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

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

FUSVAF
- Fuzzy Sensor Validation and Fusion

- raw sensor readings
- determine confidence values for sensor readings
- fuse sensor readings
- fused value for machine level controller/supervisory controller

- calculate new predicted value
- calculate new $\alpha$
Validation Gates

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

Operative Equation for Fusion

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

- $\hat{x}_f$: fused value
- $z_i$: measurements
- $\sigma$: confidence values
- $\alpha$: adaptive parameter representing the system state
- $\omega$: 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 \( \alpha \) 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.

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**Design of Membership Functions**

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

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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

last slide