### Fuzzy Applications

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### Feedback Control Systems

State equations for linear feedback control system

\[
\dot{x}(t) = Ax(t) + Bu(t) \quad \text{plant dynamics}
\]

\[
u(t) = Kx(t) \quad \text{linear controller}
\]

where

- A: system matrix
- B: controller input
- K: measurement matrix

### FLC

1. Define Observed states & control actions
2. Fix how observations are expressed as fuzzy sets
3. Design rule base
4. Supply algorithms for fuzzy inference
5. Determine defuzzification method

### Engine-Boiler FLC

1. Define Observed states & control actions

**Observed Variables:**  
steam pressure in boiler  
speed of engine

**Control Actions:**  
heat input change in controller  
throttle opening change of engine

States are described as deviation from a standard

### Engine-Boiler FLC

2. Fix how observations are expressed as fuzzy sets

- Error & change of error are quantized into points
- Assign grades of membership for
  - positive big (PB)
  - positive medium (PM)
  - positive small (PS)
  - positive nil (PO)
  - negative nil (NO)
  - negative small (NS)
  - negative medium (NM)
  - negative big (NB)

Pressure Error and Speed Error are quantized into

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Note: 0 is divided into +0 (just above set point) and -0 (just below set point)  
Same is done for Change in Pressure & Speed Error, Heat Change and Throttle Change
Engine-Boiler FLC

3. Design rule base
If PE = NB and CPE = not(NB or NM) then HC = PB
If PE = (NB or NM) and CPE = NS then HC = PM
If PE = NS and CPE = (PS or NO) then HC = PM
If PE = NO and CPE = (PB or PM) then HC = PM
If SE = NB and CSE = not(NB or NM) then TC = PB
If SE = NM and CSE = (PB or PM or PS) then TC = PS
IF SE = NS and CSE = (PB or PM) then TC = PS
If SE = NO and CSE = PB then TC = PS

Temperature Controller
Omron uses a hybrid system using a PID controller amended by a fuzzy unit to compensate for disturbances and to reduce overshoot.
Consider the following controller:

\[ u = \frac{1}{u_{\text{max}}} x \]

reduce deviation from desired line and change of deviation

Controller Design

Rulebase

Output of Controller - Surface Plot
Japanese Research Labs

- Human Features and Interface Control Recognition
- Image Understanding
- Handwritten Character Recognition
- Social Phenomena
  - Fuzzy Information Retrieval
  - Reliability Estimation
  - Earthquake Prediction
  - Modeling of Plant Growth

Other Early Applications

- Group Control Operation of Elevators (Hitachi)
  - during rush hour, it scatters the operation of elevators to reduce waiting and idling times
- Ventilation System in Expressway Tunnels (Toshiba)
  - depending on the amount of traffic, it lessens the number of times the fans are switched off and on => save electricity, prolong life of fans
- City Garbage Incinerators (Mitsubishi)
  - regulating the thickness of the layers of garbage => reduce damage to incinerators
- Powder substance measuring system (Fuji)
  - Process supply flow speed of powder substances => attain high grade measurement

Fuzzy Consumer Goods

- Fuzzy Washing Machine (Panasonic): amount, type, dirtiness for water quantity, water flow speed, and cycle times
- Fuzzy Vacuum Cleaners (Matsushita)
- Fuzzy Refrigerators (Sharp)
- Fuzzy fans, heaters, air conditioners, etc.
- Sendai Subway water tank
- Cameras & Camcorders (focus, exposure, zoom, handshaking
- Photocopiing (Ricoh, ...) humidity, temperature for toner
- TV ambient brightness and distance to viewer for image quality

Image Processing Equipment (Canon) - Decision Making

- Autofocus
  - earlier cameras used the object centered in the field of view as the desired focus. In case of two objects, errors occur.
  - fuzzy reasoning measures the distances to three points. Using these locations and the relationships between them to determine the focus. 300 pictures were taken by 8 persons to come up with a reasonable set of fuzzy rules.
  - Focus on center: 73.6%
  - Fuzzy focus: 96.5%

Canon Autofocus

- IF C is near THEN P is high
- IF L is near THEN P is high
- IF R is far AND C is medium AND L is near THEN P is very high

Minolta

- Autofocus
  - similar to Canon’s
- Autoexposure
  - exposure:
    - brightness from 14 zones
    - position of main subject
    - shutter speed, aperture:
      - scene
      - type of lens
- Autozoom
  - correct for moving object
Camcorders

Sanyo:
- Autofocus
  - high frequency components
- brightness
- Autoexposure
- Auto-White Balancing
  - establish color reference (white)
  - assume many colors in image
  - average these out

More Camcorders

Image Stabilization
- camcorders become smaller
  => handshaking becomes more acute
- compare successive frames to compute spatial difference of 30 subareas
- if there are no moving objects, then net difference is very small
  compensate with the frame in memory

HMS (Omron) - Fuzzy Expert System

Balances diet, stress, physical exercise, work activities for employees of large corporations.
Expert system with fuzzy logic inference mechanism (500 rules). Knowledge base contains medical knowledge
Input:
  - medical history, family history, social history, lab data, physical exam, fitness data
Output:
  - personal diagnosis, health maintenance guide, preventative measures.

Motion Planning for Auton. Vehicles

Navigation Control under uncertainty about the environment
Planning issues:
- incomplete knowledge about environment
  - metric information imprecise
  - environment may have changed
- reliability of information
  - sensor noise
  - limited range
  - occlusion
- control action not reliable

Autonomous Vehicles - FLAKEY (SRI)

Building Blocks are expressed as behavior
- IF obstacle close in front
- AND NOT obstacle close on left
  THEN turn sharp left
Desirable traits are expressed as preferences
- Compute desirability of action wrt to goal

Fuzzy Application - Rest of the World

Fuzzy Battery Charger charging time - overcharging
Fuzzy Transmission - Volkswagen
Fuzzy Docking Maneuver - NASA Space Shuttle
Fuzzy Cement Kiln
Fuzzy Water Treatment Plant
Fuzzy Chemical Process Control
Fuzzy Train Control