Sensors

- Have transducers which convert mechanical or radiant energy to electrical signals

**Active vs Passive Sensors**

**Passive:** Process signals from the world

**Active:** See how the world transforms signals emitted by the sensor

**Examples**

**Passive:** Eyes, ears, cameras, microphones, thermometers (w/o flash)

**Active:** IR Distance, Sonar, Kinect, Radar

**External vs Internal Sensors**

- Sensors can detect internal state
  - Joint/Wheel Encoders
  - Battery Voltage  \( \text{(Proprioception } \Rightarrow \text{"Sensing Self"}) \)

**Light Sensors**

- Photodiodes
- Photo transistors
- Photodiodes

\[ V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_{in} \]

**IR Range Sensor**

- Sends out light
- Takes it back
- Where it lands in the detector tells distance
**Photo Interrupter**
- Uses phototransistors & photodiodes
- Detects if light passes through by shooting IR beam at phototransistor. If IR beam is not detected something passed through.

**Rotary Encoder**
- Semi-transparent wheel + Photo interruptors
- Photointerruptors
- Quadrature Encoder

→ This is relative encoder, only tells position relative to robot

**Gray Code**
- Set of data where each set only differs from the next set by one bit
  - 000
  - 001 → can use wheel with 3 light sensors to detect position of the wheel
  - 011
  - 010 → with gray code direction is not ambiguous
  - Need lots of sensors

**Encoder Resolution**
- Average is 1024 - 4096 ticks per revolution ($2^{10} - 2^{12}$)

**Potentiometer**
- Changes resistance w/ angle (old volume controllers)
Analog vs Digital
• Analog: Continuous Signal (voltage, current)
• Digital: Discrete (usually 0's & 1's)

A/D Converter
• Fixed # of bits
• Fixed or variable input range

ex 3 Bit A/D, 0-5v

* Stay in input Range for voltage
* can't tell small voltage changes

→ 8-10 bits typical for Robotics

Cameras & Data Processing
• Cameras transform Photons into bytes

Photons → aperture → exposure time → A/D gain → Software/Firmware → Bytes

9/17 Torque
\[ T = rF \]

Other Units

<table>
<thead>
<tr>
<th>Base</th>
<th>Derived</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force (N)</td>
<td>(N = \frac{Kg \cdot m}{s^2})</td>
</tr>
<tr>
<td>Time (s)</td>
<td>(J = N \cdot m = \frac{Kg \cdot m^2}{s^2})</td>
</tr>
<tr>
<td>mass (Kg)</td>
<td></td>
</tr>
<tr>
<td>current (A)</td>
<td></td>
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</tbody>
</table>

- Torque has direction & quantity (vector)
- Energy does not itself have direction (scalar)

1 radian = circumference \(\frac{rad}{s} = \frac{1}{s} = \text{Hz}\)
Brushed DC Motor Theory

1. A motor is electrically, a resistor and a voltage drop.
2. There is a linear relationship between torque and speed.
3. There is a quadratic relationship between torque and power.
4. Gears are good.

- Running current creates electromagnet charges ends and can rapidly change polarity to be constantly repelled, spinning due to magnetic forces.

Electrically

```
\[ \begin{align*}
R &= \text{internal motor resistance} \\
e &= \text{voltage drop due to back-emf} \\
\text{Volts} &= \text{speed dependent voltage drop} \\
\end{align*} \]
```

\[ V = IR + e \quad (\text{KVL}) \]

- Torque that motor is exerting is proportional to the current.
  \[ T = K_t I, \quad I = \frac{T}{K_t} \]
  \[ \rightarrow V = \frac{K_e}{K_e} R + K_e \omega \]
  \[ \star K_b = K_e \text{ due to } I^2R \text{ losses } \star \]

2. Torque-Speed Linear Relationship

\[ w = \frac{1}{K} - \frac{T}{K}^2 \quad (y \text{ intercept form}) \]

\[ T_s = \frac{K_v}{R} \]

\[ w_{\text{max}} = \frac{1}{K} \text{ (no load speed)} \]

- Voltage constant, varying load on motor.

```
N

[Diagram of a motor showing components like brushes, permanent magnets, and armature.]
```
3. **Power**
   - two kinds: electrical & mechanical

   **Electrical:** \( P_e = VI = \frac{V^2}{R} \text{ (W)} \)

   **Mechanical:** \( P_m = Tw \text{ (W)} \) ★ Not equal \( P_e \neq P_m \) ★

   \( P_m = N P_e, \) \( (N = \text{constant of efficiency, } N < 1, \text{ also torque dependent}) \)

   \( P_m(T=0) = 0, \quad P_m(t=T_s) = 0 \) (due \( kW = 0 \) @ \( T_s \))

   \( \cdot \) max power \( @ \ T_s/2 \)
   \( \cdot \) Peak \( N \) at much lower

4. **We like gears**
   - Peak efficiency \( @ \) High speed \& low torque
   - many applications want Low speed/high torque

   \[ G = \frac{r_1}{r_2}, \quad P_1 = P_2 \quad \text{(efficient approximation)} \]

   \[ T_1w_1 = T_2w_2 \]

   \[ w_1 = \frac{w_2 r_1}{r_2} = w_2 G \]

   \[ T_1 = \frac{T_2}{G} \]