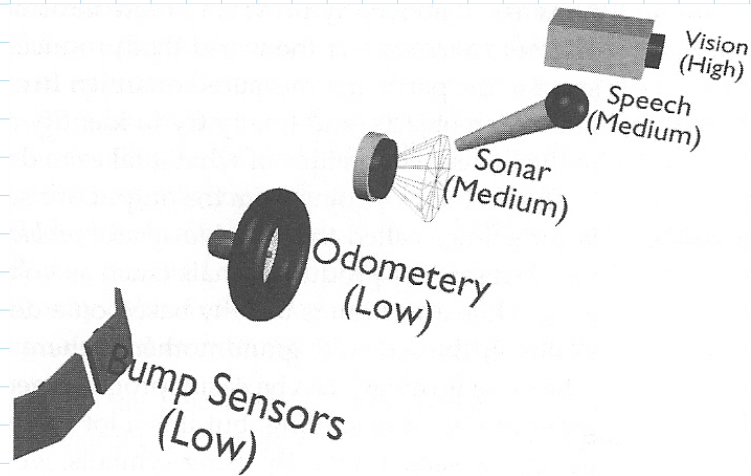
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## Simple and Complex Sensors

- Sensory information can be used to answer two questions
  1. Given that sensory reading, what should robot do?
  2. Given that sensory reading, what was the world like when the reading was taken?
- Simple sensors can be used to answer the first question (e.g. a touch sensor to detect bumping into obstacles) and no or very little processing is needed
- Complex sensors are used to answer the second question (such as a camera) and a great deal of processing is required to extract the information the robot needs

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## Sensors of Different Levels

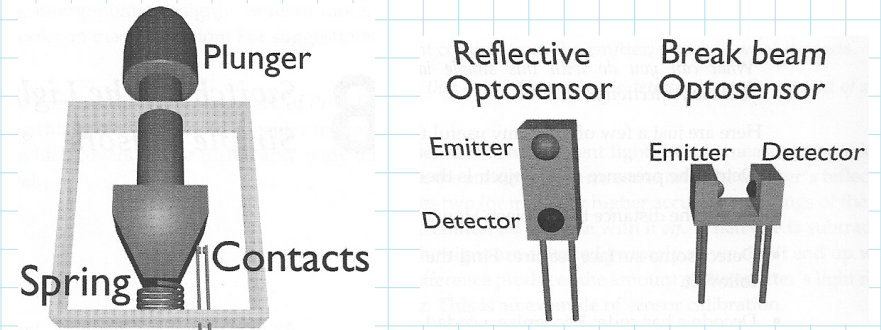


Levels of sensory processing

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## Simple Sensors

- Touch/contact sensor: simple-passive; open vs. closed circuit
- Light sensor: simple-active; emitter (LED) & detector (photodiode/phototransistor)



D-6

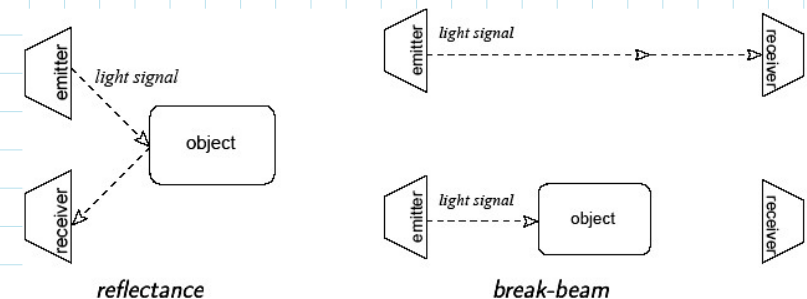
## Complex Sensors

- Ultrasonic or sonar sensing
  - Uses *echolocation* process to find the location
  - Calculation of distance is based on *time-of-flight* principle
  - Ex: bats, dolphins, submarines, sonogram
- Laser sensing
  - Higher resolution and much more accurate
  - Larger and more expensive, not suitable for small robots
- Visual sensing
  - Requires complex processing of the light pattern information provided by cameras

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## Operation Modes of Sensors

- Operation modes:
  - Passive: senses the environment without active probing; consists of only a detector
  - Active: actively probes the environment; provides signal/stimulus; consists of an emitter and a detector



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## Noise of Sensors

- Noise can cause sensors to function improperly
  - Internal noise / external noise
- Calibration (a software process to check, adjust, or determine by comparison with a standard) can help eliminate / reduce noise
- Combining multiple sensors to get better information about the world is called sensor fusion (a hardware solution)
  - E.g. Stanley has GPS, radar, stereo, video sensors and lasers

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## VEXcode VR Decision Making

- So far, our programs have been sequential. They can't choose which instruction to execute next
- We might like to program our robot to do one action (go forward) when some condition is true (eye sensor sees black) or do some other action (go backward) when the condition is not true (eye sensor sees white)
- We need a **decision-making** mechanism so that our robots can react to their environment autonomously (without a human touching it)
- Sensory inputs, such as the value of the eye sensor, will make the robot a little more intelligent

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## VEXcode VR Decision Making

- Decision making is achieved by **conditional execution** in the programming environment
- In VEXcode VR, by using **if-then** or **if-then-else** blocks, we can allow programs to behave differently based on different values of sensor inputs

1) **if-then block**

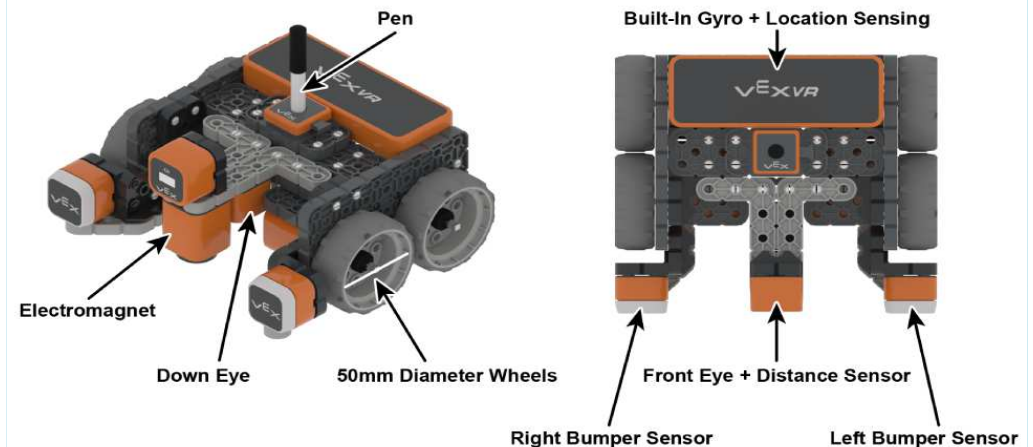


2) **if-then-else block**



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## VEXcode VR Sensors



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## VEXcode VR Eye Sensors

- The eye sensor has a transmitter and a receiver. It transmits light which bounces off objects and then returns in the direction of the receiver.
- The returned light produces a value between 0 and 100, where 100 means very bright and 0 means very dark.
- The eye sensor can tell the brightness, color and the distance of the object it is pointing at.

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## VEXcode VR Bumper Sensors

- The bumper sensor is used to avoid bumping into obstacles
- **Obstacle avoidance** means robots use bumper sensors to avoid bumping into things
- They do this by bumping into obstacles (to discover that they are there) and then backing up and/or turning around to avoid them

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## Robotic Vacuum Models

- Sensors play an important role in the function of vacuum-cleaning robots
- The vacuum-cleaning robots:
  - Can vacuum autonomously
  - Feature a set of sensors to avoid obstacles, detect dirt spots, sense the steps, etc.
  - Can be operated manually or with a remote control

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## iRobot Roomba

- A series of autonomous robotic vacuum cleaners sold by iRobot
  - models: original, 400 ~ 900, i7+, e5, and S series

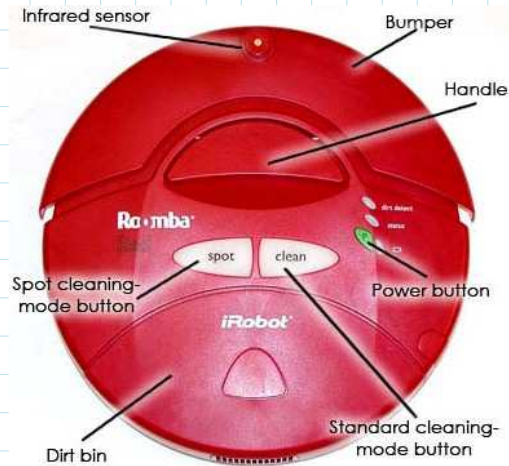


- [Watch iRobot Roomba 560 video](#)
- [Watch iRobot Roomba 980 video](#)

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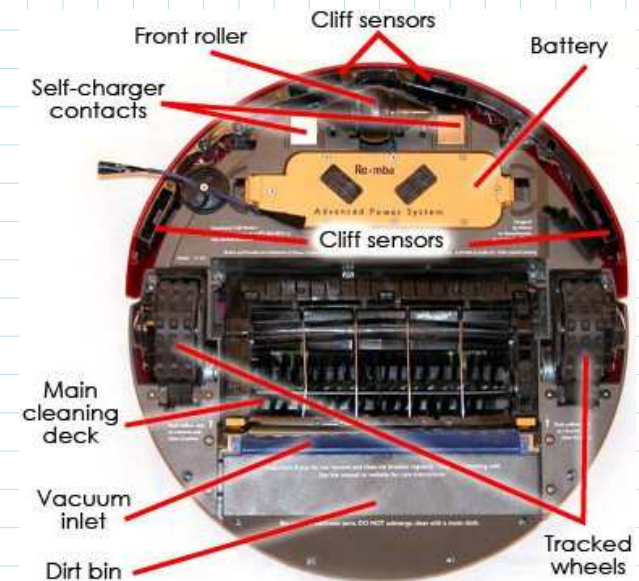
## Inside a Roomba

- The iRobot Roomba Red (410) is approximately 13 inches (33 cm) in diameter and 3.5 inches (9 cm) tall



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## Inside a Roomba



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## Motors / Actuators

- One thing Roomba can do that a human and an upright vacuum can't is to get completely under furniture. Because Roomba Red is only about 3.5 inches tall, it can easily get under most coffee tables, nightstands, beds and some couches.
- Roomba uses five motors as its actuators
  - One driving each wheel (2 total)
  - One driving the vacuum
  - One driving the spinning side brush
  - One driving the agitator assembly

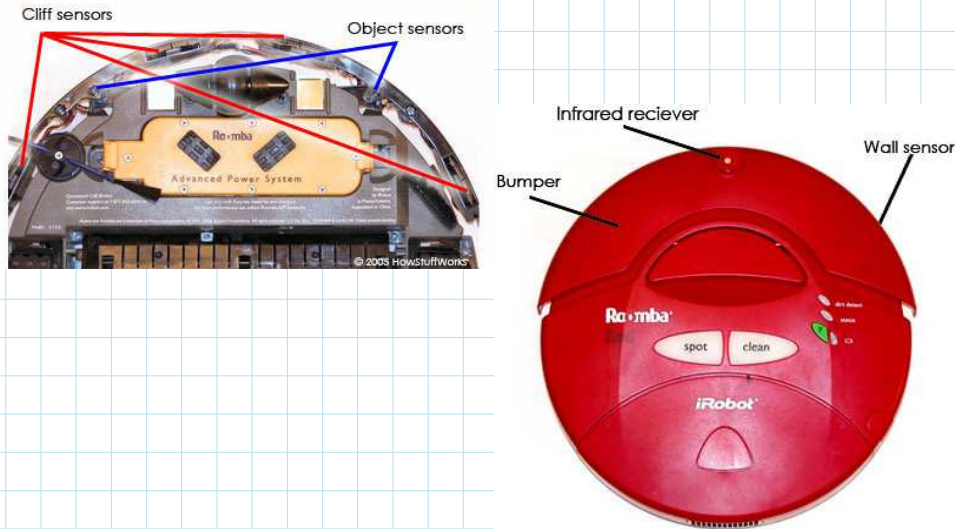
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## Sensors

- The **cliff sensors** constantly send out infrared signals, and Roomba expects them to immediately bounce back. If it's approaching a cliff (steps), the signals get lost and the Roomba knows to head the other way.
- When Roomba knocks into something, its bumper retracts, activating mechanical **object sensors** that tell Roomba it has encountered an obstacle. It then backs up, rotates, and moves forward until it finds a clear path.

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## Sensors



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## Sensors

- The **wall sensor** (infra-red sensor) is located on the right side of the bumper and lets Roomba follow very closely along walls and around objects (like furniture) without touching them. It cleans pretty close to these obstacles without bumping into them.
- The **dirt sensors** (acoustic impact sensors) are located immediately above the agitator brush and are used to figure out which areas need more cleaning. When the agitator kicks up a large amount of dirt, it causes more vibration when it hits the metal plates of the sensors. The sensors detect that increase and tell Roomba to go over the area again.

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## Sensors

- The **infrared receiver** is located on the front bumper and is used to locate the charging base. When the battery power gets low or when Roomba has finished cleaning, the vacuum starts looking for the infrared signal (infrared beep) emitted by the charging base. Once it finds it, Roomba follows the signal and docks itself to the charger.

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## Decision Making

- Roomba's onboard computer (microprocessor) runs iRobot's AWARE Robotic Intelligence software to make many decisions for itself, so minimal human input is required.
- The AWARE system uses Roomba's multiple sensors to pick up the environmental data, send it to the robot's *microprocessor* and change Roomba's actions accordingly.
- Roomba's multiple sensors allow it to navigate your home with relative autonomy.

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## Other iRobot Roomba Models

### ■ iRobotDiscovery 4210

- takes less than three hours to charge
- has a larger dust bin than previous models
- has software that calculates room size



### ■ iRobotRoomba 560

- features a forward-looking infrared sensor to detect obstacles and reduce speed
- can set cleaning cycles in advance
- two virtual walls confine Roomba to a particular room or area using infra-red signal



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## Other iRobot Roomba Models

### ■ iRobotRoomba 690

- has WiFi connectivity so it can be started with an app

### ■ iRobotRoomba 700 & 800 series

- has a more powerful cleaning system and longer battery life

### ■ iRobotRoomba 980

- features a camera which works in conjunction with onboard mapping, indoor positioning system and navigation software, to systematically cover all floor area

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## Other Robotic Vacuum Models

### ■ Kärcher RC3

- manufactured by German company Kärcher
- uses camera-laser navigation technology to create a cleaning map of the surrounding
- besides finding its way back to the charging station, it also empties its own dust bin there



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## Other Robotic Vacuum Models

### ■ Electrolux Trilobite EL520A

1. more accurate  
2. not affected by strong light  
3. more expensive

- manufactured by Swedish company Electrolux
- uses sonar (vs. infrared) to navigate and can easily avoid almost any type of obstacle
- creates a map of the room and calculates a cleaning path that will maximize coverage
- recognizes doorways by way of little magnetic strips that you apply and uses them to keep itself in the room



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# Homework Assignment

Answer the following questions, based on the lecture notes and “Maid to Order” (Coursepack, Unit D, Case Study):

1. Identify and describe what each of the six components (i.e. the controller, actuators, effectors, sensors, power source and communications) of Roomba is made of. (2 pts)
2. Compared with an upright vacuum cleaner, what are the advantages of Roomba? (1 pt)
3. What are the disadvantages? (1 pt)
4. (a) Name and describe another home-helper robot out there that was not discussed in class. You may refer to Case Study of Unit D from the Coursepack. (0.5 pt)  
(b) Describe a possible future home-helping robot not mentioned in class. (0.5 pt)