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# Embedded Systems
# Sensors and Odometry





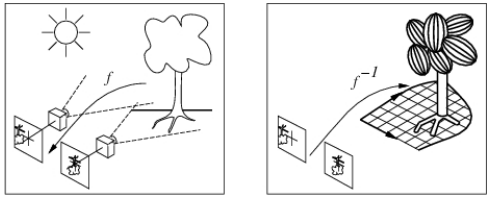
## Sensing vs. Perception

- transducers - devices that convert some physical phenomenon into electrical signals
- A/D conversion - the conversion from analog signal (0-5V) into a fixed precision (typically 8-12 bits) digital representation
- perception - the interpretation of signals derived from transducers in order to estimate state information required for control.
- observability - if state $x(t_0)$ can be determined given measurements $z(t)$ in the interval between $t_0$ and $t_1$, then $x(t_0)$ is observable. If $x(t)$ is observable for all t, x is completely observable.
- controllability - a system is controllable at time $t_1 > t_0$ if a suitable control $u(t)$ can be found to drive the system from an arbitrary $x(t_0)$ to another arbitrary state $x(t_1)$.





## Reconstruction




Stimulus = f(World) World = $f^{-1}(S)$

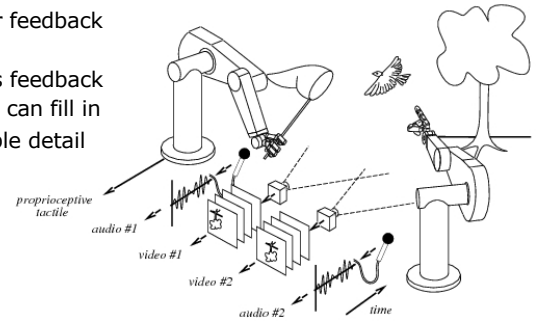
- in general, the inverse of f() is not well-conditioned
- function, f(), is only partially known
- the world is only partially observable
- time spent "perceiving" often renders world models obsolete





## Embodied Perceptual Systems

- rich sensor feedback
- interaction
- time series feedback
- knowledge can fill in inaccessible detail



## Sensor Drivers and Interface Circuitry

*photosensors, micro switches, microphones, pyroelectric, near IR reflectance, sonar, strain gauges, gyroscopes, accelerometers, force, compasses, vision,...*

- sensitivity S - a property of the transducer and describes the $\Delta x$ (physical quantity) that is required to produce a $\Delta r$ (change in response)...

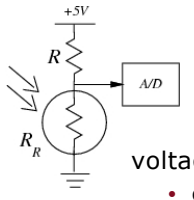
$$S = \Delta x/\Delta r$$

- range, R - the range in the observable quantity x that maps onto the 0-5 V transducer output
- resolution - the smallest $\Delta x$ that can be observed, i.e., R/255 (linear transducer and 8-bit A/D).





## Light Sensors - Photoresistor




voltage divider $V_{signal} = (5V)\ R_R/(R + R_R)$

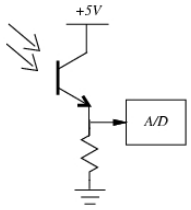
- choose $R=R_R$ when ambient light is midrange
- Cadmium Sulfide (CdS)
- cheap





## Light Sensors - Phototransistor

greater sensitivity

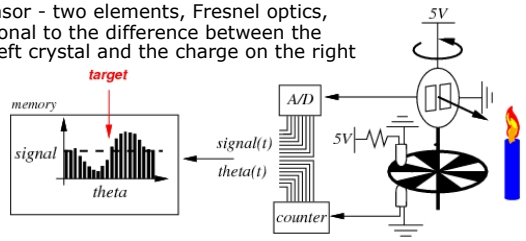







## Active Sensors - Pyroelectric Sensors

- lithium tantalate crystal is heated by thermal radiation inducing charge
- tuned to 8-10 μm radiation - respond to human IR signature
- motion detecting burglar alarm
- Eltec 442-3 sensor - two elements, Fresnel optics, output proportional to the difference between the charge on the left crystal and the charge on the right crystal.



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## Other Common Sensor Technologies

Force
- strain gauges - foil, conductive ink
- piezoelectric films
- conductive rubber
- capacitive force
- rheostatic fluids

Sound
- microphones
- sonar (ping)

Position
- microswitches
- shaft encoders
- gyros
- tilt/compasses

Proprioceptive
- battery-level
- motor current - stall, external force
- temperature

Vision



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## Quadrature Encoder



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## Interupt Handling with Arduino

```
int pin = 13;
volatile int state = LOW;

void setup(){
  pinMode(pin, OUTPUT); //specify pin 13 as output
  attachInterrupt(0, blink, CHANGE);
  // the number of the interrupt (int) [interrupt 0 takes inputs from digit input port 2]
  // when the interrupt occurs call the blink function;
  // a constant (CHANGE) defines how the interrupt is triggered.
 }

void loop(){
  digitalWrite(pin, state);
 }

void blink(){
  state = !state;
}
```

LOW to trigger the interrupt whenever the pin is low,
CHANGE to trigger the interrupt whenever the pin changes value
RISING to trigger when the pin goes from low to high,
FALLING for when the pin goes from high to low.