ROBOT SENSES

AT A GLANCE Students will learn that robot sensors can either mimic human sensors or do things that humans cannot. They will use their knowledge to move through an obstacle course, then design a robot to complete a specific task.

OBJECTIVES

Students will:

- Describe the difference between a sense and a sensor.
- Identify human senses and sensors.
- Explain similarities and differences between human senses and robot sensors.
- Choose robot sensors appropriate to a robot's function.
- Make predictions based on observations using tools and their own senses.

KEY VOCABULARY

Sense, Sensor, Robot, Model, Context, Electro-magnetic spectrum, Echolocation, Proprioception

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Engaging in argument from evidence

Crosscutting Concepts:

- Cause and effect
- Scale, proportion and quantity
- Systems and system models

Disciplinary Core Ideas:

- LS1: From molecules to organisms: structures and processes
- PS1: Matter and its interactions
- ETS1: Engineering design
- ETS2: Links among engineering, technology, science and society

PACE YOURSELF

- 45-60 minutes per lesson over two days

ADVANCE PREPARATION

1. Print out robot cards and sensor cards.

2. Arrange the classroom into three aisles of desks.

3. Place objects in the aisles, like chairs or boxes, to act as obstacles. You will move these obstacles throughout the activity, so choose items that are easy to move and safe to bump into. Make the aisles wide enough that students can walk through them with a hula hoop.

MATERIALS

Per class:

- Whiteboard/chalkboard/large paper to write on
- Classroom objects such as chairs, desks, boxes
- 3 blindfolds (could be scarves, eye masks, or other fabric)
- 3 hula hoops
- Printed robot cards and sensor cards
- Cymbal, horn, or other noise-making instrument (optional)
- Timer (optional)

Per student:

- Plain paper
- Pencils

WHAT YOU NEED TO KNOW

We humans are experts at using our senses. A **sense** is a way in which we perceive our surroundings. Humans have a sense of sight, sound, touch, smell, and taste. A **sensor** is a device that detects something; for example, your nose is the sensor you use in your sense of smell.

Robots are machines that can sense, plan, and act. To be a robot, a machine needs sensors. Some of these sensors mimic or enhance human abilities, and some sensors do things that humans can't perceive. Robot sensors allow them to reach beyond human capabilities in order to achieve new tasks, like exploring the surface of Mars or delivering packages across the globe in record time.

When designing and building a robot, engineers often use human and animal models to decide which sensors that robot might need. A **model** is a representation of something that can be used or applied to better understand a concept. For example, engineers designing a sound-detecting robot might use bats as an animal model for echolocation.

ROBOT SENSES

The activities in this lesson compare human sensors to robot sensors. Here is a breakdown of sensors by sense:

TYPES OF ROBOTIC SENSORS:

- Thermometer
- Camera
- Ultrasound
- Thermal Camera
- Gyroscope
- Ultrasound
- Accelerometer
- Microphone
- Pressure sensors: air, water, touch
- Chemical detection (like spectrometers and filters)
- EM wave detection (like RADAR, LIDAR, UV and IR sensors)

Sight

Robots detect vision in ways that are both like and unlike human vision. Some robots have cameras that create images similar to what we see with our eyes. Robots process these images very differently than humans; human brains give context to the images we see, while robot computers process information as objects in space. **Context** is the interrelated information about something that gives it *meaning*. A robot wouldn't know that a chair is a chair; it knows that there are rectangles and squares next to each other in space. Robots can see using sensors that detect waves in the **electromagnetic (EM) spectrum**, the electromagnetic waves that travel through space. Humans can see the part of the EM spectrum known as visible light, i.e. the colors of the rainbow. Robots can detect radio waves, ultraviolet (UV) waves, infrared (IR) waves and more—all of which are outside the range of what humans can see.

Sound

Robot sensors and ears detect EM waves. The sound waves heard with human ears can also be detected by some robot sensors, like microphones. Other robot sensors can detect waves beyond our capabilities, such as ultrasound.

A bird, a falling piano, rain on the roof and a ringing phone all have different meanings to different people. We use sounds both to tell where things are and to tell what those things are. (Fun fact: people with low vision sometimes use clicks to tell where things are around them!) The human brain makes connections between sounds we hear to let us recognize and identify our environment, which robots cannot do yet. Robots can use sound for **echolocation**, locating an object using sound. Robots still have a hard time recognizing the difference between sounds (a bird vs. a plane vs. Superman). This challenge is on the forefront of robotics research.

Touch

Humans use touch to determine features of our surroundings, like temperature, pressure and texture. Robot sensors can sense these same qualities and more. Some robots use sensors to detect objects through contact, like a Roomba. Similar to sight and sound, a robot doesn't necessarily know the content of what they detect (a chair, a slimy banana peel, or Grandma giving you a hug); it knows that there is an obstacle to be avoided or to find.

Smell and taste

Smell and taste, seemingly straightforward senses, are actually very complex and involve a lot of human memory in addition to the sensing actions of the nose and tongue. Neuroscientists are still working to figure out exactly how these complicated senses work. Robot sensors can mimic a nose or tongue by using chemical detection technologies such as spectrometers or other filters that react to certain chemicals (imagine a litmus paper, used inside a robot). These sensors can go beyond human capabilities of smell and taste, since there are some chemicals humans definitely would not want to ingest. Robots don't need to worry about getting sick!

Proprioception: A hidden sense

Proprioception is your body's awareness of where it is in space. When you stand up, your body is able to balance itself and recognize that you are standing. This sense involves multiple sensors, including touch and your body's internal balancing mechanisms. Robots have many sensors that compare to this ability. Gyroscopes and accelerometers detect movement and speed; air pressure sensors and other touch sensors allow robots to position themselves for different tasks. Robots can also detect their exact position in space using sensors like the Global Positioning System (GPS) – something we humans can only do with our smartphones, thanks to robotics!

The activities in this lesson use multiple human senses, focusing mostly on sight, sound, touch and proprioception. Have students identify these senses throughout the lesson, and encourage them to think about how their human sensors compare to those of robots.

WARM UP

1. Ask students to identify human senses and how we use them for different tasks. Define the difference between a sense and a sensor. Make student-generated lists of senses and sensors on the board.
2. Brainstorm and record a list of inventions humans use to enhance our senses (glasses, hearing aids, etc.).
3. Brainstorm with students to define a robot. Be sure to include that a robot senses, plans and acts.
4. Pass out the robot cards. Ask students to identify sensors those robots might use. Do you see a camera? Bumpers? A microphone?
5. Point to a chair in the room and ask the students, what is this? A chair. Ask how they knew it was a chair. They recognized it, they remember being told it's called a chair, they know that a chair is something they sit on etc.
6. Discuss with students that robots can detect objects, sometimes with better accuracy than we can, but they do not attach meaning to objects the way we do. A robot identifies that chair as a series of connecting shapes in space. Ask the students: What shapes make up that chair? Different-sized rectangles.
7. Pass out paper and pencils. Have students draw shapes of objects they see in the classroom. A chair is a bunch of rectangles, a crayon bin is a rectangle with cylinders in it, a water bottle is a long rectangle with a half-circle at the top, etc.

ACTIVITY

Part I:

1. Split the class into three groups.

2. Station each group at one of the three aisles. These aisles are the obstacle courses.
- Ask the class: If I told you to walk down the aisles right now, which senses would you use? Mostly sight.
- Robot sensors don't really see the way we see, so let's take that sense away.

3. Have each group choose one student to be the "robot" who will walk down the course blindfolded. Remind the class that whoever volunteers must be comfortable being blindfolded!

4. Place the blindfold over the volunteers' eyes.

5. Tell the volunteers to walk down the course. Their goal is to avoid any obstacles as they go.
- Ask the volunteers: What senses did you use when you couldn't use sight? Mostly touch.
- Ask the class: Which sensors did you use/observe the robot use? Hands, feet, other parts of the body.
- Robots can use sensors that we humans don't have. Let's add a sensor that might help.

6. Give each volunteer a hula hoop. They can take their blindfold off to put the hula hoop around them, but make sure they cover their eyes again before they go through the course. Tell them they can hold on to the hula hoop to detect when they bump into an obstacle.

7. After the volunteers put their blindfolds back on, have the rest of each group rearrange the obstacles in the courses so the volunteer doesn't know what the course looks like.
- Ask the class to predict how the hula hoop will affect the robot's performance.

8. Tell the volunteers to walk down the course again, this time using the hula hoop to help them.
- Ask the volunteers: How did your sensor help you get through the course?
- Ask the class: What did you observe?
- Ask the class: How do animals find their way in the dark? What is an animal that mostly uses a sense other than sight to maneuver? Bats, fish etc. How do those animals find their way around? Mostly sound.
- Engineers look to animals as well as humans when they design robots. Some sensors use ideas from animals like bats. Let's add another sensor.

9. Have the class come up with three different sounds: one to signal that there is an obstacle in front of the robot, one to signal an obstacle to the left, and one to signal an obstacle to the right. If you have easy access to instruments, you could use cymbals, horns, or other things that make distinct sounds—alternatively, have students use only their voices!
- Make sure these sounds are very different from each other, so the robot can tell the difference between left, right and ahead.

10. Rearrange the objects in each course one more time.
- Ask the class to predict how their sound cues will affect the robot's performance.

11. Instruct the volunteer, blindfolded and with the hula hoop, to go through the course one more time.
- This time, the other students will make sounds to signal the volunteer that they are near an obstacle. If you want, use a timer to track whether the student gets through the course faster than before.
- Ask the volunteers: Was it helpful to have those sound signals?
- Ask the class: How do we use sound? Mostly to identify things around us.

12. Have the students give themselves a round of applause for working together to get their robot through the course! Students can head back to their seats.

Part II:

13. Pass out robot sensor cards.

14. Ask the students to identify which sensors are like human sensors, and which ones aren't.

15. Tell the students that it's time for them to be the engineers. They need to choose sensors for robots to perform certain jobs. Depending on your class, you can have students work in groups of two to three or on their own.

16. Assign the students different jobs for their robots. You may want to write them on slips of paper and pass them out.

- Examples of jobs: analyze rocks on Mars; assemble a toy in a factory; deliver mail to desks in an office; play soccer; lift debris from a beach; drive a car; be a companion for humans; put together a puzzle; climb up a skyscraper; or help someone with low vision or low hearing complete daily activities.

17. Give the students constraints for their choices.

- Tell students they can only choose three sensors.
- Examples of other constraints: budget, weight etc.

18. Have the students write down, report and explain their choices.

CHECK FOR UNDERSTANDING:

Throughout the activites, ask the following questions:

- When you walked through the course the first time, did you recognize objects when you touched them? How did you know the chair was a chair?
- When you had the hula hoop, did you know what an object was when the hoop touched it? Robots can detect obstacles, but do not add context the way humans do.
- When talking about constraints: Was it easier or harder to get through the course when we added the hula hoop? When we added sound? Too many sensors could confuse a robot or make it inefficient, or just be too expensive.

WHAT'S HAPPENING?

Some robot sensors mimic human sensors like eyes, ears and hands. Other robot sensors do things humans can't do like sense infrared light or global positioning. Engineers design robot sensors based on the specific job the robot needs to accomplish.

DIFFERENTIATED INSTRUCTION

- For older or more advanced students, change the constraints in day two to incorporate more math, such as a specific budget or weight allowance. If desired, you can add your own dollar amounts and specific weights to the sensor cards.
- Many of the jobs in day two are examples of robots you'll see in *Robot Revolution*. You are welcome to add anything supporting your current curriculum. For example, if you're doing a weather unit, you might add hurricane prediction or water pollution detection to the list of robot jobs.

ROBOT SENSES

EXTENSIONS

- Open a discussion about uniquely human abilities, like social interaction. Ask students: What combinations of senses do we use to recognize our friend from a stranger? Some senses we take for granted and do really well, like recognizing faces, walking up stairs or knowing how to pick up a dictionary when someone asks for the dictionary. Robots can't do these kinds of tasks well. Some of the robots in the exhibit, like EMYS and PARO, are on the forefront of research to make robots more "like us."
- If you have access to an Xbox Kinect, or a small budget to purchase one for the classroom, you can connect it to a TV screen to show how a robot sees using LIDAR and RADAR sensing technology.
- Have students make videos identifying robot sensors they use in daily life.
- For older students, start a conversation about chemical detection involved in smell and taste. Mass spectroscopy for example is a technology used by the Curiosity rover to analyze chemical properties of Mars rocks and soil.
- Have students walk through the course with just one eye covered to talk about depth perception. Some robots are built with two cameras to act as "eyes."
- Have a discussion about careers that involve not just robot sensors, but human sensors and senses as well. This can be a tie-in to health careers and biological and life science careers.

DIGITAL RESOURCES

Computer science non-profit organization
http://code.org/

Science Buddies explanation of infrared (IR) light sensing
http://www.sciencebuddies.org/science-fair-projects/project_ideas/Robotics_p021.shtml#background

NASA animation of how GPS works
http://spaceplace.nasa.gov/gps-pizza/en/

NASA space and robotics activities
http://spaceplace.nasa.gov/gps/en/

Discovery lessons on human senses for younger grades
http://www.discoveryeducation.com/teachers/free-lesson-plans/the-incredible-human-body-the-five-senses.cfm

NASA Space Place activity on making a topographical map of an unknown object
http://spaceplace.nasa.gov/review/topo-bear/topo-bear.pdf

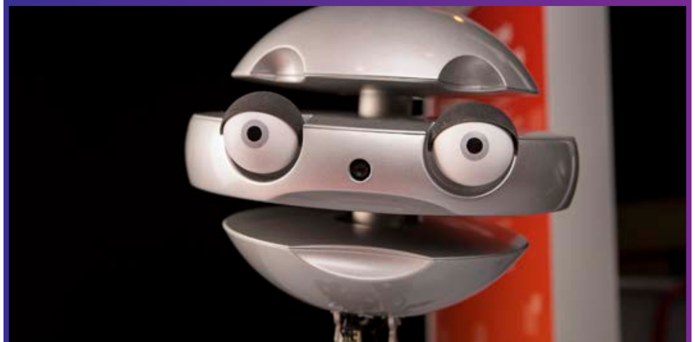
NASA explanation of robots and depth perception
http://spaceplace.nasa.gov/stereo-vision/en/

NASA object identification activity
http://spaceplace.nasa.gov/stereo-vision/en/

IN THE EXHIBIT

- Gripper robots
- Google Self Driving Car
- EMYS: mimics expressions
- UR5 Universal Robotic Arm: proprioception
- ROBOTIS OP: vision tracking, patterns
- PARO: touch sensors

EMYS



EMYS stands for "Emotive headY System." It was designed to research how humans react to robots that show emotions. EMYS can show emotions like happiness, sadness, surprise and anger by moving its three disks and two eyes. EMYS can respond to "seeing" a person's face and also responds to touch.

UNMANNED AERIAL VEHICLE

This robotic vehicle flies without a pilot. It is controlled by people on the ground or pre-programmed with missions before take-off. A drone can sense and respond to its surroundings, such as wind, bad weather, or obstacles in its path.

Drones are used for many jobs, including farming, photography, military surveillance, search and rescue, and supply delivery.

SWARM ROBOTS

Inspired by flocks of birds and swarms of insects in nature, swarm robots work together in groups to operate. Each robot performs its own task, but they all follow one leader in the pack.

These robots are currently in the research phase. Potential future uses include search and rescue, mining and even miniaturization for medicine.

VIDEO CAMERA

Vision sensor most similar to human sight, as it detects the same wavelengths as human eyes. Used to produce images like photographs or moving videos.

Cost: Moderate
Weight: Medium

MICROPHONE

Sound sensor that detects sound signals within the human range of hearing. Used to detect sounds from objects ranging from the very small, like insects, to the very large, like airplanes.

Cost: Moderate
Weight: Medium

TACTILE SENSOR

Pressure sensor that detects physical contact. Can sense a squeeze, but cannot measure weight. Often used in everyday objects, such as keyboards, or to test performance of products, like car brakes.

Cost: Inexpensive
Weight: Light

GYROSCOPE

Movement sensor that detects velocity and orientation. Used inside robots to measure balance. Allows a robot to correct its own movement to stabilize itself.

Cost: Inexpensive
Weight: Light

THERMAL CAMERA (INFRARED)

Detects light wavelengths outside the range of human vision and creates an image on a screen. Often used to detect temperature differences. Can also be used for night vision.

Cost: Expensive
Weight: Medium

LIDAR

Measures distance, shape and speed of objects by bouncing a laser off an object and analyzing the reflected light. Often used to make high-resolution maps.

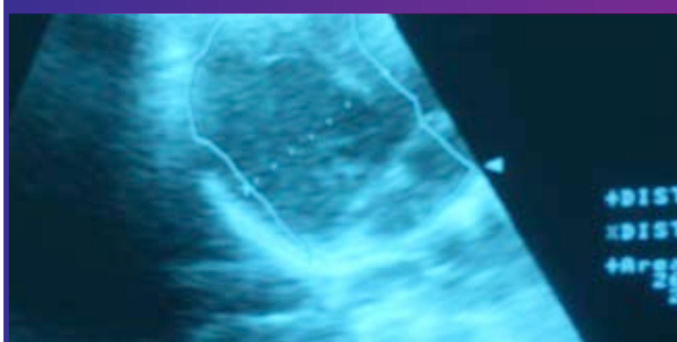
Cost: Expensive
Weight: Medium

INFRARED THERMOMETER

Uses a laser to detect temperatures from a distance. Sometimes accuracy can be affected by surrounding objects. Often used to measure temperatures of moving objects, objects out of reach, or objects too hot or too cold to touch.

Cost: Inexpensive
Weight: Medium

ULTRASOUND DETECTOR



Senses sound wavelengths higher than the range of human hearing. Used to detect objects and measure distances. Can detect a wide area from a single point. Used in medicine, underwater exploration (called Sonar), materials science and more.

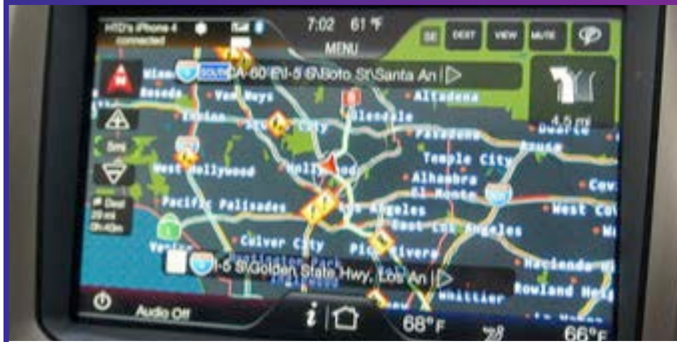
Cost: Inexpensive
Weight: Light-Medium

MASS SPECTROMETER

Uses a laser to measure the mass of atoms and molecules. Can identify substances, such as rocks or metals, by separating individual elements and compounds.

Cost: Expensive
Weight: Heavy

GLOBAL POSITIONING SYSTEM



Detects exact location by determining its own distance from satellites orbiting Earth. Often used to track devices and objects, such as in cars and smartphones.

Cost: Moderate
Weight: Light

MAKE YOUR OWN SENSOR

Description:

Cost:
Weight:

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