Sensing, Actuation, & Computation

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Overview

What is sensing? The process of [illegible]
from [illegible]

What is actuation? Causing motion to happen

What is computation? Algorithms

Related fields

Roomba

palindrome

- Robotics: Roomba, humanoid, DARPA urban challenge
  elderly care, transportation, [illegible]mation
- Sensor networks
- Cyber-physical systems (NSF)
- Computer vision

control theory

actuation

theory of computation

AI

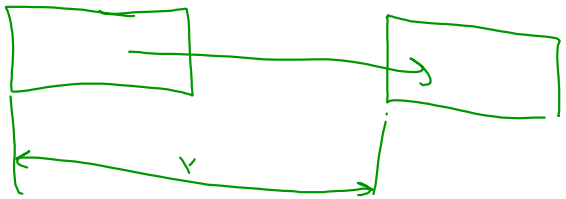
Physical Sensors

real world (stimulus, measurand) ⇒ electrical signal

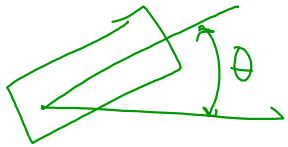
acceleration — linear, angular

What are we mostly?

1. Spatial quantities



$\dot{x} = \frac{dx}{dt}$ $\ddot{x} = \frac{d^2x}{dt^2}$



θ $\dot{\theta} = \frac{d\theta}{dt}$ $\ddot{\theta} = \frac{d^2\theta}{dt^2}$

What else?

distance to something
proximity (close ?)
position
attitude (orientation)
area/volume
tilt
motion detection

? Time

Clock - current time
21:05:16.2 GMT

Chronometer - elapsed time
27.16.2s

Timing
frequency

3. Mechanical quantities
   Solid: Mass, weight, density, force
   Fluid: Acoustic, pressure, flow
   Thermal: Temperature, calori...
4. Electromagnetic quantities
   Voltage, current, charge, ...
   Magnetic field, optical

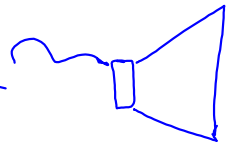
? 6. Chemical
   pH meter ... acidity
   ... activity level
   ... tribologicles

7. Biomedical
   Blood pressure

Sensor Building Blocks

A transducer is a device that converts one form of energy into another.

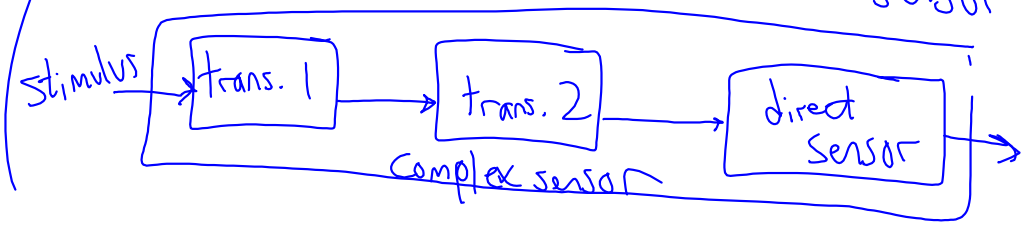
Ex Loudspeaker



electrical signal → magnetic field → acoustic waves

A direct sensor is a transducer that converts energy into an electric signal.

A complex sensor is composed of one or more transducers and a direct sensor



A composite sensor is a sensor that is made from a collection of other sensors that interconnected.

A [illegible] a special case [illegible] ies relative to

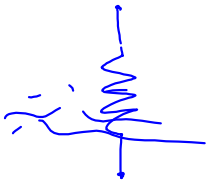
Absolute vs Relative Sensing

An absolute sensor yields values on an absolute scale, independently of measurement conditions.

Absolute: clock

Relative: stopwatch

hourglass



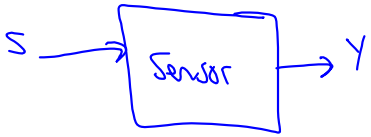
position (coordinates)

distance traveled

temperature

thermistor

Thermocouple



<u>Sensor domain</u> (Span, Full Scale Input)

S - set of all inputs over which the sensor works

<u>Sensor range</u> (Observation space, Full Scale Ouput

Y - set of all possible outputs

Continuous observation space

$Y \subset \mathbb{R}$

or

$Y = [0, \infty) \subset \mathbb{R}$

Discrete observation space

$Y = \{0, 1, \ldots, 255\}$

$Y = \{0, 1\}$

Ideally, should be able to define a <u>transfer function</u> from stimulus to output

$f: S \to Y$

Ex Could be <u>linear sensor</u>

$Y = f(s) = a + bs \quad a, b \in \mathbb{R}$

Ex Could be <u>logarithmic sensor</u>

$Y = a + b \ln s$

Note: If [illegible] injective then we can always (1-1) find $f^{-1}(y)$ to exactly obtain the stimulus, s.

Sensitivity $\left.\frac{df}{ds}\right|_y$

accuracy,

resolution, repeatability,

calibration

temperature sensor

Obs: $\frac{14°C}{C}$ $5.2°C$

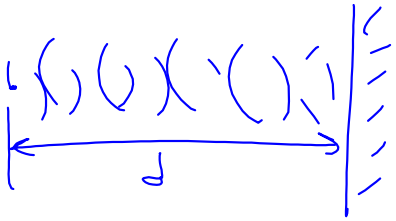
Important Examples of Sensors

Measuring distance

3 common ways:

1) Time of flight
2) Triangulation
3) Field-based

1) Time of flight



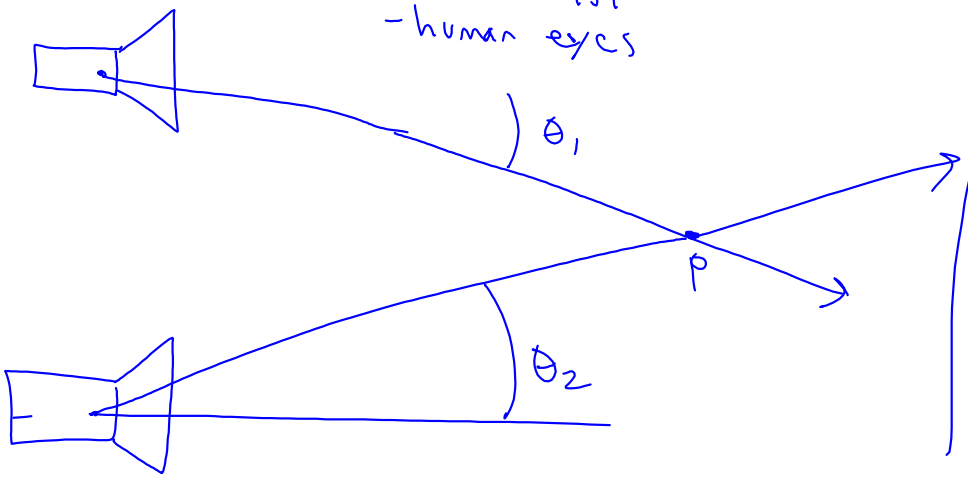
V = wave velocity in a medium

$vt = 2d$ $\quad d = vt/2$

[illegible] using ultrasound
bats
pinging submarines

2) Triangulation

Ex - stereo vision
- human eyes



3) Field based

Could be:
- electromagnetic field
- magnetic
- light field
- WiFi
heat sound

Wikipedia: sensor

list of "interesting" sensors