Modern Sensor Systems

Sensors, Systems, Materials & Nanotechnology

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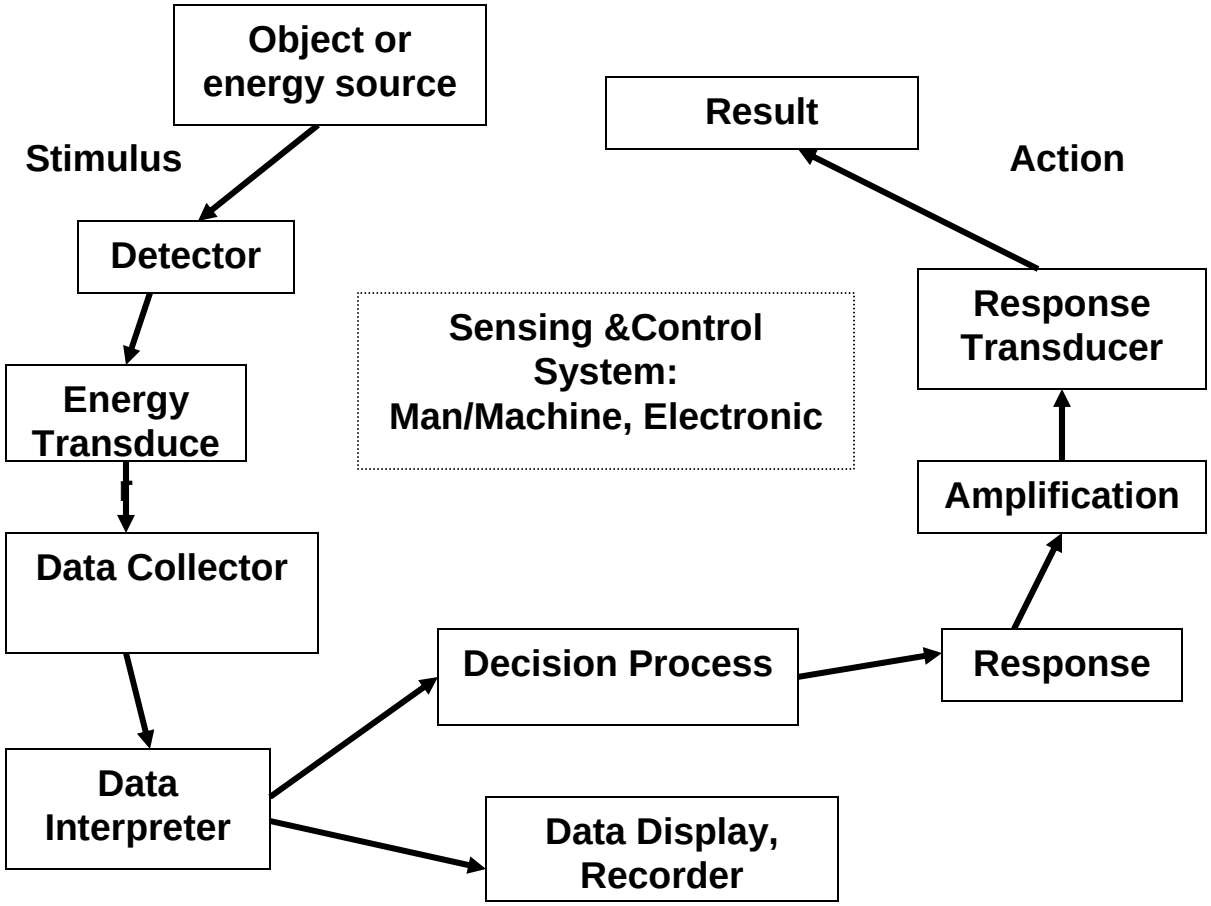
Modern Sensor Systems

- Why Sensors?
  - Interface: Physical World Versus Electronic
- World: inherently analog phenomena
- Diversity of technologies…
- Where does “Nano” come in to play.

Systems Level Perspective:



Sensor Classification

- So Much to Sense!
  - Diversity
- “Let Me Count the Ways” (to Measure)!
  - Review: White, Richard M. “A Sensor Classification Scheme,” IEEE Trans. Ultrason. Ferrolec. Freq. Contr., UFFC-34, no. 2, pp 124-126, March 1987.
- Best Way: Performance vs. Cost

Sensor System Design: Global Issues

- What is to be measured?
  - Measurand/Stimulus (examples):
    - Distance/orientation/velocity/acceleration
    - Time
    - Temperature
    - Force/strain/pressure/weight/sound
    - Fields/magnetic/electric
    - Radiation/light/images
    - Chemistry/identification/reactivity/rates/acidity
    - Current/voltage/phase/power

Sensor System Design: Global Issues

- How it is to be measured?
  - Delta of physical phenomena (examples):
    - Current/voltage/phase/power (energy)
    - Resistance/capacitance/inductance
    - Operation: passive vs. active

Sensor System Design: Global Issues

- How well is it to be measured?
  - Performance criteria: (examples):
    - Sensor vs. system
    - Transfer/response function
    - Sensitivity/responsively
    - Resolution(units)/accuracy(errors)/quantization/repeatability
    - Range/span/linearity(non-linearity)/hysteresis(dead band)
    - Response time/recovery time/saturation/overload response

    - Calibration
    - Environmental characteristics/reliability/drift

    - NOISE/interference/discrimination/selectivity
    - Repeated measurements vs. multiple sensors

Detection/Transduction Phenomena

- Physical
- Chemical
- Biological

Challenge: Keep it Simple…

- Many useful Phenomena:
  - Resistance/Capacitance/Inductance
  - Optical/Mechanical..piezo…?/
  - Etc…

  - Resistance Examples:
    - Distance/position
    - Temperature/moisture
    - Force/acceleration/strain
    - Magnetic

Noise Sources (Devil in the Details)

- Fluctuations…Inherently Statistical
- Thermal fluctuations
  - Resistor noise?
  - Capacitor noise?
- Quantized events
  - Shot noise
    - Photon noise

Signal to Noise Ratio (SNR)

- Johnson noise
  - $V_{rms} = (4k_BTR_oB_w)^{1/2}$ (volts)
    - k_B (Boltzman Constant)
    - T (Temperature in degrees Kelvin)
    - R_o (Resistance in Ohms)
    - B_w (Bandwidth in Hertz)

Example Sensor Devices

- Show and Tell
  - Distance/velocity/acceleration
    - Resistance, acoustics, optics, inductive
  - Vibration/Force
    - Accelerometer-gravimetric MEMS, piezoelectric, inductive, strain gage (resistance)
  - Temperature
    - Expansion, resistance, diode, pyroelectric, optical etc.
  - Etc….