Applications of Fuzzy Systems

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# Examples of applications of fuzzy models

- **Fuzzy control**

- **Interfaces**
  - user modeling
  - information retrieval
  - database queries

- **"AI" Systems**
  - Expert Systems
  - Scheduling
  - Decision Support Systems (DSS)

The role of these slides

- Show some applications of fuzzy systems

- Show why and when a fuzzy system could be adopted

- Show some possible ways to design a fuzzy system

What is a control system?

A system able to control the behavior of another system
(a device, a biological body, a plant, a community, the society, …)
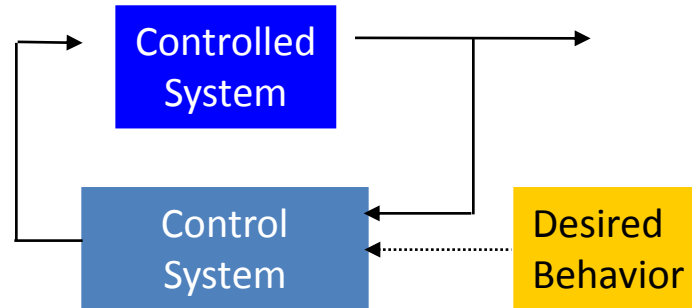
In most cases it is a PID controller, where the output **u** depends on the difference **e** between the desired, and the observed behavior, its derivative (how fast **e** changes) and its integral (how large **e** has been in the past):

$$u = K_P e + K_D \frac{de}{dt} + K_I \frac{1}{T} \int_0^t e\, dt$$

What is a fuzzy control system?
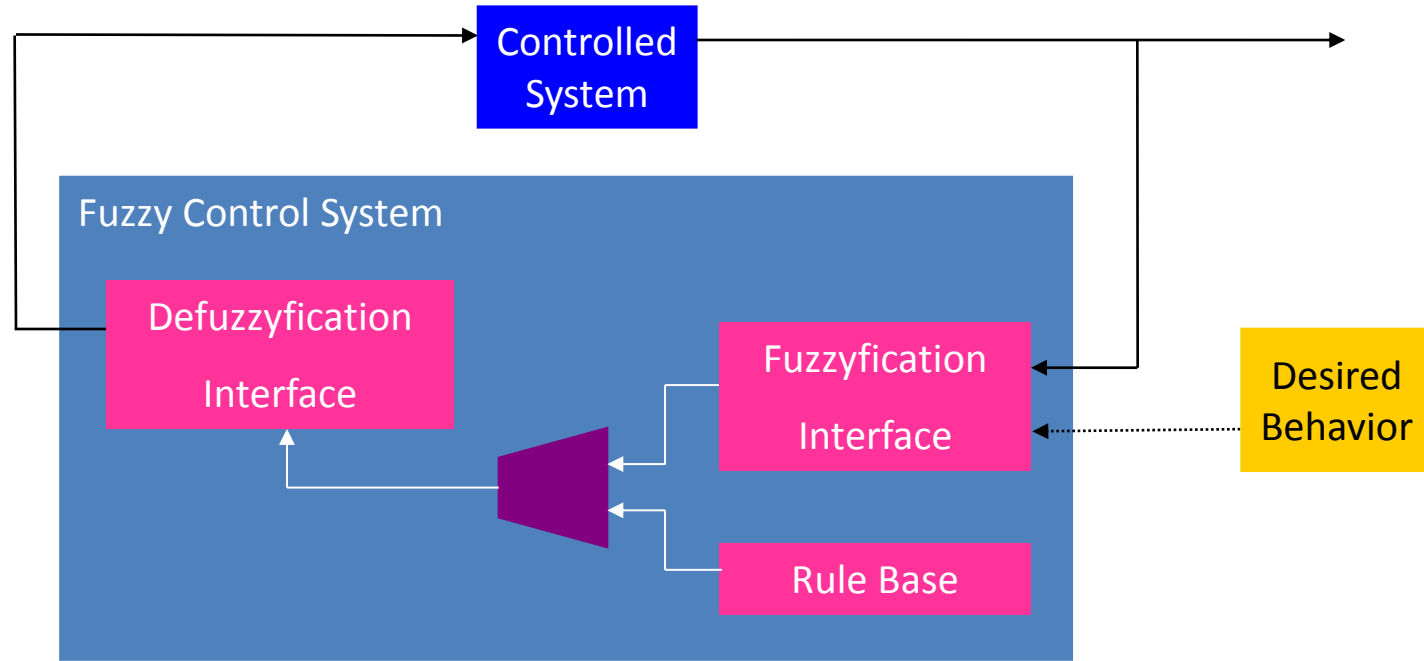
Why fuzzy control is so successful?

Interesting features:

- Robustness w.r.t. noise
- Control rules defined over a wide range of applicability
- Possibility to model heuristics from experts
- Smoothness of action
- Non linearity

Example FLC - 1: Wide range of variable values

1985: Sendai (Japan) metro

Goal: Control train stop

Why fuzzy?

Different load conditions in the different stations

Results

- Energy saving
- Precision
- Higher comfort

Example FLC - 2: wide range of variable values

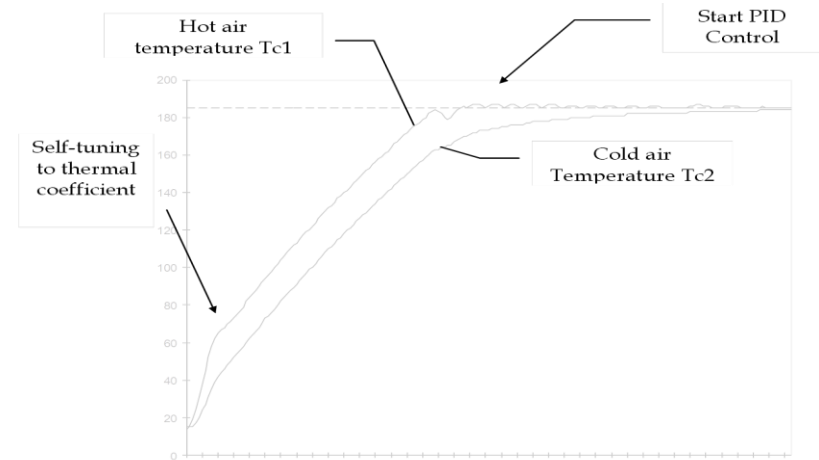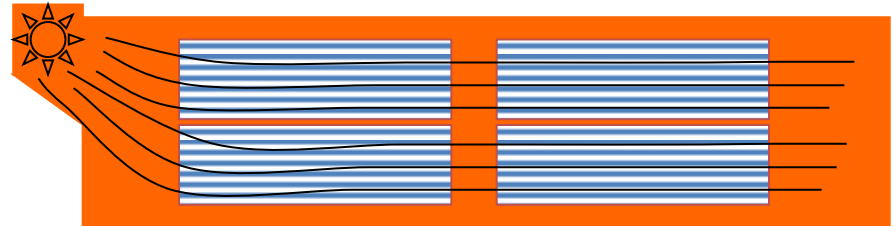1996: oven for alluminum bars aging

Goal: reach the aging temperature according to technological constraints, in the shortest time

Why fuzzy?
- Need to adapt to different load conditions (10,000 different profiles)
- Low quality of sensor data (air temperature at the end of the bars)

Results
- Energy saving
- Higher speed
- No need to continuously tune the system

Example FLC - 3: noisy systems

1990: mini-helicopter in windy days (Japan)

Goal: Control the stability and movement of the helicopter

Why fuzzy?

No forecast about the situation

Results

It flies…

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Example FLC - 4: Low cost control

1990: fuzzy video cameras, fuzzy vacuum cleaners, fuzzy washing machines, fuzzy refrigerators, fuzzy rice cookers, fuzzy taps…

Why fuzzy?

- Simplify the interaction with the user
- Nice performance at a low cost (low cost sensors, low cost processors, …)

Results

Reliable and simple mass products at a cost compatible with the market

FLC-4 – An example: fuzzy washing machine

Goals:
1. recognize the kind of fabric and adapt washing
2. rinse till needed
3. adapt to the water hardness

How:
1. Measure the charging time of a condenser and the number of pressostate activations
2. measure the dielectric coefficient of the water at the beginning and rinse till it become the same at the end
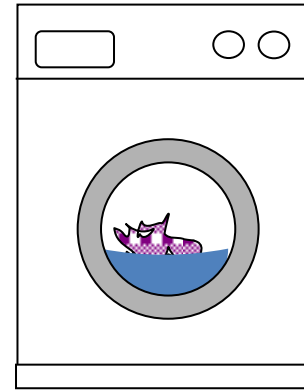
Example FLC - 5: control of complex systems

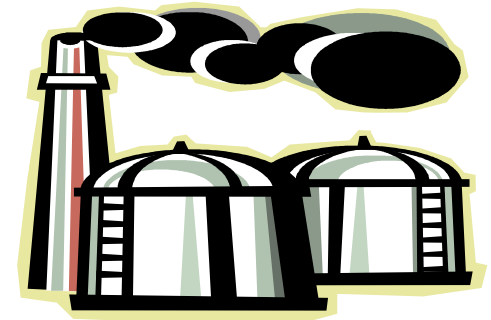1986: cement kiln, chemical plants

Goal: control the plant

Why fuzzy?

- hard to define and parametrize a mathematical model
- experts available (operators)

Results

- effective and robust control
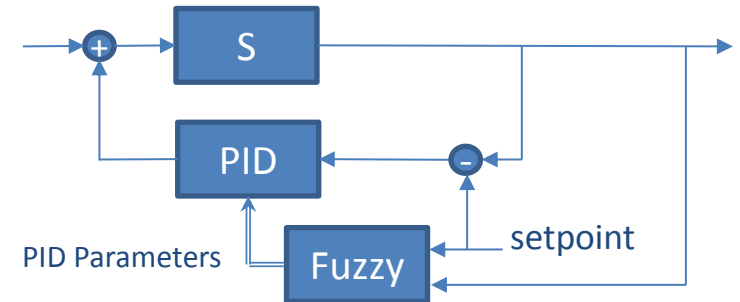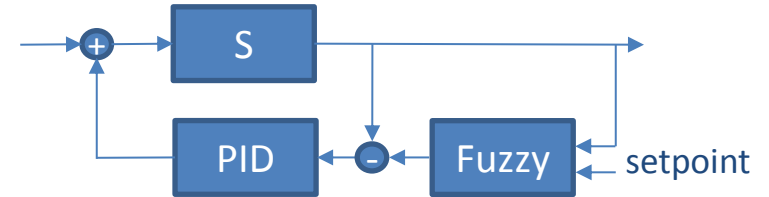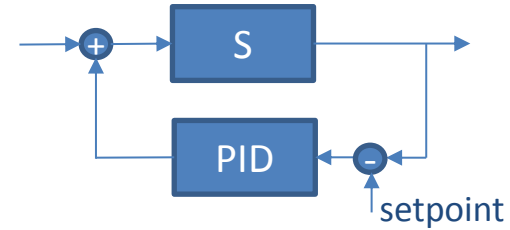
Example FLC - 6: hybrid control
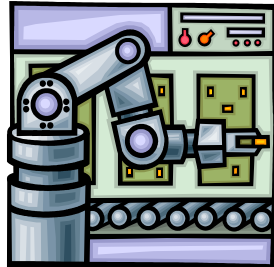
1990: temperature sensor, robot arm, ...

Why fuzzy + PID?

Extend the range of applicability of a PID

Results

Fast control without overshooting

Example FLC - 7: high-level control

1998: autonomous robot

Goal: implement behaviors for the robot

Why fuzzy?
- Clear representation of control rules
- High level tasks

Results

Good control developed in a short time

Example FLC - 8: Noisy sensors

2012: Jedi trainer

Why fuzzy?

Very noisy interpretation of sensor data

Results: Smooth adaptation and believable behavior

Fuzzy databases and information retrieval

Flexible queries with human-like sensibility

E.g.:

"Give me the names of all the people that have **recently** invested **a lot**"

SELECT Name, MatchingRate
FROM Investments
WHERE ((InvestmentDate is Recent) 0.8) AND ((InvestedAmount is Large) 0.5)

Name	InvestmentDate	InvestedAmount
PAOLO BIANCHI	28	310
MARTA ROSSI	10	170
...		

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Fuzzy databases and information retrieval

Flexible queries with human-like sensibility

E.g.:

"Give me the names of all the people that have **recently** invested **a lot**"

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Fuzzy databases and information retrieval

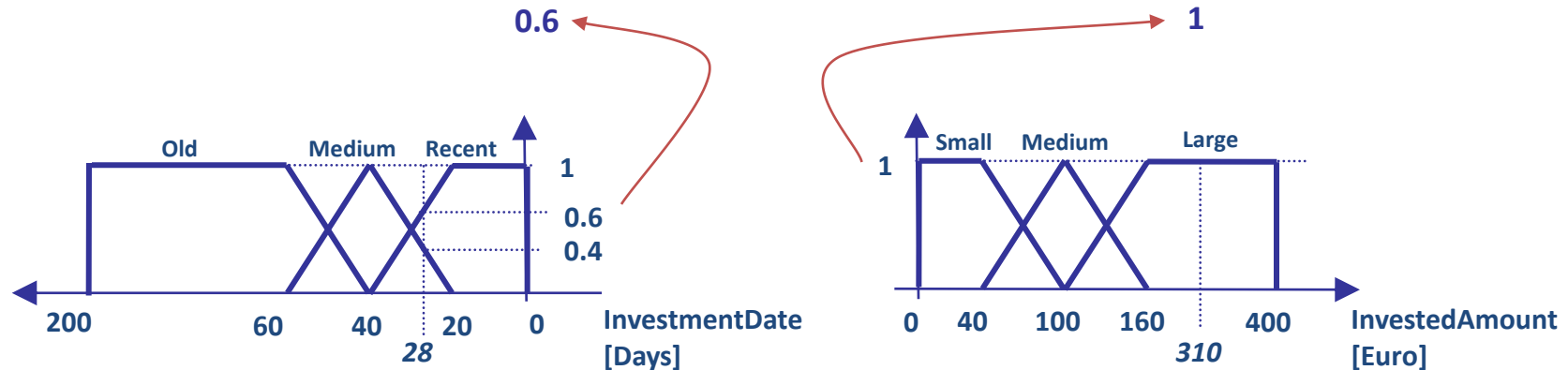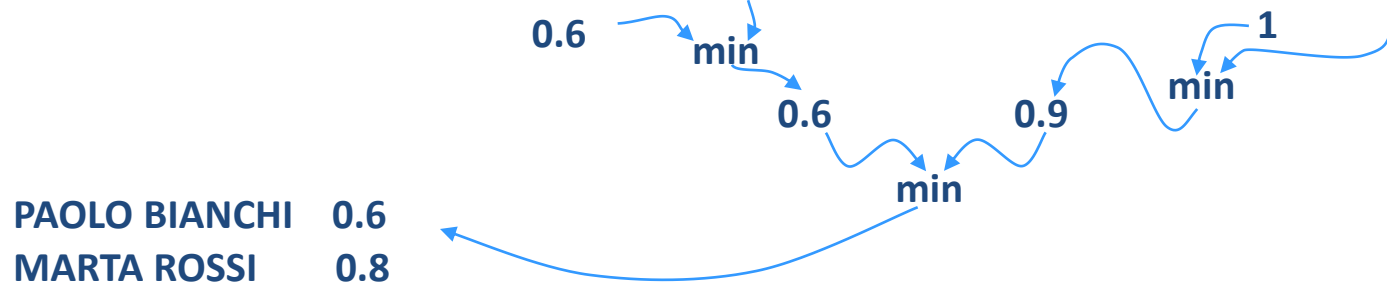Flexible queries with human-like sensibility

E.g.:

"Give me the names of all the people that have **recently** invested **a lot**"

SELECT Name, MatchingRate
FROM Investments
WHERE ((InvestmentDate is Recent) 0.8) AND ((InvestedAmount is Large) 0.9)

0.6 → **min**

min ← 1

0.6   0.9

min

PAOLO BIANCHI   0.6
MARTA ROSSI   0.8

Fuzzy databases and information retrieval

"Give me the names of all the people that have **recently** invested **a lot**"

(A much better alternative)

SELECT Name, MatchingRate
FROM Investments
WHERE ((InvestmentDate is Recent) 0.8) AND ((InvestedAmount is Large) 0.9)

0.6   *   1

0.48   0.9   *

*

PAOLO BIANCHI   0.432
MARTA ROSSI   0.72
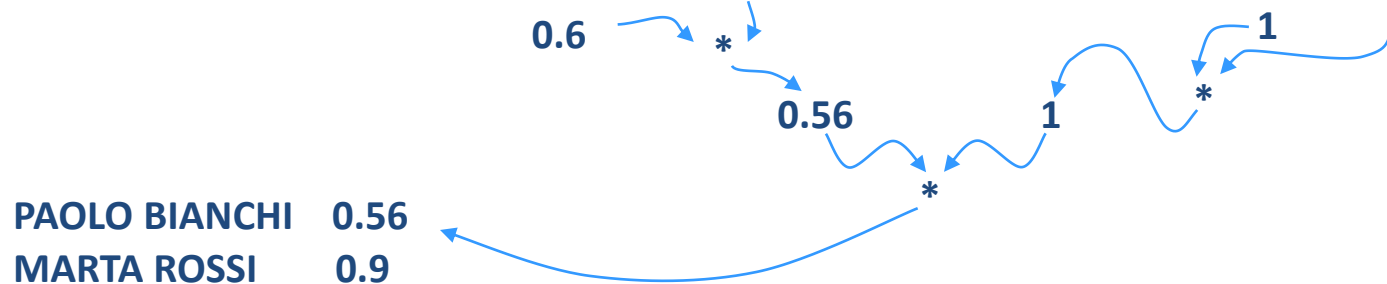
Fuzzy databases and information retrieval

"Give me the names of all the people that have **recently** invested **a lot**"

(An even better alternative)

SELECT Name, MatchingRate
FROM Investments
WHERE ((InvestmentDate is Recent) 0.9) AND ((InvestedAmount is Large) 1)

0.6 → * ←

0.56

1

1 →
* ←

*

PAOLO BIANCHI   0.56
MARTA ROSSI   0.9

Example AIFS - 1: Quality control

Goal:

Control the quality of a product (car, beer,...) in a qualitative way, and relate the results to the part of the production process responsible for eventual problems

Why fuzzy?

Qualitative data from operators

Results

Quality control at low cost: the operator provides data, he/she should not interpret them

Example AIFS - 2: diagnosis

Goal:

Diagnosis of industrial plants in the commissioning phase

Why fuzzy?

- approximate, uncertain data
- approximate diagnostic knowledge, low reliability

Results

- fast diagnosis at low cost
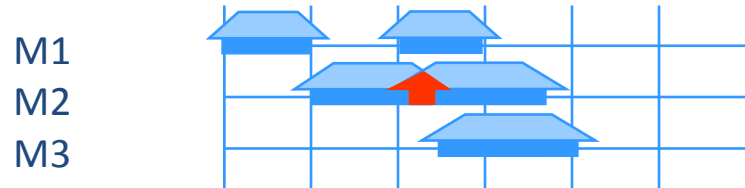- it's easy to understand the diagnostic process

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Example AIFS - 3: scheduling

Goal:

    production scheduling in a job-shop production plant

Why fuzzy?

    fuzzy definition of constraints

M1
M2
M3

Results:

    fast and effective scheduling systems

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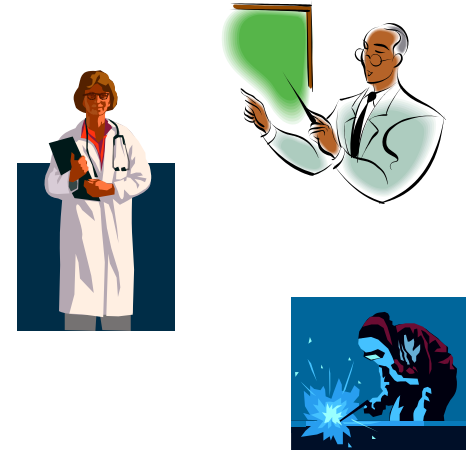
Example AIFS - 4: advice-giving

Goal:

decision support (e.g.: when to buy bonds,
who is the right person for a job,…)

Why fuzzy?
- uncertain and approximate data
- approximate decision process
- shared formal model

Results

suggestions about decisions to be taken,
weighted by criteria that can be easily
defined by the management

Example AIFS - 5: User-modeling

Goal:
model how a driver changes gears in different road situations to implement a robotic gear shift (CRF)

Why fuzzy?
• uncertain and approximate data
• approximate decision process
• high level features synthesized from objective data

Results
adaptive robotic gear shift

What to remember from these slides?

- General design principles
- Potential application fields
- How to decide to adopt a fuzzy system to solve a problem