Fuzzy Data Fusion

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Data Fusion

❖ Sensor measurements are imprecise
   – noise
   ▷ deficiency of complete understanding of the principles governing the operation of the sensor
   ▷ incomplete knowledge of the environment
   ▷ tolerances added during manufacturing
   ▷ receptiveness to environmental conditions
   – sensor failure (wear, …)
   – system dynamics

Redundant Sensor Systems

❖ Use several sensors measuring the same quantity
❖ Issues:
   what if they disagree?

Sensor Validation

❖ Ensure that measurement is correct within bounds
❖ Approach
   – Model system behavior
   – Compare sensor value to predicted value
   – Assign confidence
   – Adjust model

Sensor Fusion

❖ Integrate information from several sources
❖ Traditional Methods:
   – Voting
     ▷ Most likely one
     ▷ Best one
     ▷ Closest to model
   – Average
   – Weighted average
**Sensor Validation & Fusion Scheme**

- Sensor Validation
- Sensor Fusion
- Machine Level Controller
- Supervisory Controller
- Diagnosis

**FUSVAF**

- Fuzzy Sensor Validation and Fusion

1. Raw sensor readings
2. Fuzzy validation gate
3. Fuzzy sensor validation and fusion
4. Diagnoses
5. Machine level controller/supervisory controller

**Validation Gates**

- z_i: sensor measurements
- σ_i: sensor confidence values
- z(k): predicted value
- x(k-1): old value at previous time step

**Operative Equation for Fusion**

\[ \hat{x}_k = \frac{\sum(z_i \sigma_i) \alpha_i}{\sum(z_i) \sigma_i} \]

- \( \hat{x}_k \): fused value
- z_i: measurements
- σ_i: confidence values
- \( \alpha \): adaptive parameter representing the system state
- \( \sigma \): constant scaling factor
- \( \hat{x} \): expected value

**FEWMA**

- Fuzzy Exponential Weighted Moving Average
  \[ x(k+1) = \alpha x(k) + (1-\alpha)y(k) \]

- Make \( \alpha \) adaptive depending on system state
  - IF change of readings small THEN \( \alpha \) large
  - IF change of readings medium THEN \( \alpha \) medium
  - IF change of readings large THEN \( \alpha \) small.

**Design of Membership Functions**

- Maximum overlap
- Triangular shaped functions
- Need only two parameters
Intelligent Vehicles Highway Systems

- Intelligent Vehicle Highway System (IVHS)
- Increase safety and highway capacity
- Closely spaced automated vehicles traveling at high velocities
- Needs lots of sensors

Fusion Scheme Applied to IVHS

IVHS in action