Sensing, Actuation, & Computation
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Overview

What is sensing? The process of detecting inputs from the environment.

What is actuation? Causing motion to happen.

What is computation? Algorithms.
Related Fields

- Robotics: Roomba, humanoid, DARPA
- Urban elderly care, transportation
- Sensor networks
- Cyber-physical systems (NSF)
- Computer vision

Roomba palindrome

Control theory, actuation, theory of computation

AI
Physical Sensors

real world $\Rightarrow$ electrical signal
(stimulus, measurand)

What $\tau_{fr}$ is modelled?

1. Spatial quantities

\[ x = \frac{dx}{dt}, \quad \dot{x} = \frac{d^2x}{dt^2} \]

\[ \theta = \frac{d\theta}{dt}, \quad \dot{\theta} = \frac{d^2\theta}{dt^2} \]
What else?

distance to something
proximity (cl.,...)
position
attitude (orientation)
area/volume
tilt
motion detection

Time:

21:05:16.2 GMT

Chronometer - elapsed time

27.16.2s

Frequency
3. Mechanical quantities
   Solid: Mass, weight, density, force
   Fluid: Acoustic, pressure, flow
   Thermal: Temperature, calorimetry

4. Electromagnetic quantities
   Voltage, current, charge,
   Magnetic field, optical

5. Proximate activity level
   Epidemiological articles

6. Chemical
   pH meter, toxicity

7. Biomedical
   Blood pressure
Sensor Building Blocks

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

Ex: Loudspeaker

Electrical → magnetic → acoustic waves

A 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.

stimulus → trans. 1 → trans. 2 → direct sensor → complex sensor
A composite sensor is a sensor that is made from a collection of other sensors that interconnected.

Absolute vs Relative Sensing

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

Absolute: clock
Relative: stopwatch

Position (coordinates)

Temperature

Thermistor

Thermocouple
Sensor domain (Span, Full Scale Input)

S - set of all inputs over which the sensor works

Sensor range (Observation space, Full Scale Output)

Y - set of all possible outputs

Continuous observation space
\[ Y = (0, \infty) \subset \mathbb{R} \]

Discrete observation space
\[ Y = \{0, 1, \ldots, 255\} \]
\[ Y = \{0, 1\} \]
Idea: ideally, should be able to define a \textit{transfer function} from stimulus to output $f: S \rightarrow Y$

\textbf{Ex:} could be \underline{linear sensor}

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

\textbf{Ex:} could be \underline{logarithmic sensor}

$Y = at \log_{10} s$

\textbf{Note:} if $f$ is \underline{injective} then we can always find $f^{-1}(y)$ to exactly obtain the stimulus, $s$. 

\textbf{Sensitivity:} $\frac{df}{ds} |_{y}$

\textbf{Accuracy, resolution, repeatability, calibration,}

\underline{Temperature sensor}

\textbf{Obs:} $14^\circ C \rightarrow 5.2^\circ C$
**Important Examples of Sensors**

**Measuring Distance**

3 common ways:

1) **Time of Flight**

2) **Triangulation**

3) **Field-based**

1) **Time of Flight**

\[ t = \frac{2d}{v} \]

\[ v = \text{wave velocity in a medium} \]

\[ d = \frac{vt}{2} \]

- Uses ultrasonic boats or pinging submarines
2) Triangulation

- stereo vision
- human eyes

\[ \theta_1 \]

\[ \theta_2 \]

3) Field based

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

Could be, i.e.
Wikipedia: Sensor

list of "interesting" sensors