Fuzzy Applications

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Feedback Control Systems

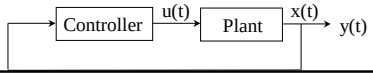
State equations for linear feedback control system

$\dot{x}(t) = Ax(t) + Bu(t)$ **plant dynamics**

$u(t) = Kx(t)$ **linear controller**

where

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



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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

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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

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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)

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Engine-Boiler FLC

Pressure Error and Speed Error are quantized into

	-6	-5	-4	-3	-2	-1	+0	-0	1	2	3	4	5	6
PB	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.8	1
PM	0	0	0	0	0	0	0	0	0	0.2	0.7	1	0.7	0.2
PS	0	0	0	0	0	0	0	0.3	0.8	1	0.5	0.1	0	0
PO	0	0	0	0	0	0	0	1	0.6	0.1	0	0	0	0
NO	0	0	0	0	0.1	0.6	1	0	0	0	0	0	0	0
NS	0	0	0.1	0.5	1	0.8	0.3	0	0	0	0	0	0	0
NM	0.2	0.7	1	0.7	0.2	0	0	0	0	0	0	0	0	0
NB	1	0.8	0.4	0.1	0	0	0	0	0	0	0	0	0	0

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

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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

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Engine-Boiler FLC

4. Supply algorithms for fuzzy inference (previous lecture)
5. Determine defuzzification method (previous lecture)

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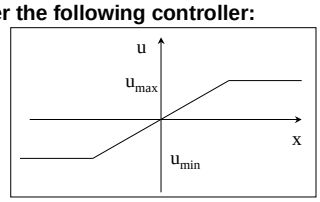
Temperature Controller

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:



reduce deviation from desired line and change of deviation

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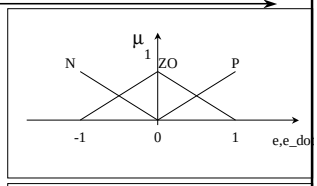
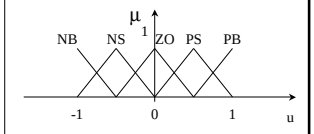
Input



Output



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Controller Design

Rulebase

$\dot{e}$ \ e	N	Z	P
N	PB	PS	ZO
Z	PS	ZO	NS
P	ZO	NS	NB

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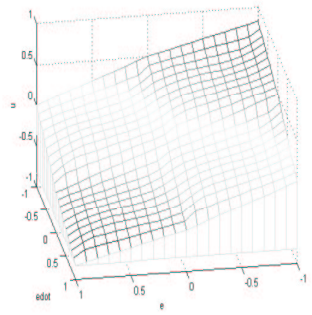
Output of Controller - Surface Plot



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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

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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 live 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

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Fuzzy Consumer Goods

Fuzzy Washing Machine (Panasonic); amount, type, dirtiness for water quantity, water flow speed, and cycle times

Fuzzy Vacuum Cleaners (Matsushita)

Fuzzy Rice Cookers (Hitachi)

Fuzzy Refrigerators (Sharp)

Fuzzy fans, heaters, air conditioners, etc.

Sendai Subway water tank

Cameras & Camcorders focus, exposure, zoom, handshaking

Photocopiers (Ricoh, …) humidity, temperature for toner

TV ambient brightness and distance to viewer for image quality

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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%

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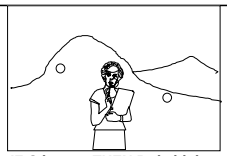
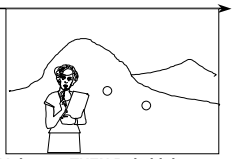
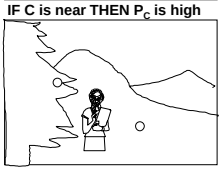
Canon Autofocus



IF C is near THEN P_C is high



IF L is near THEN P_L is high



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

inference realized on a 4-bit microcontroller with a 500-byte memory; on market in 1989

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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

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Camcorders

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

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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

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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.

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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

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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

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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

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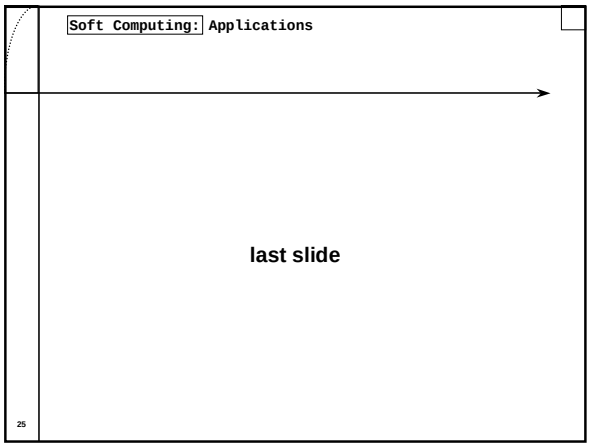
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