IVR: Sensing the World

**Keypoints:**

- Why robots need sensing
- Factors that affect sensing capability
- Contact sensing
- Proximity and range sensing
- Sensing light
Why robots need sensing

For a robot to act successfully in the real world it needs to be able to perceive the world, and itself in the world.

Can consider sensing tasks in two broad classes:

Finding out **what** is out there: e.g. is there a goal; is this a team-mate; is there danger? = Recognition

Finding out **where** things are: e.g. where is the ball and how can I get to it; where is the cliff-edge and how can I avoid it? = Location

But note that this need not be explicit knowledge
Sensing capability depends on a number of factors:

1. What signals are available?

   Light  Pressure & Sound  Chemicals
N.B. Many more signals in world than humans usually sense: e.g. Electric fish generate electric field and detect distortion
# Sensing capability

1. What signals are available?
2. What are the capabilities of the sensors?

<table>
<thead>
<tr>
<th>Distance</th>
<th>Contact</th>
<th>Internal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>Taste</td>
<td>Balance</td>
</tr>
<tr>
<td>Hearing</td>
<td>Pressure</td>
<td>Actuator position</td>
</tr>
<tr>
<td>Smell</td>
<td>Temperature</td>
<td>and movement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pain or damage</td>
</tr>
</tbody>
</table>
Note this differs across animals: e.g. Bees see ultraviolet light

Need to choose what to build in to robot – options and costs

Visible

Ultraviolet

More like a target?
Sensors perform transduction

Transduction: transformation of energy from one form to another (typically, into electrical signals)
Sensors perform transduction

Sensor characteristics mean there is rarely an isomorphic mapping between the environment and the internal signal, e.g:

- Most transducers have a limited range
- Most transducers have a limited resolution, accuracy, and repeatability
- Most transducers have lags or sampling delays
- Many transducers have a non-linear response
- Biological transducers are often adaptive
- Good sensors are usually expensive in cost, power, size...
Sensing capability

1 What signals are available?
2 What are the capabilities of the sensors?
3 What processing is taking place?

E.g. extracting useful information from a sound signal is difficult:
Sound sources cause air vibration.

Diaphragm (ear drum or microphone) has complex pattern of vibration in response to sound.

Usually analysed by separating frequencies and grouping through harmonic/temporal cues.
Artificial sensing in neuroprosthetics

- Cochlear implant
- Retinal implant
- Cortical/brainstem implants
- Foot-drop neuro-prosthesis
- Touch in handprosthesis
Sensing capability

depends on a number of factors:

1. What signals are available?
2. What are the capabilities of our sensors?
3. What processing is taking place?
4. What is the task?
‘Classical’ view

Transduction → Processing → Internal model → Actuators

Task → Decision on Action → Plan of Action

Alternative view

Task 1 specific transduction → Task 1 specific processing → Task 1 specific action

Task 2 specific transduction → Task 2 specific processing → Task 2 specific action

Task 3 specific transduction → Task 3 specific processing → Task 3 specific action
Affordances

“Perceivable potentialities of the environment for an action”

Scan scene, build surface model, analyse surfaces, find flat one near feet

vs.

Use “flat surface near feet” special detector

First is traditional, second affordance-based: sensors tuned for exactly what is needed for the task
Keep close count of how many times the white team pass their ball

(Please remain silent till the end of the video clip)
Simons & Chabris (1999) – only 50% of subjects see the ........ Using “Count white team passes” affordance rather than complete analysis
Contact sensors

Principal function is location
e.g. bump switch or pressure sensor:
Is the object contacting this part of the robot?
Contact sensors

Principal function is location
e.g. bump switch or pressure sensor:
Is the object contacting this part of the robot?
Antennae: Extend the range with flexible element
Contact sensors

Can also use for recognition e.g.
- Is it moving or are you?
- Human touch can distinguish shape, elastic force, slip, surface texture, ...
- Rat whiskers also use active sensing
‘Contact’ sensors

Note these kinds of sensors can also be used to detect flow e.g. wind sensors
Proximity and range sensors

• Again main function is position: distance to object at specific angle to robot
• Typically works by emitting signal and detecting reflection
• Short-range: proximity sensor, e.g. IR
Figure 11: Measurements of the light reflected by various kinds of objects versus the distance to the object.
Proximity and range sensors
Over longer distance: range sensors e.g. Sonar: emit sound and detect reflection

\[
\text{Distance} = \frac{\text{Time of flight} \times \text{Speed in medium}}{2}
\]

\[
\text{Beam diameter} = 2 \times \text{distance} \times \tan(\text{beam angle})
\]
a. Sonar reflection time gives range
b. Can only resolve objects of beam width
c. Apparent range shorter than axial range
d. Angle too large so wall invisible
e. Invisible corner
f. False reflection makes apparent range greater
Using sonar to construct an occupancy grid

- Robot wants to know about free space
- Map space as grid
- Each element has a value which is the probability it contains an obstacle
- Update probability estimates from sonar readings
Sample occupancy grid

Noisy fusion of multiple sonar observations
Learning the map

Assuming robot knows where it is in grid, sensory input provides noisy information about obstacles, e.g. from sonar.

Probability $p(z|O)$ of grid element $z=(r,\alpha)$ in region I if occupied $(O)$ given measurement $s$.

Using Bayesian approach where $p(O)$ will depend on previous measurements:

$$p(O|z)=\frac{p(z|O)p(O)}{p(z|O)p(O)+p(z|\sim O)p(\sim O)}$$
Proximity and range sensors

- More accurate information from laser rangefinder
- Either planar or scanning
- 1,000,000 pixels per second
- Range of 100s of metres (typical values for robots)
- Accuracy of sub-mm
- Errors possible due to reflections, temperature gradients or small objects
Sample laser scan
Light sensors

Why is it so useful to detect light?

- Straight lines mean the rays reflected from objects can be used to form an image, giving you ‘where’.
- Very short wavelengths gives detailed structural information (including reflectance properties of surface, seen as colour) to determine ‘what’.
- Very fast, it is especially useful over large distances.
- But requires half our brain to do vision…
Conclusions and outlook

- Robots need sensing: location, objects, obstacles
- Commonly used sensors: laser range, sonar, contact, GPS (outdoors), markers
- General scene scanning vs. affordances
- Proprioceptive sensors monitor the state of the robot (later)
- Redundant sensors: Sensor fusion
- Distributed sensing in cooperative robots