

Fuzzy Logic and Fuzzy Inference

- Fuzzy Logic
- Fuzzy Sets
- Fuzzy Inference
- Fuzzy Control



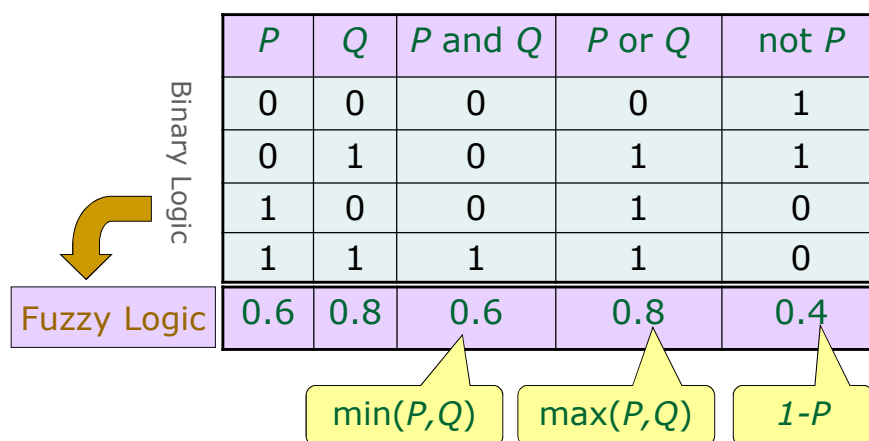
Youtube video

1. **An Egg-Boiling Fuzzy Logic Robot:** KIOS Research Center for Intelligent Systems and Networks, University of Cyprus

Fuzzy Theory

- **What Fuzzy?** -- Fuzzy logic is a tool for Embedding Human Structured Knowledge (Experience, Expertise, Heuristic)
- **Why Fuzzy?** – Human knowledge is fuzzy: expressed in 'Fuzzy' Linguistic Terms – Young, Old, Big, Cheap are FUZZY word. Temperature is expressed as Cold, Warm or Hot. No quantitative meaning

Fuzzy Logic



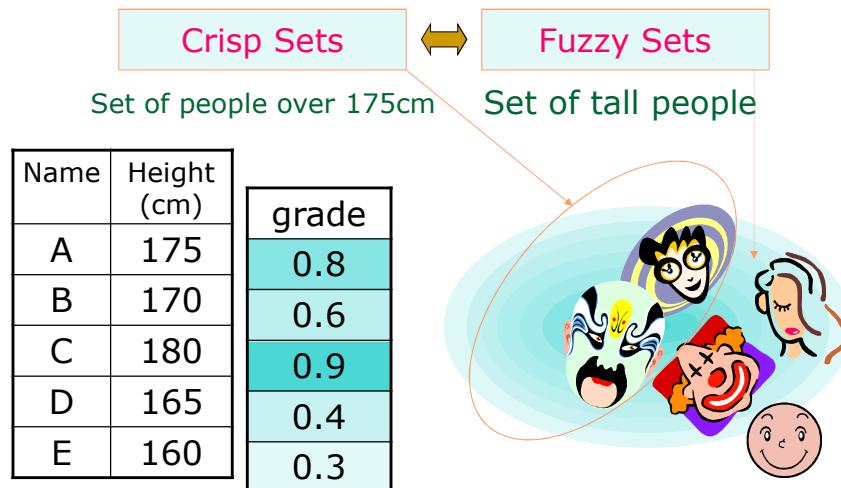
<i>P</i>	<i>Q</i>	<i>P and Q</i>	<i>P or Q</i>	not <i>P</i>
0	0	0	0	1
0	1	0	1	1
1	0	0	1	0
1	1	1	1	0
0.6	0.8	0.6	0.8	0.4

Binary Logic

Fuzzy Logic

$\min(P, Q)$ $\max(P, Q)$ $1 - P$

Fuzzy Sets(1/6) Fuzzy Sets



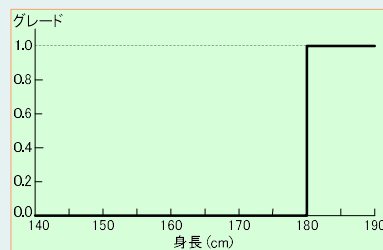
Fuzzy Sets(2/6) Membership Function

Characteristic Function

$$f_A(x): X \rightarrow \{0,1\}$$

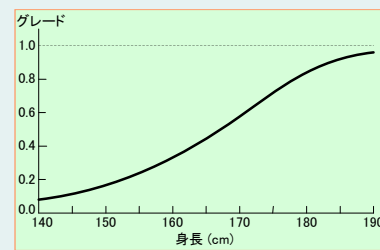
crisp

$$f_A(x) = \begin{cases} 1, & \text{if } x \in A \\ 0, & \text{if } x \notin A \end{cases}$$

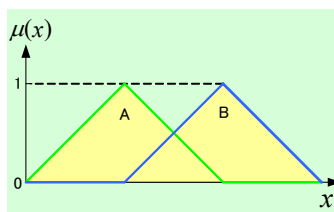


Membership Function

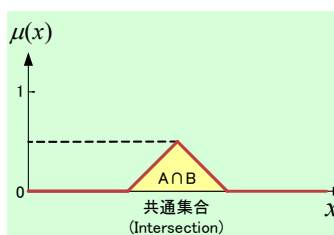
$$\mu_A(x): X \rightarrow [0,1]$$



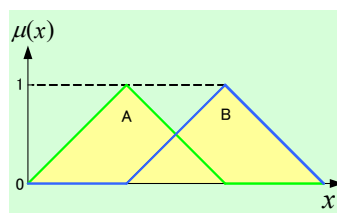
Fuzzy Sets(3/6) Intersection



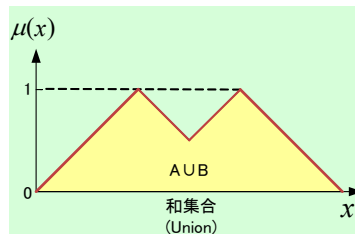
$$\begin{aligned}\mu_{A \cap B}(x) &= \mu_A(x) \wedge \mu_B(x) \\ &= \min[\mu_A(x), \mu_B(x)]\end{aligned}$$



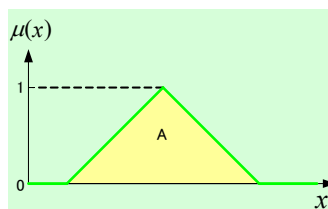
Fuzzy Sets(4/6) Union



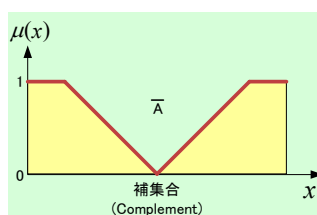
$$\begin{aligned}\mu_{A \cup B}(x) &= \mu_A(x) \vee \mu_B(x) \\ &= \max[\mu_A(x), \mu_B(x)]\end{aligned}$$



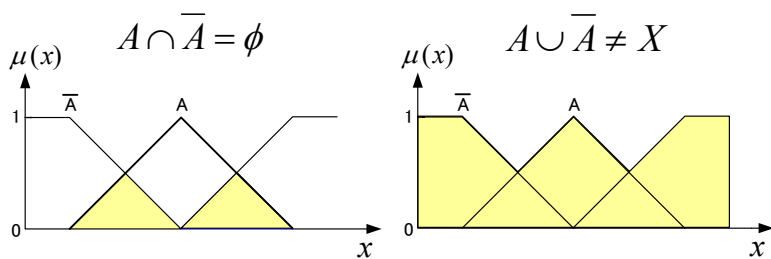
Fuzzy Sets(5/6) Complement




$$\mu_{\bar{A}}(x) = 1 - \mu_A(x)$$



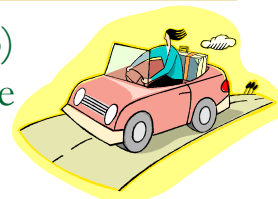
Fuzzy Sets(6/6) Nature don't hold



Fuzzy Inference and Fuzzy Control

Link  A fuzzy-based control system

Fuzzy Inference Example(1/6) Fuzzy Rule

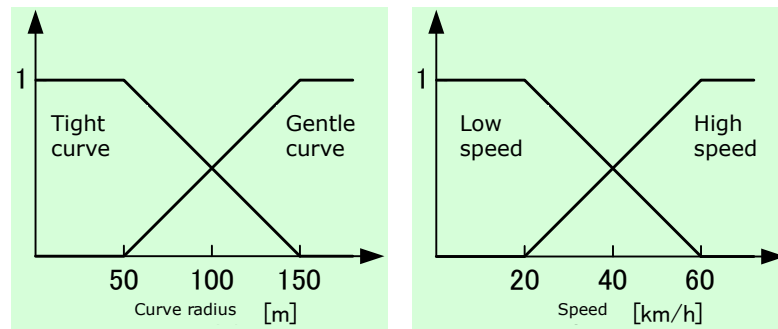


Rule	IF	x is A
	AND	y is B
	THEN	z is C

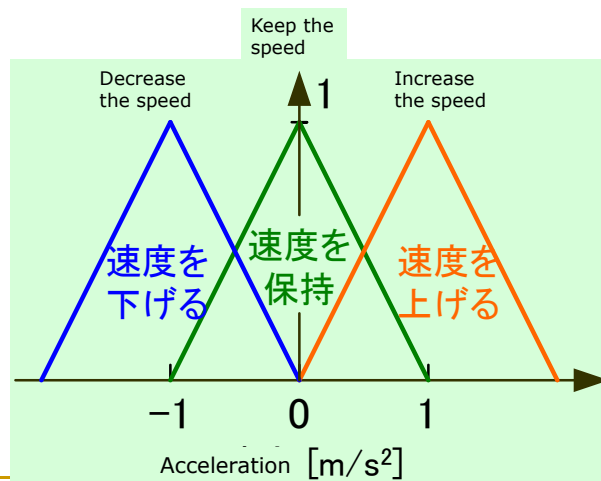
- | | |
|--------|--|
| Rule 1 | If the curve is tight, but the speed is low, then keep the speed |
| Rule 2 | If the curve is tight and the speed is high, then decrease the speed |
| Rule 3 | If the curve is gentle and the speed is low, then increase the speed |
| Rule 4 | If the curve is gentle and the speed is high, the keep the speed |

Question	If curve radius = 60m, speed = 50km/h, acceleration = ?
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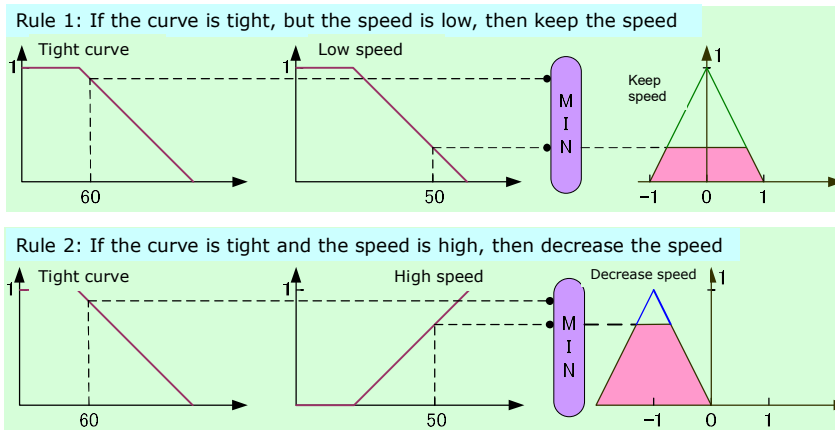
Fuzzy Inference Example(2/6) Membership Function (Antecedent part)



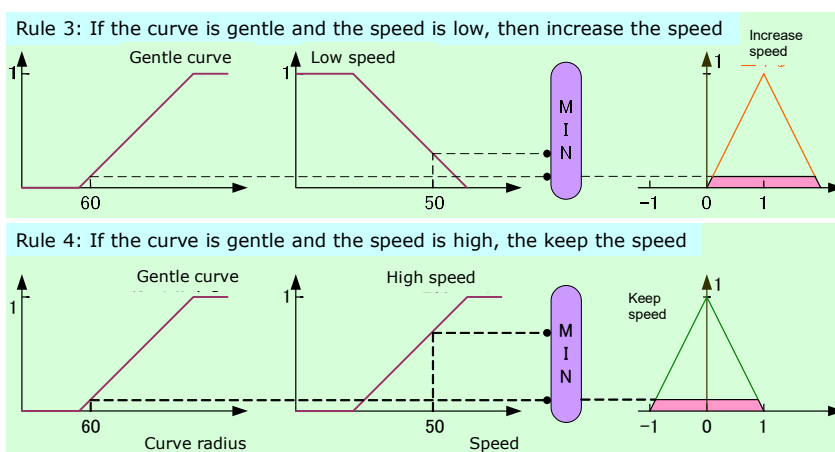
Fuzzy Inference Example(3/6) Membership Function (Consequent part)

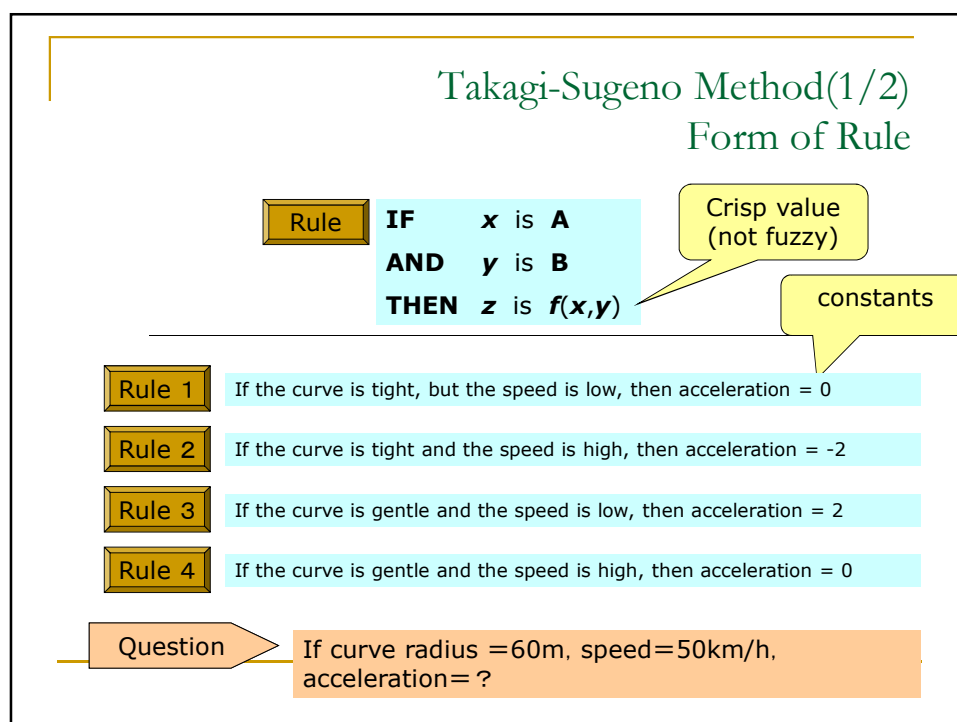
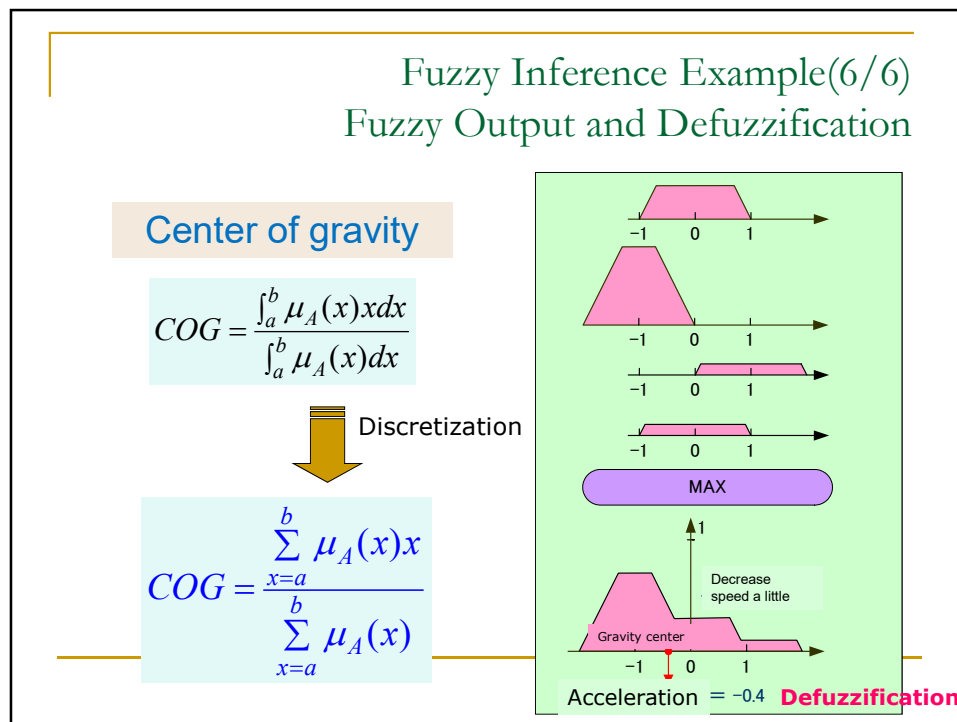


Fuzzy Inference Example(4/6) Rule Evaluation

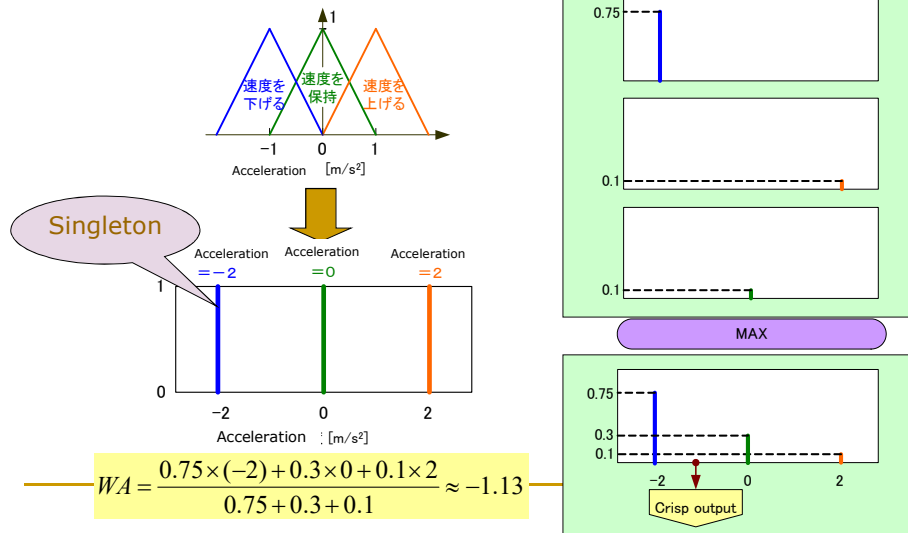


Fuzzy Inference Example(5/6) Rule Evaluation (cont'd)





Takagi-Sugeno Method(2/2) Inference



Design Membership Function

Learning

- Parameterize it, then train the parameters

