Robot Sensors

- Allow a robot to interact with its environment in a flexible, and intelligent manner
- A robot that can see and feel is much easier to train and deploy to perform complex tasks
- Provide position and velocity of wheels as a continuous stream of feedback signals that possess an integral part of the control loop
- Provide information about the environment and the objects therein

Sensor Characteristics

- Dynamic range
  - Minimum and maximum values of the input signal for which the sensor responds
- Response
  - Sensor should respond to the stimuli almost instantaneously
- Sensitivity
  - The change in sensor output for a unit change in input
- Linearity
  - Whether the sensor maintains same sensitivity within the entire dynamic range
- Other considerations
  - Sensor should not disturb the physical quantity it measures
  - Sensor should be suitable for the environment it is exposed
  - Sensor should be isolated from noise, and protected from physical damages
  - Size, cost, and ease of operation

Switch Sensor

- Indicates whether or not a contact has been made, while disregarding the magnitude of the contact force
  - Micro switches, limit switches

Robot Sensors

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Microswitch-style sensor

5V: not pressed ("false")
0V: pressed ("true")

Touch sensor pressed

Touch sensor released

0V

+5V
electrical flow

Microswitch

47kΩ

GND

signal

-electrical flow

no electrical flow

47kΩ

5V

NS

NC

0V
Applications of Switch Sensors

- Collision detection and ground detection

Optosensors

- Passive Sensors
  - Photocell (LDR): street light trigger
  - Slow response
  - 10kΩ in the dark (open cct), and 10Ω (short cct) in bright light
    - Used in potential divider configuration
    - Light (photons) transfer energy to bound electrons
    - Responsiveness to a wide range of frequencies
      - IR, visible, UV

Optosensors cntd..

- Active sensors
  - Emitter: Infra red LED
  - Detector: Photodiode (faster), or Phototransistor (sensitive)
  - Performance
    - fast response, low light levels, wavelength match
- Two kinds of active Optosensors
  - Reflective: light is reflected off a surface onto the detector
    - Used for proximity sensing
  - Break beam: light is shined directly onto the detector, and is obstructed by an opaque object
    - Used for shaft encoding (with a slotted wheel)

Interfacing a Photocell

Potential divider

Robot Control board

Light Baffling
Interfacing Active Optosensors

- Adjust pull-up resistor
  - Light falls on ⇒ detector current ↑ ⇒ voltage across pull-up resistor ↑ ⇒ analog reading ↓
  - Use different pull-up resistors to improve response
- Emitter brightness control
  - 5V through 500Ω ⇒ 10mA. Check whether it is bright enough.

Properties of Optosensors

- Emitter testing
  - IR is invisible
  - use IR detector card, camcoder, or camera phone to check whether IR emitter works
- IR filter
  - Semiconductor junction is most efficient in infra-red wavelengths. Detector is usually attached with a filter, which allows infra-red to pass through while blocking ambient light interference
- Correction for ambient light
  - Switch emitter ON and OFF and get the difference of the two readings
  - Reduce power consumption too

Break-Beam Sensor

- Digital IR Sensors
  - Whether you see through the slot

Reflective Optosensor

- Digital IR Sensors
  - Whether you are in very close proximity of an obstacle

5V (logic 1) on black
0V (logic 0) on white
Absolute Encoder

Resolution = $360/2^n$

$n$ = number of bits

This track and sensor is missing in figure.

Eg. $110010 = 3 \times 360/2^6 = 6.875^\circ$

Parallel Data

No initialization needed

Quadrature Shaft Encoder (two tracks)

Distinguishing clockwise and counter-clockwise rotations

Track A is 90 degrees ahead of track B.

Track A is 90 degrees behind.

Phase ⇒ Direction of motion

Pulse count (and derivative) ⇒ position (and velocity)

Quadrature Shaft Encoder (one track)

Encoder A

Encoder B

clockwise

-1

+1

counter clockwise

IR Distance Measuring Sensors

• Measures distance to obstacle
IR Distance Measuring Sensor

- Use reception intensity as a measure of distance
- SHARP GP2D12: Distance output type (10cm~80cm)
- SHARP GP2D12: Distance judgment type (24cm)

Sensing High Speeds

Velocity ≈ Pulse Frequency

Counter clear

Sampling period $T$
= Pulse counting interval

Sensing Low Speeds

As the angular velocity gets slower, only a few pulses are observed in the fixed time interval: discretization error increases.

$$\omega \approx \frac{3}{T}$$
or
$$\omega \approx \frac{4}{T + \delta T}$$

A better alternative is to measure the interval between adjacent pulses $t_{int}$, and take the reciprocal for estimating the velocity.

$$\omega \propto \frac{1}{t_{int}}$$
Ultrasound Range Sensor

- **3cm ~ 4m, 40~60kHz**
- **Emits ultrasonic ping and listen to the echo**
  - time of flight \( \times 0.5 \times \text{sound speed} = \text{distance to obstacle} 
- **Problems**
  - Wide field of reception: where is the obstacle exactly??
  - False echoes: ground reflection, etc..
  - Not very accurate: sound speed changes on temperature and humidity

Sonar Sensor Interface

Internal resonances take 2.38ms to decay out. Echoes can be detected after this interval (min distance limit)

At a distance, echo becomes too weak to be detected (max distance)

Timing Diagram Mode 1 (two pin)

Sonar Sensor Beam width

As frequency increase attenuation increases and beam width reduces

Beam width shouldn’t be too wide to hear false echoes. It shouldn’t be too narrow to miss a legitimate obstacle

Narrow beam width sensors are used atop a scanning (servo) mechanisms

Robots with Ultrasonic Sensors

- **Real-time Collision Avoidance**