Introduction to Sensing Technologies for Control

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.

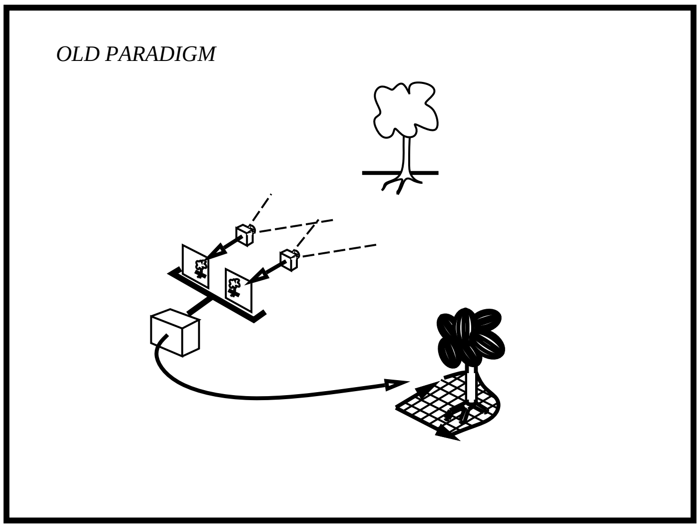
observability - if state $\vec{x}(t_0)$ can be determined given measurements $\vec{z}(t)$ in the interval between t_0 and t_1, then $\vec{x}(t_0)$ is observable. If $\vec{x}(t)$ is observable for all t, $\vec{x}$ is completely observable.

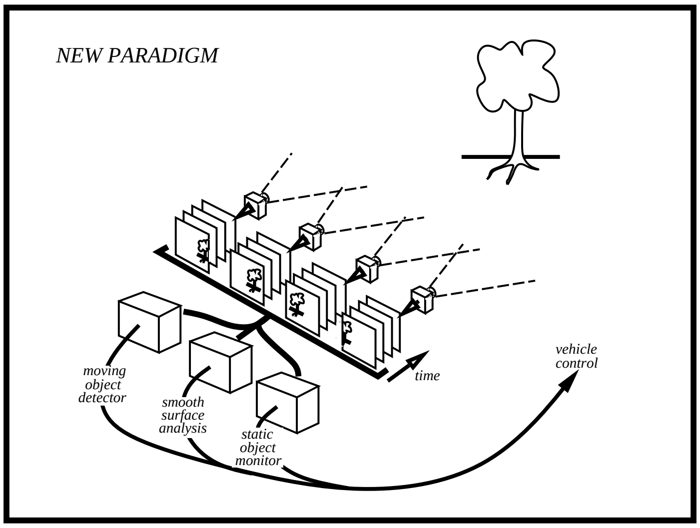
controllability - a system is controllable at time $t_1 > t_0$ if a suitable control $\vec{u}(t)$ can be found to drive the system from an arbitrary $\vec{x}(t_0)$ to another arbitrary state $\vec{x}(t_1)$.

sensory overload - in biology and in many synthetic embedded systems, often too many types of measurements (transducers) are available and are irrelevant in many contexts. Mechanisms for focusing attention on the relevant aspects of state are critical.

Sensing for Embedded Systems

Bolles - ISIC-93

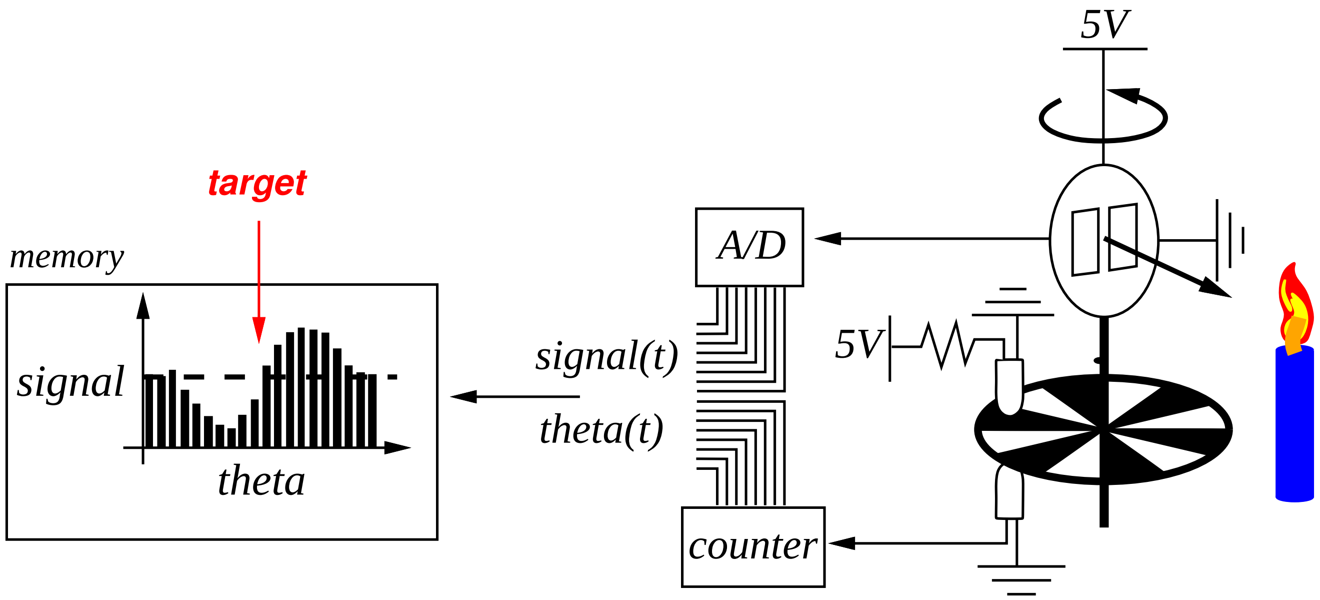




adapted from material presented by Bob Bolles at the 1993 International Symposium on Intelligent Control

Perception for Embedded Control Application

in the most general sense, perception implies abstractions derived from temporal sequences of observations over multiple sensing modalities



Sensor Drivers and Interface Circuitry

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

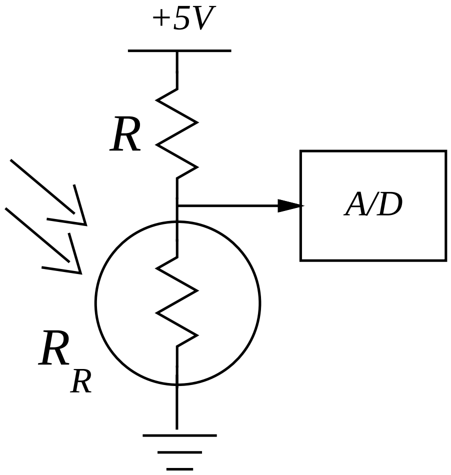
sensitivity, S - a property of the transducer and describes the Δx (physical quantity) that is required to produce a Δr (change in response)...

$$\frac{\Delta r}{r} = S \frac{\Delta x}{x}$$

range, R - the range in the observable quantity x that maps onto the 0-5 V transducer output

resolution - the smallest Δx that can be observed, i.e., $R/255$ (linear transducer and 8-bit A/D).

Light Sensors

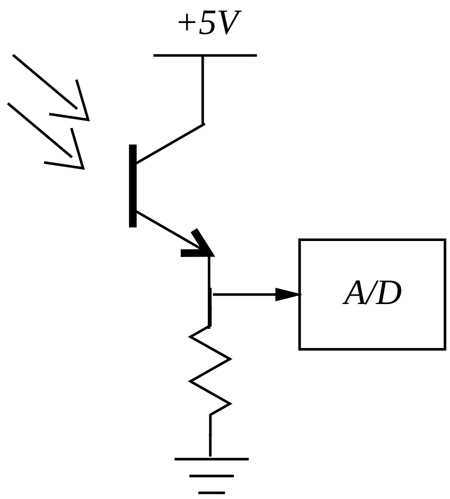


Photoresistor

- voltage divider

$$V_{signal} = \frac{R_R}{R + R_R}(5V)$$

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



Phototransistor

- greater sensitivity

EXAMPLE: 68HC11 Software Driver for Photoresistor

- voltage reference pins on the 68HC11 (V_{RH} and V_{RL})
- results are placed in internal registers, ADR1, ADR2, ADR3, ADR4
- A/D control word ADCTL

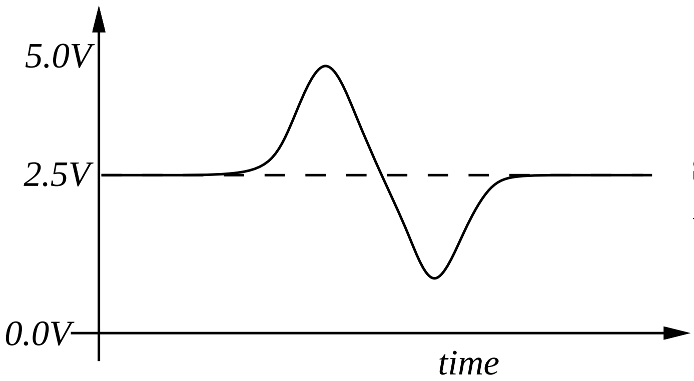
	7	6	5	4	3	2	1	0
ADCTL ($1030)	CCF	–	SCAN	MULT	CD	CC	CB	CA

$$
\begin{aligned}
CCF &= \text{ conversion complete flag} \\
SCAN &= \text{0 single pass of four analog input channels} \\
&= \text{1 continuous round-robin of 4 analog input channels} \\
MULT &= \text{0 four consecutive conversions on a single channel} \\
&= \text{1 bank of four consecutive channels is converted}
\end{aligned}
$$

```
int photoresistor = 0;
void update_photo()
{ poke(option,0b10000000); /* enable A/D */
  poke(adctl,0b00010000); /* begin conversion */
  while((peek(adctl) & 0b10000000) == 0 ) { }
  poke(photoresist, peek(adr1)); /* get/store A/D channel 1 */
}
```

Pyroelectric Sensors

- lithium tantalate crystal is heated by thermal radiation inducing charge
- tuned to $8 - 10\mu m$ radiation - respond to "human" IR signiture
- 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.



source moving from the left to the right receptive field

Other Common Sensor Technologies

- force
  - strain gauges - foil, conductive ink
  - piezoelectric films
  - conductive rubber
  - capacitive force
  - rheostatic fluids
- Sound
  - microphones
  - sonar
- position
  - microswitches
  - shaft encoders
  - gyros
  - tilt/compasses
- proprioceptive
  - battery-level
  - motor current - stall, external force
  - temperature