Fuzzy Logic Controller ⇒ Used when an exact mathematical formulation of the problem is not possible or very difficult.

It consist of four modules:- a) a fuzzy rule base b) a fuzzy inference engine
c) a fuzzification module d) a defuzzification module

Step-1:- Measurements are taken for all variables that represent relevant inf.

Step-2:- This measurement converted to app. fuzzy sets to express measurement uncertainties.

Step-3:- This set then used by fuzzy engine to evaluate the control rules. The result of this evaluation is a fuzzy set.

Step-4:- The output fuzzy set converted to single crisp value

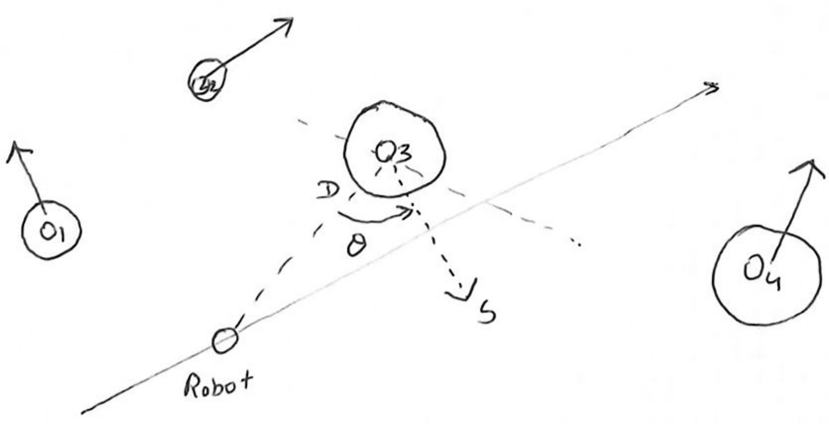
Two approach of FLC

⇒ Mamdani follows linguistic fuzzy modelling & characterized by its high interpretability & low accuracy.

⇒ Takagi & Sugeno's approach follows precise fuzzy modelling obtain high accuracy but the cost of low interpretability.

eg. Mamdani approach: Mobile Robot

We have 4 moving objects, each of equal size with same speed
We have to navigate a robot in their presence



Input for robot we consider two parameters

↳ D : Distance from the robot to an object

→ θ : Angle of motion of an object wrt the robot

Output for robot is decided by value of this input

↳ δ : Deviation.

Now we figure out ranges of both inputs

$D \Rightarrow [0.1, ----, 2.2]\ m$ $\theta \Rightarrow [-90, ----, 0, ----, 90]$ degree

After this mamdani approach is to select some meaningful states called 'linguistic states' for each variable & express them by app. fuzzy sets.

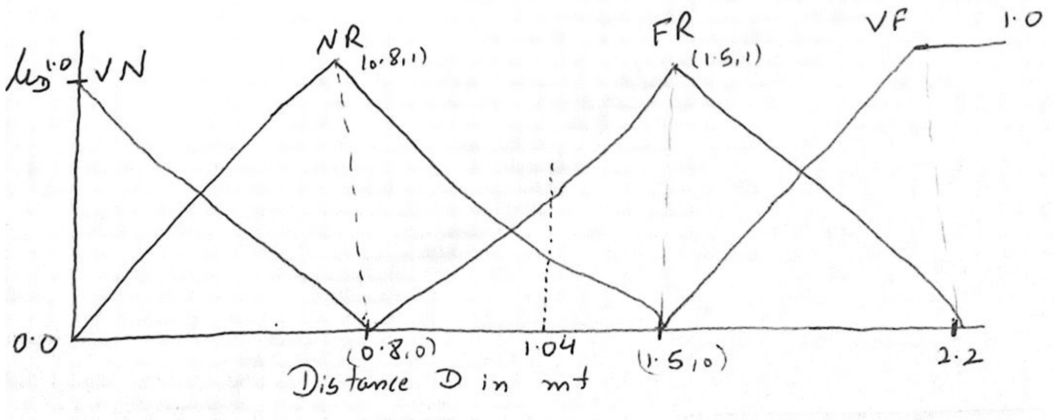
for Distance (D) we using for linguistic states

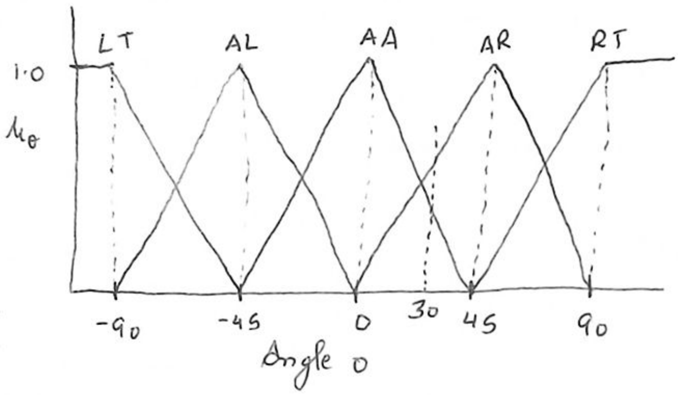
- VN ⇒ Very Near
- NR ⇒ Near
- VF ⇒ Very Far
- FR ⇒ Far

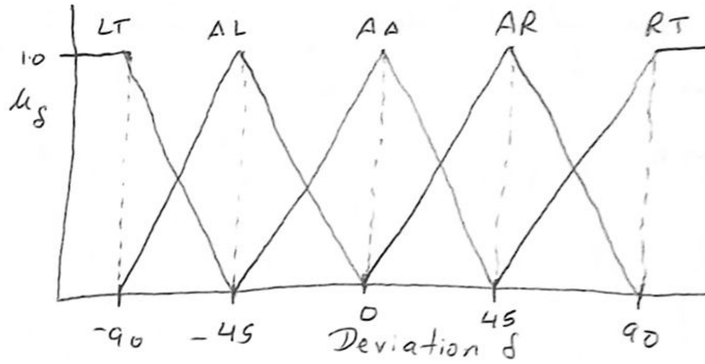
for Angle both (θ & δ) we using five linguistic states

- LT : left
- AL : Ahead left
- AA :- Ahead
- AR :- Ahead Right
- RT :- Right

Membership functions for these sets are







After this we need to design fuzzy rule base for FLC

	LT	AL	AA	AR	RT
VN	AA	AR	AL	AL	AA
NR	AA	AA	RT	AA	AA
FR	AA	AA	AR	AA	AA
VF	AA	AA	AA	AA	AA

4×5

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Rule If x is D, y is θ then Z is δ

So there are 20 rules

Then we do fuzzification of inputs

Let consider an instant of object O_3 $D = 1.04$, $\theta = 30°$

for this we have to decide deviation δ as output

for $D = 1.04\,m$ ⇒ It may be NR (Near) or FR (far)

for $\theta = 30°$ ⇒ It may be AA (Ahead) or AR (ahead right)

for NR $y - 0 = \frac{-1}{0.7}(x - 1.5)$ μ_{NR} at $x = 1.04$ $y = \frac{0.46}{0.7}$ $\mu_{NR\theta}(x) = 0.6571$

for FR = $y - 1 = \frac{1}{0.7}(x - 1.5)$ μ_{FR} at $x = 1.04$ $\mu_{FR}(x) = 0.3429$

for AA = $y - 0 = \frac{-1}{45}(x - 45)$ μ_{AA} at $\theta = 30$ $y = \frac{1}{3}$ $\mu_{AA}(y) = 0.3333$

for AR = $y - 1 = \frac{1}{45}(x - 45)$ $y = \frac{2}{3}$ $\mu_{AR}(y) = 0.6667$

There are many rules in FLC but for given values only 4 rules are applicable

R1:- If Distance is NR & $\dot{\theta}$ is AA then δ is RT

R2:- If D is NR & θ is AR then δ is AA

R3:- If D is FR & θ is AA then δ is AR

R4:- If D is FR & θ is AR then δ is AA

Rule strength computation

$\alpha(R_1) = \min(\mu_{NR}(x), \mu_{AA}(y)) = \min(0.6571, 0.3333) = 0.3333$

$\alpha(R_2) = \min(\mu_{NR}(x), \mu_{AR}(y)) = \min(0.6571, 0.6667) = 0.6571$

$\alpha(R_3) = \min(\mu_{FR}(x), \mu_{AA}(y)) = \min(0.3429, 0.3333) = 0.3333$

$\alpha(R_4) = \min(\mu_{FR}(x), \mu_{AR}(y)) = \min(0.3429, 0.6667) = 0.3429$

In practice all rules which are above certain threshold value of the rule strength are selected for the output computation.

Let threshold value of α be 0.3400

$\alpha(R_2): \min(\mu_{NR}(x), \mu_{AR}(y)) = 0.6571$

$\alpha(R_4) = \min(\mu_{FR}(x), \mu_{AR}(y)) = 0.3429$

Now we have to decide fuzzy output for these values or rules

R_1: If (S_2 is A_1) AND (S_2 is B_1) THEN (f is C_1)

R_2: If (S_1 is A_2) AND (S_2 is B_2) THEN (f is C_2)

S_1^* & S_2^* are input of fuzzy variables S_1 & S_2, $\mu_{A_1}, \mu_{A_2}, \mu_{B_1}, \mu_{B_2}$, μ_{C_1}, μ_{C_2} are memb. values for diff fuzzy sets

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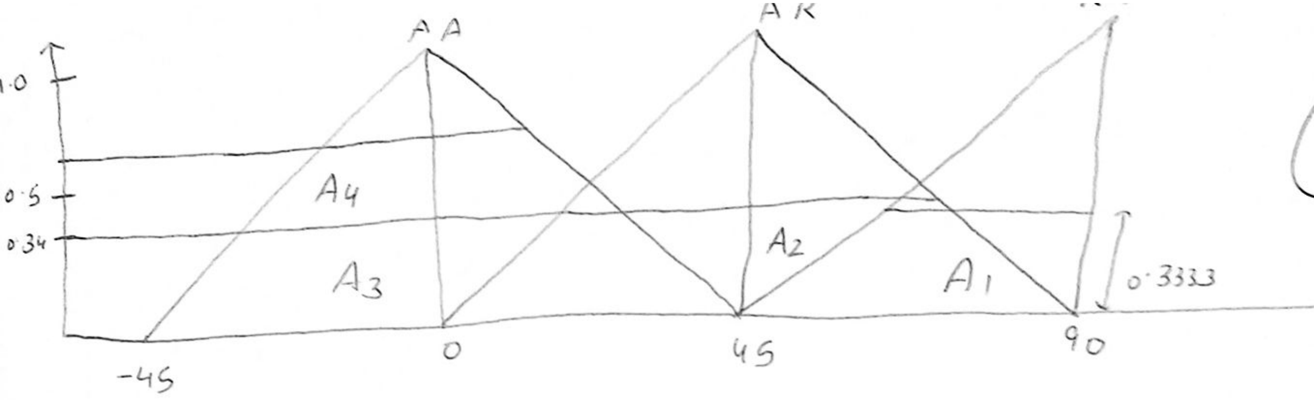
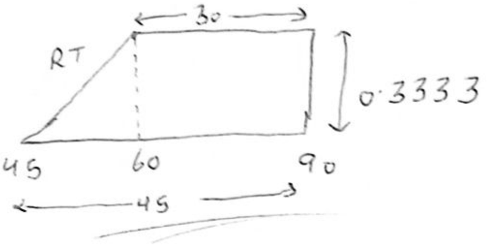
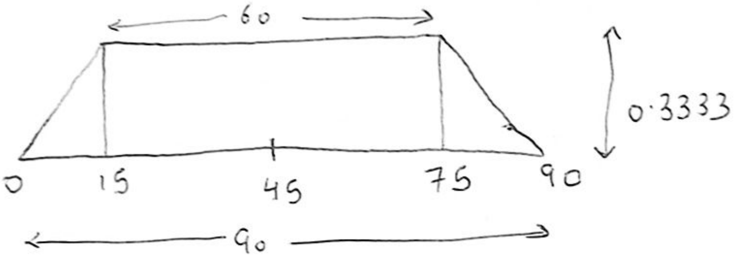


for A_1



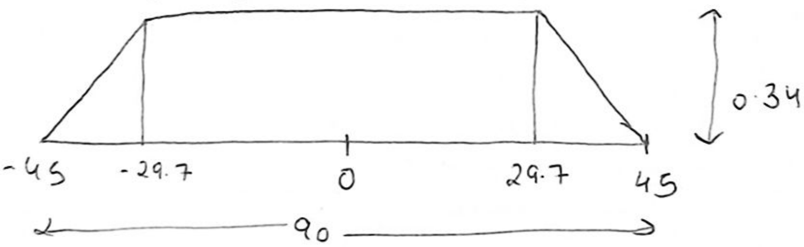
$A_1 = \frac{1}{2} \times (45+30) \times 0.3333 = 12.5$

for A_2



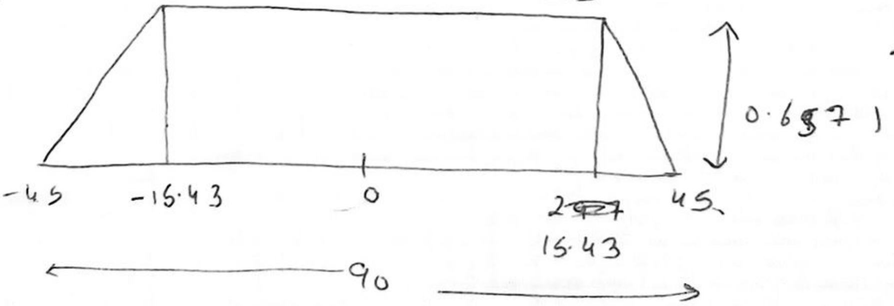
$A_2 = \frac{1}{2} \times (90+60) \times 0.3333 = \underline{\underline{25}}$

for A_3



$\frac{1}{2} \times (149.4) \times 0.34 = \underline{\underline{25.39}}$

for A_4



$A_4 = \frac{1}{2} \times 120.86 \times 0.6571$

$\underline{\underline{39.70}}$

18.88