Robotics: Perception

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The see-think-act cycle

- **Perception**
  - Sensing
  - Raw data
  - Environment model
  - Local map
  - Knowledge, data base

- **Localization**
  - Map Building

- **Cognition**
  - Path Planning
  - Global map

- **Path Execution**
  - Actuator commands
  - Motion control

- **Acting**

**Real World Environment**

The cycle repeats as the system perceives, localizes, cognizes, and acts.
Sensors for Mobile Robots

- Robot = sensors + actuators
- Sensors are the key components for perceiving the environment
Robot = sensors + actuators

Sensors are the key components for perceiving the environment

Perception is the HOT research topic of the last years

Sensors vary according to: physical principle, resolution, bandwidth, price, energy needed
Perception is hard!

- Understanding = raw data + (probabilistic) models + context
- Intelligent systems interpret raw data according to probabilistic models and using contextual information that gives meaning to the data.
Perception is hard!

“In robotics, the easy problems are hard and the hard problems are easy”

Perception for Mobile Robots

- **Places / Situations**
  A specific room, a meeting situation, ...

- **Servicing / Reasoning**

- **Objects**
  Doors, Humans, Coke bottle, car, ...

- **Interaction**

- **Features**
  Corners, Lines, Colors, Phonemes, ...

- **Navigation**

- **Raw Data**
  Vision, Laser, Sound, Smell, ...

-Martin Ruff, Davide Scaramuzza, Roland Siegwart
Evolution of robotic sensors

Historically, robotic sensors have become richer and richer

- 1960s: Shakey
- 1990s: Tourguide robots
- 2010s: Willow Garage PR2
- 2011: Google autonomous car
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Reasons:

- Commodization of consumer electronics
- More computation available to process the data
Sensors

- Optical encoders
- *Heading sensors*: Compass, Gyroscopes
- Accelerometer
- IMU (Inertial Measurement Unit)
- GPS
- *Range sensors*: Sonar, Laser, Structured light
- Vision
<table>
<thead>
<tr>
<th>Sensor Modality</th>
<th>Description</th>
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<tbody>
<tr>
<td>Sound</td>
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Sensor Modality

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Different modalities:

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- Light (Visible light, Infrared light, X-rays, Etc.)
Classification of Sensors: What

Proprioceptive sensors
measure values internally to the system (robot),
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measure values internally to the system (robot),
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Exteroceptive sensors
information from the robots environment,
e.g., distances to objects, intensity of the ambient light, unique features.
Classification of Sensors: How

Passive sensors
energy coming from the environment.
Classification of Sensors: How

Passive sensors
- energy coming from the environment.

Active sensors
- emit their proper energy and measure the reaction
- better performance, but some influence on environment
<table>
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<th>General classification</th>
<th>Sensor</th>
<th>PC or EC</th>
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<tr>
<td>Tactile sensors</td>
<td>contact switches, bumpers</td>
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<td>Optical barriers</td>
<td>EC</td>
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<td>Noncontact proximity sens</td>
<td>EC</td>
<td>A</td>
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<td>Wheel/motor sensors</td>
<td>Brush encoders</td>
<td>PC</td>
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<td>and position)</td>
<td>Magnetic encoders, ...</td>
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Characterizing Sensor Performance

Basic sensor response ratings

- **Range**
  - lower and upper limits
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- **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
  - one also has to consider signal delay
In Situ Sensor Performance

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  - ratio of output change to input change
  - however, in real world environment, the sensor has very often high sensitivity to other environmental changes, e.g. illumination
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- **Error / Accuracy**
  - difference between the sensor’s output and the true value

\[
\text{accuracy} = 1 - \left( \frac{m - v}{v} \right)
\]

\( m = \text{measured value} \)
\( v = \text{true value} \)
In Situ Sensor Performance

- Systematic error → deterministic errors
  - caused by factors that can (in theory) be modeled → prediction
  - e.g. calibration of a laser sensor or of the distortion caused by the optic of a camera
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- Precision
  - reproducibility of sensor results
EV3 Sensor Example: Gyroscopes

- Preserve their orientation in relation to a fixed reference frame
- They provide an absolute measure for the heading of a mobile system
- Measure rotational motion and changes in its orientation;
- +/- 3 degrees accuracy;
- Maximum output of 440 degrees/second;
- Sample rate of 1 kHz;