Fuzzy Data Fusion

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Information Fusion

- Data Fusion
- Feature Fusion
- Decision Fusion

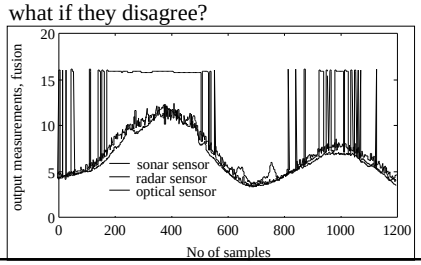
Data Fusion

- 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?



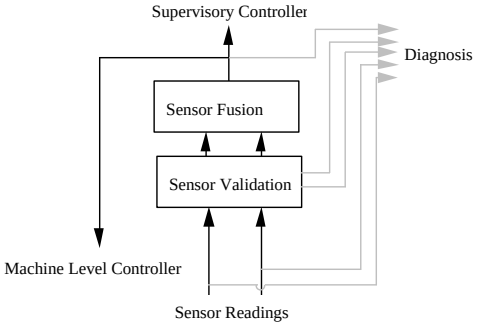
Sensor Validation

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

Sensor Fusion

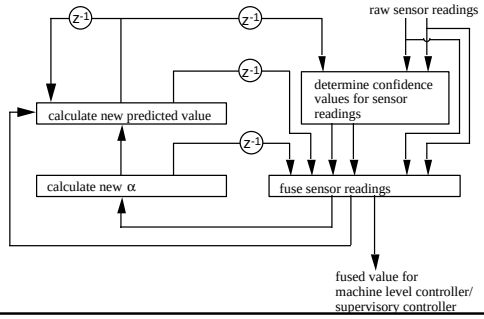
- Integrate information from several sources
- Traditional Methods:
  - Voting
    - Most likely one
    - Best one
    - Closest to model
  - Average
  - Weighted average

Sensor Validation & Fusion Scheme

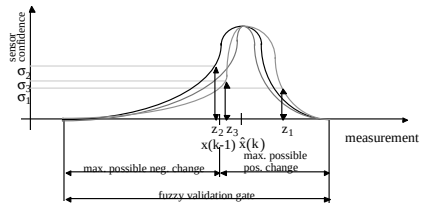


FUSVAF

- Fuzzy Sensor Validation and Fusion



Validation Gates



- **z_i sensor measurements**
- **σ_i sensor confidence values**
- **$\hat{x}(k)$ predicted value**
- **x(k-1) old value at previous time step**

Operative Equation for Fusion

$$\hat{x}_f = \frac{\sum_{i=1}^{n} z_i \sigma(z_i) + \frac{\alpha \hat{x}}{\omega}}{\sum_{i=1}^{n} \sigma(z_i) + \frac{\alpha}{\omega}}$$

- **$\hat{x}_f$: fused value**
- **z_i: measurements**
- **σ: confidence values**
- **α: adaptive parameter representing the system state**
- **ω: constant scaling factor**
- **$\hat{x}$: expected value**

FEWMA

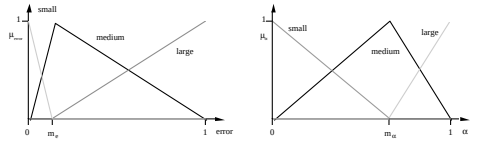
- Fuzzy Exponential Weighted Moving Average

$$\hat{x}(k+1) = \alpha\hat{x}(k) + (1-\alpha)y(k)$$

- Make α adaptive depending on system state
  - *IF change of readings small THEN α large*
  - *IF change of readings medium THEN α medium*
  - *IF change of readings large THEN α small.*

Design of Membership Functions

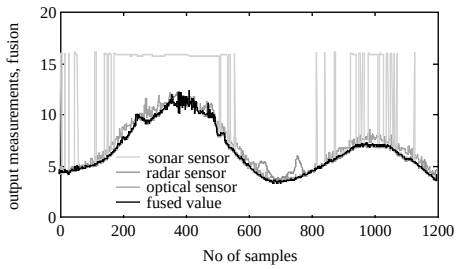
- maximum overlap
- triangular shaped functions
- need only two parameters



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