Sensors and Cables

Maslab 2005

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Maslab Sensor Types

- **Common types:**
  - Camera
  - Infra-Red (IR) range finders/reflectance
    - Auto-flush toilets
  - Ultrasound
    - Cameras
  - Physical contact
    - Roomba
  - Gyroscopes: Angular Rate Sensor
    - Automotive, GPS-assist
  - Motor current sense
  - Optical encoders
  - Timer?

- **Other types:**
  - Photodiodes from 6.270
  - Digital Compass
  - Reed switch
  - Mercury switch
  - Be creative!
Infrared

- 750 nm to 1,000,000 nm
  - We typically use near-infrared, ~900nm. Near-infrared used on many camcorders for “night vision”
  - Far-infrared is used for body heat detection
  - Cheapest: excited silicon emits IR
  - Does not penetrate walls
- Transmitters (LEDs or thermal)
  - In our case, almost always LEDs
- Detectors (photo diodes, photo transistors)
  - Sensors use notch filter to pass only IR
Simple IR sensors

- **Break-beam**
  - Shine a light directly onto a detector. You can detect if something breaks the beam of light.

- **Reflection**
  - Shine a light and detect its reflection off a nearby object

- **Triangulation**
  - Shine a light at an angle, have an array of detectors
Maslab Infrared Range Detectors

- Sensor includes:
  - Infrared light emitting diode (IR LED)
  - Position sensing device (PSD) uses small lens to focus reflected pulse onto a linear CCD array (or magic, differential FET)

- To detect an object:
  - IR pulse is emitted by the IR LED
  - Pulse hopefully reflects off object and returns to the PSD
  - PSD measures the angle at which the pulse returns

Wider angle = greater distance

Figure: Acroname.com
Lies, damn lies, and datasheets? Characterize your sensors. Understand the default profiles.

**GP2D12: Theoretical Range:**
4in (10cm) to 31in (80cm)

**GP2D12: Measured Range:**
~4in (10cm) to ~18in (45cm)
Non-linear response presents small problems

- **Ultra short readings** can look “far-away”
  - Mount to accommodate this
- **Larger error in steep part of curve**

- Orc library use inverse of curve and fits a line
  - Voltage = \(1/(\text{distance} + Xd) \times Xm + Xb\)
  - Distance = \((Xm/(\text{Voltage}-Xb)) - Xd\)
Long range IR sensor uses different lens; increases both min and max limits

GP2Y0A02YK

[Graph showing the relationship between distance to reflective object (L) in cm and analog output voltage (V). The graph includes two lines indicating White Reflectivity:90% and Gray Reflectivity:18%.]

Red circles highlight the distance points where the voltage drops significantly.
IR Ranger Properties

- Small, eraser-sized point beam
  - Easy to resolve details; easy to miss small objects if you’re not looking right at them.
  - Set up a perimeter
IR Rangefinders

- Can use signal strength
  - Sort of.

- Can use time-of-flight, $c=299,792,458 \text{ m/s}$
  - How fast can you count?
    - Not fast enough!

- Sick industrial laser scanner: $5000$
  - Provides $\sim5\text{cm}$ accuracy, $\frac{1}{4} \text{ degree}$ resolution, $30\text{m}$ range
  - (collective “ooooh!”)
Ultrasound Rangers

- Send an ultrasonic pulse, listen for an echo
- Time of flight. Speed of sound only ~347 m/s
- Limited supply?
Ultrasound Ranger Properties

![Graph 1: Echo Pulse Width (m/s) vs. Distance to reflected object (in)](image1)

![Graph 2: Echo Pulse Width (m/s) vs. Distance to reflected object (ft)](image2)
Ultrasound Ranger Properties

- Broad beam width “blurs” detail… but less likely to “miss” something

- Sound can “scatter” (shortest path) or “reflect”
  - Can dramatically overstate range.

Small detail hard to resolve

Multipath can fool you!
Optical encoders are another use for IR emitter and detector

- Attach a disk to the motor shaft and attach a break-beam sensor across the teeth.

  ![Optical Encoder Diagram]

- Or, use a reflectivity sensor and a disk with black & white colored wedges.
- What if wheel stops halfway between slats?
- Are we going forwards or backwards?
Quadrature Phase Encoders allow us to distinguish direction

- Use TWO single encoders, 90 degrees out of phase.

- Forward and backward are now distinguishable!
- Illegal state transitions cancel out (for each spurious forward tick, there’s a spurious backward tick)
Using Quad Phase

- Quad phase can allow us to:
  - Do relative positioning—i.e., rotate 10 clicks from our present position (remember that gyro can help with this)
  - Do velocity control.
    - “driving” but not ticking? Probably stuck. Current spike may reveal this, too.
    - It’s hard to drive in a straight line. PID.
  - Compute the robot’s path using odometry.
Digital Inputs

- Bump sensors
- NES, anyone?
- Uses an internal pullup resistor.
MEMS Gyroscope

- Outputs a voltage corresponding to degrees/sec
- Note that OrcBoard integrates for you
  - Thanks, Ed!
  - But, what is effect of noise
    - Small voltages could mean the gyro thinks it’s turning.
    - Lots of “slow turns” + Integration = Drift
  - Study odometry tutorial
- Uses
  - Accurate turns, straight lines
  - Combine with other sensor data (camera, encoders, etc) for dead reckoning “Columbus Style”
MEMS Gyroscope takes advantage of coriolis effect

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Images by
Sensors Online Magazine (sensormag.com)
David Krakauer, Analog Devices Inc.
Two sensors allow differential sensing to eliminate common-mode error (shock, vibration)

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Maslab bloopers

- Be aware of the size of your robot
- You clock is a sort of sensor, timeout!
Orc board features

- Configurable low-pass filter on analog inputs removes noise
  - Less need for a capacitor on the IR sensor

- Built-in current sense:
  - Approximate, but useful
  - All drive motors, servos 0 and 1
  - Current is proportional to torque
  - A known Rsense and measured voltage (Vx) yield current: V=IR

- Optional optical encoders
  - We’ll demo, distribute today
  - Q = motor.encoder()
  - Q = motor.encoderAbsolute();
Some additional soldering points

- For MASLab-style soldering, a cheap iron probably will do.
  - Still, if you’re in the “biz”, an investment makes sense

- Some tools available for purchase through 6.270 store
  - Cheap soldering irons, helping hands, wire strippers
  - So cheap, who cares if it’s crappy?
  - Tell them you’re with MASLab.
Soldering Mistakes

- Use a wet sponge to keep your iron tip clean
  - If you don’t *have* a sponge, **get one**
  - Keep it *quite* damp. Don’t want sponge to burn onto tip
- Make sure you apply heat to both surfaces to be joined and that solder “wets” both.

![Diagram showing different soldering outcomes](image)
Soldering Mistakes

- Watch out for “ears”
  - Indicates a bit of oxidation, often aggravated by too much solder.
  - If the solder feels “thick”, then it’s oxidized some.
  - Connection is probably okay, but something to work on!
- On cables, can poke through insulation and heatshrinking!
Cable making: General Tips

- Use Stranded Wire only, strip only $\frac{1}{4}$”, twist strands together
- Pre-tin all wire leads and header
- Use heatshrink on connections
- Header is plastic and will melt easily
- Use a dab of hot glue to reinforce (optional)
- Color code! Make absolutely sure pin 1 is indicated! (Use sharpie to indicate a pin if it’s not otherwise obvious to you and any random person.)
Pre-tin (add some solder) the stranded wire.

Pre-tin the connector.

Add heat shrink tubing and solder the pins together.

Solder the wire to the header (not shown)…
Step 4

This cable is now ready for shrinking.

Step 5

Shrink the heatshrink tubing.
Cable Making: Pinouts

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See Orc Manual for connector pinouts
Reminder

- Java for the clueless” - tonight, 7-9PM
- Today:
  - Make sensor cables; start with short range IR
  - Characterize sensors
    - Handy worksheets
    - Build your intuition and start making [mental] selections
  - PegBot: IR proximity with OrcPad feedback. Choose bump/nobump or edge finder.