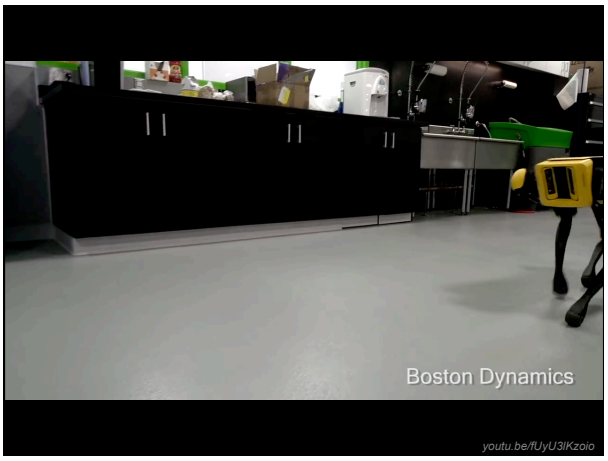
Intro to Sensing

Characterizing Sensors
Pose and Location

Many slides adapted from slides © R. Siegwart, ETH Zürich – Autonomous Systems Laboratory



What's a Sensor?

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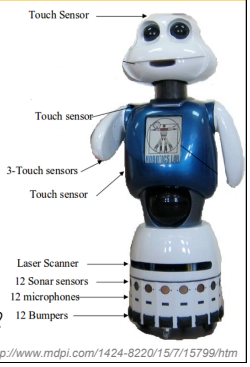
- Anything that gives a system information about its **physical environment**
  - Robots exist in a physical world
- How many can we think of?

sight/RGB	chemicals (gas)	bump
texture	temperature	location
pressure	electricity	sound
light	joint encoders	acceleration
taste	range/distance	humidity

etc., etc., etc...

- What does robot need to know?



http://www.mdpi.com/1424-8220/15/7/15799/htm

For Example…

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Classification of Sensors

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- What do you need to know about a sensor to…
  - **Design** a robot?
  - **Understand** an existing robot?
  - **Use** a robot?
- Characteristics of a sensor
- Six main either/or characteristics
  - Exteroceptive / Proprioceptive
  - Passive / Active
  - Incremental / Absolute

Aldebaran NAO robots

https://newatlas.com/nao-humanoid-robot-aldebaran-robotics/20802/

Exteroceptive/Proprioceptive

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- **Exteroceptive** sensors
  - Retrieve information from the robot's environment
  - This is most of what we think of when we think "sensors"
  - Examples?

    camera bump sensors thermometer range finder
- **Proprioceptive** sensors
  - Measure values internal to the system (robot)
  - Just as common and just as important
  - Examples?

    battery status joint encoders wheel load

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Passive/Active

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- **Passive** sensors
  - Don't send anything "out"
  - Energy comes from the environment
  - Examples?

    camera thermometer microphone e-field sensor
- **Active** sensors
  - Emit energy and measure the reaction
  - Better performance, but influences environment
  - Examples?

    sonar/lidar camera with flash x-rays

Absolute/Relative

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- **Incremental** sensors
  - Reports an incremental change (up/down, warmer/cooler)
  - Requires calibration
  - Examples?

    beacon-based distance magnetic joint encoder
- **Absolute** sensors
  - Unambiguously reports its state
    - Within a known scale or range
  - No need for any reference information
  - Examples?

    GPS thermocouple range sensor color vision

General Classification (1)

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General classification (typical use)	Sensor Sensor System	PC or EC	A or P
Tactile sensors (detection of physical contact or closeness; security switches)	Contact switches, bumpers	EC	P
	Optical barriers	EC	A
	Noncontact proximity sensors	EC	A
Wheel/motor sensors (wheel/motor speed and position)	Brush encoders	PC	P
	Potentiometers	PC	P
	Synchros, resolvers	PC	A
	Optical encoders	PC	A
	Magnetic encoders	PC	A
	Inductive encoders	PC	A
	Capacitive encoders	PC	A
Heading sensors (orientation of the robot in relation to a fixed reference frame)	Compass	EC	P
	Gyroscopes	PC	P
	Inclinometers	EC	A/P

A, active; P, passive; P/A, passive/active; PC, proprioceptive; EC, exteroceptive.

General Classification (2)

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General classification (typical use)	Sensor Sensor System	PC or EC	A or P
Ground-based beacons (localization in a fixed reference frame)	GPS	EC	A
	Active optical or RF beacons	EC	A
	Active ultrasonic beacons	EC	A
	Reflective beacons	EC	A
Active ranging (reflectivity, time-of-flight, and geometric triangulation)	Reflectivity sensors	EC	A
	Ultrasonic sensor	EC	A
	Laser rangefinder	EC	A
	Optical triangulation (1D)	EC	A
	Structured light (2D)	EC	A
Motion/speed sensors (speed relative to fixed or moving objects)	Doppler radar	EC	A
	Doppler sound	EC	A
Vision-based sensors (visual ranging, whole-image analysis, segmentation, object recognition)	CCD/CMOS camera(s)	EC	P
	Visual ranging packages		
	Object tracking packages		

Range and Resolution

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- Range: what's the range of returnable values?
  - Upper limit, lower limit
  - For a rotation sensor, range is..?
- Resolution: how fine-grained are those values?
  - Minimum measurable difference between two values
  - For a rotation sensor: 2 degrees? 5? 0.1?

Linearity and Bandwidth

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- Linearity
  - variation of output signal as function of the input signal
  - linearity is less important when signal is after treated with a computer
- Bandwidth or Frequency
  - the speed with which a sensor can provide a stream of readings
  - usually there is an upper limit depending on the sensor and the sampling rate
  - Lower limit is also possible, e.g. acceleration sensor

Sensitivity

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Characteristics that are especially relevant for real world environments

- Sensitivity
  - How much change in world affects change in sensor readings
  - Ratio of output change to input change
  - High sensitivity often correlated to high cross-sensitivity
- Cross-sensitivity
  - Sensitivity to environmental parameters unrelated to target parameters
  - In a real world environment, a sensor has very often high sensitivity to confounding environmental changes
    - Example: Illumination

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Some Important Senses: Pose and Location

Pose

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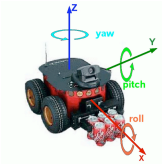
- **Pose:** How is the robot…
  - Posed: Where are its parts relative to each other
  - Oriented: With respect to an external frame of reference



- Location: where is the robot?
  - With respect to an external frame

Encoders

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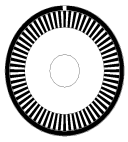
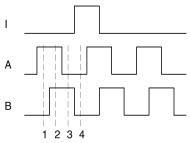
- Wheel and motor (and usually joint) encoders
- Where in its rotation are they?





State	Ch A	Ch B
S_1	High	Low
S_2	High	High
S_3	Low	High
S_4	Low	Low

- Basically same as optical mice/trackballs/etc:

Odometry (Dead Reckoning)

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- The robot can move
  - I can move, I can move!
- So where am I? ← this is known as **localization**
  - Use proprioceptive sensors to *estimate* location
- Dead reckoning
  - Given motion sensors or known commands estimate change in position over time
  - Sensitive to errors due to sensor inaccuracies, integration of velocity measurements over time, equipment calibration