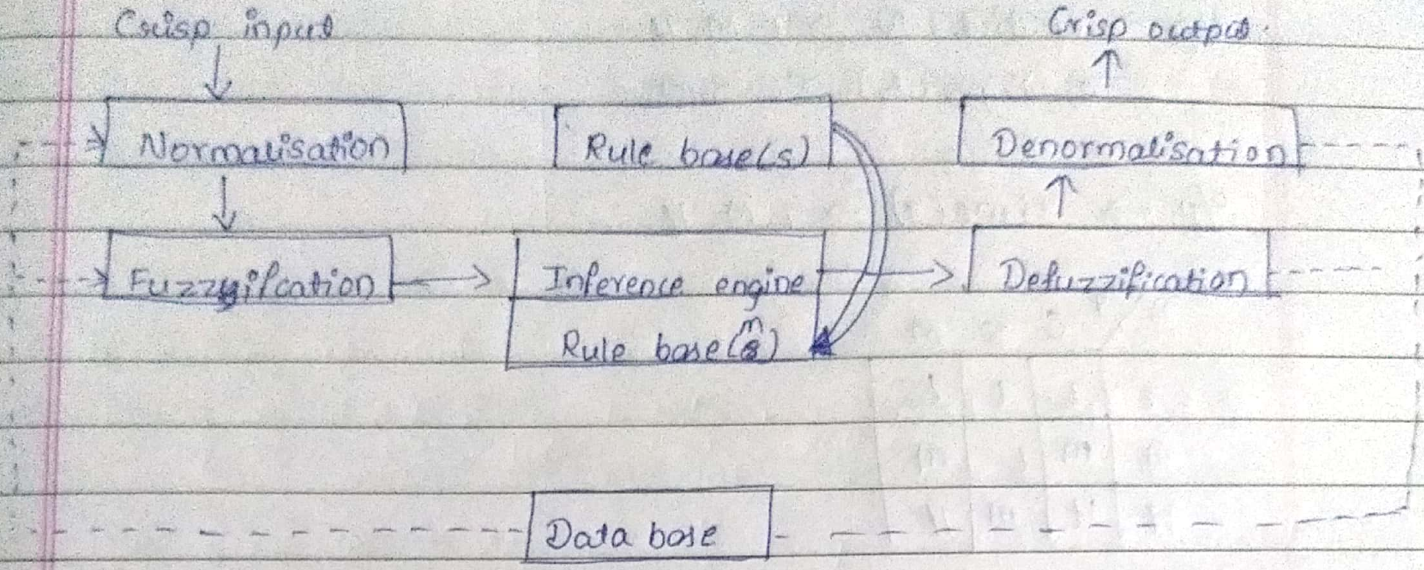
10/11/2020

Fuzzy Knowledge base controller



------ : Data flow

——— : Computational flow

⟹ : Symbolic to meaning translation.

Normalisation : Used to scale up or scale down the values. So divide by max. value.

Fuzzification : Converting crisp values to fuzzy values/sets.

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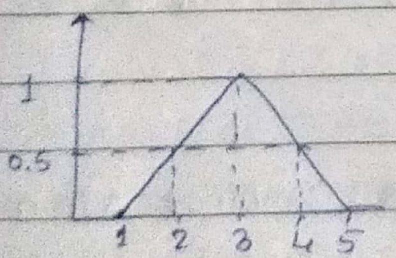
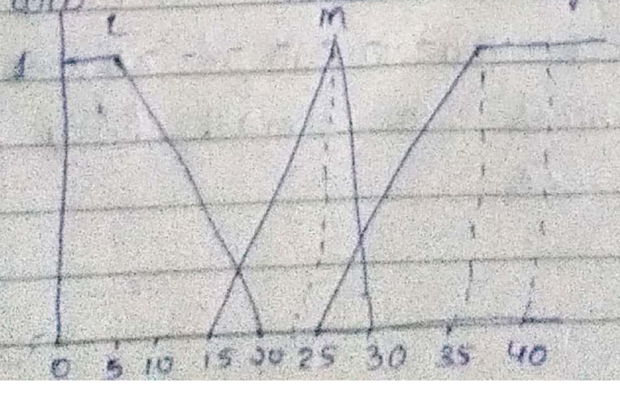


$$\Rightarrow \left\{ \frac{0}{1} + \frac{0.5}{2} + \frac{1}{3} + \frac{0.5}{4} + \frac{0}{5} \right\}$$

* If temp ⇒ [0 to 40°C]

[0 to 20] [15 to 30] [25 to 40]

low medium high



These helps to convert crisp to fuzzy values

Rule base.

2 i/p & 1 o/p

i/p → 1) Dirt (D) → L, M, H

2) Type (T_y) → C, S, M.

o/p → Time (T) → L, M, H

D \ T_y	C	S	M
L	L	L	L
M	M	L	M
H	H	M	H

3/11/2020

Denormalisation: Multiplied by max. value, so that ~~humans~~ normal people can understand.

Defuzzification: convert fuzzy values to crisp values.

Inference engine: There are many types of inference Engine.

* Composition based inference engine
* individual rule base " "

* Composition based :- first all rules are combined into a relation R & then ~~for~~ they are fired (executed) with i/p μ^* via composition.

* Individual based :- first each rule is individually fired with the crisp i/p e^* & then obtain 'n' clipped fuzzy sets that they are combined into overall fuzzy set. This is most commonly used.

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Choice of inference engine.

* Choice of representing the meaning of single produced rule.
* Choice of representing the meaning of set of rules.
* Choice of inference engine.

* Rule base :

Choice :-

* Choice of i/p & o/p variables.
* " " content of rule anticident & rule consequent.
* " " term set.
* Derivation of set of rules.

Choice of variable & content of rule.

i/p -> error -> e

-> change in error (Δe or e^*)

-> sum of erro (δe).

o/p -> control o/p (u)

1) P- type of FKBC :-

$u = K_p \cdot e$.

u -> control output (consequent) K_p -> proportional constant.

e -> error (anticident)

If e is __ then u is ____

P - D like FKBC:

$u = K_p \cdot e + K_D \, \Delta e$

u = output

$K_D \rightarrow$ differntial constant

$\Delta e \rightarrow$ change in error.

If e is ____ & Δe is ____ then u is ____

P - I type FKBC.

PID type of FKBC

$u = K_p e + K_D \cdot e' + K_I \int e \, dt.$

If e ____ & e' is ____ & $\int e$ is ____ then u is.

19/11/2020 Data base:-

All the blocks are connected by data base.

* Choice of data base:

1) Choice of membership function:

2) Choice of scaling f^n

→ normalisation - 1/scaling f^n

→ denormalisation. - × scaling f^n

1) Choice of membership f^n.

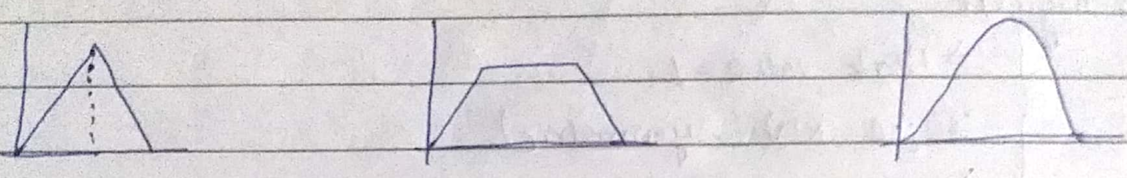
Based on shapes, height

i) higher computational efficiency (should be high).

ii) Efficient use of memory.

iii) Uniform representation.

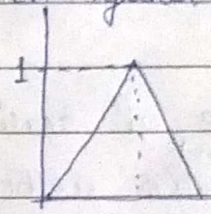
Choice of shape of membership f^n:

i) 

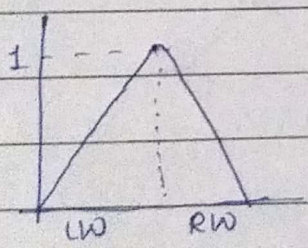
If these are the choices ideal choice is triangular.

They give the accurate result.

Peak $f^n = 1$



ii) left & right width :

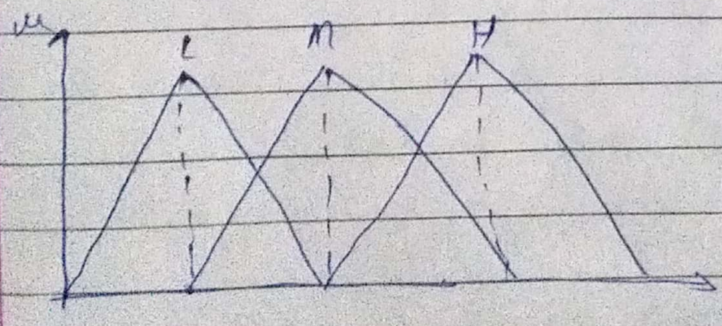


Have to choose a equilateral Δ^{le}

LW = RW.

LW = RW

iii) Cross point.



should be 1, proper symmetry.

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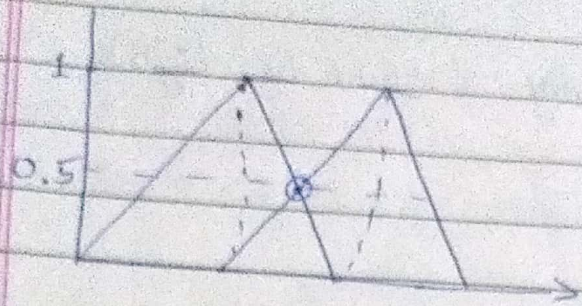
iv) Cross point ratio = 0.5



* Triangular
  → Peak value = 1
  → LW = RW (symmetric)
  → no cross point = 1
  → cross pt ratio = 0.5

2) Choice of scaling f^n

i) (Randgm) Heuristic method
   ↳ Select a f^n
   ↳ check for performance of controller.
   ↳ if not satisifacty go to step i)
   ↳ this satisifactory select.

ii) Formal method:
× ↳ set of formula. / Mathematical model.

Defuzzification: converting fuzzy to crisp value (z^*)

i) height method
ii) weighted avg.
iii) Middle of max (MOM)
iv) first of max
v) Last of max
vi) centre of gravity (COG).

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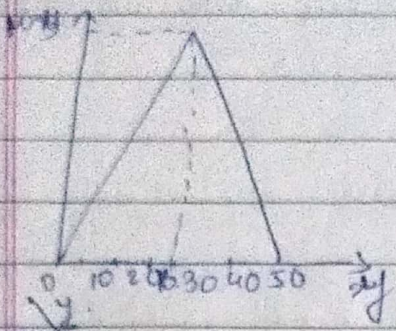
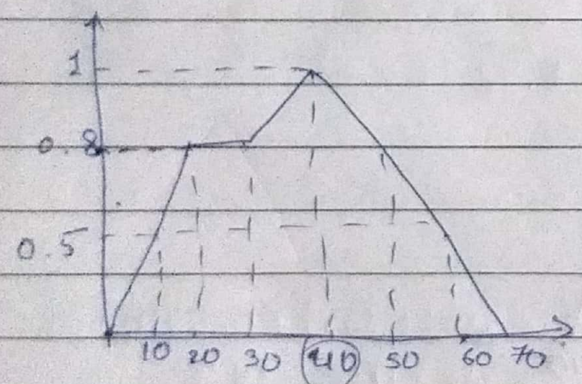
i) height method



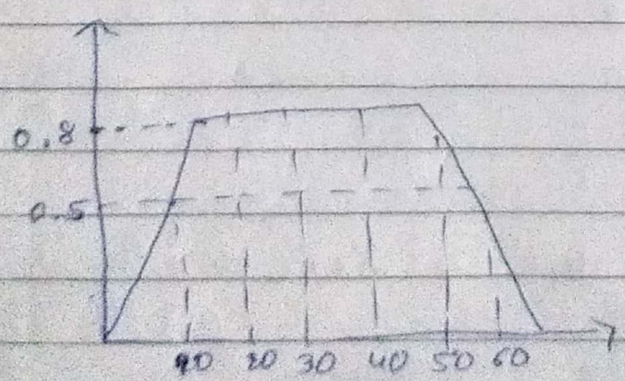
$$R = \begin{bmatrix} 0.1 & 0.2 & 0.4 & 0.9 \\ 0.8 & 0.4 & 0.6 & 0.4 \\ 1 & 0.2 & 0.4 & 0.3 \end{bmatrix}$$

if we project on y, $\left[\frac{0.1}{1} + \frac{0.2}{2} + \frac{0.4}{3} + \frac{0.9}{4}\right]$

$\therefore z^* = 16$ [the value corresponding to the peak value



$z^* = 40.$



b/w 20 & 50 bcz all have 0.8

here system collapses.

Not applicable for flat fn.

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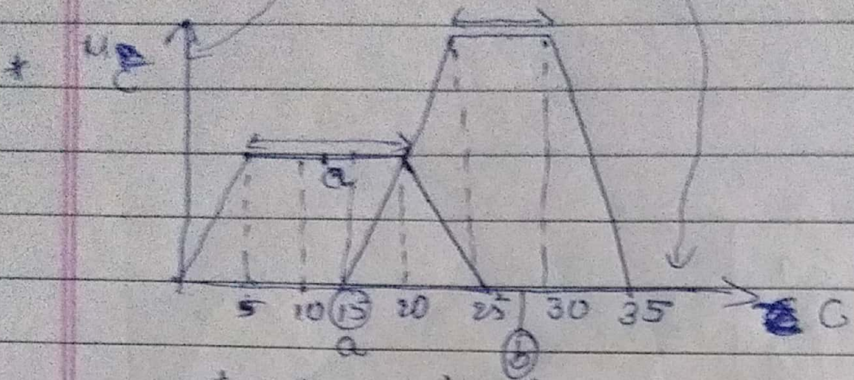
ii) Weighted average:

for flat f.n also we can apply

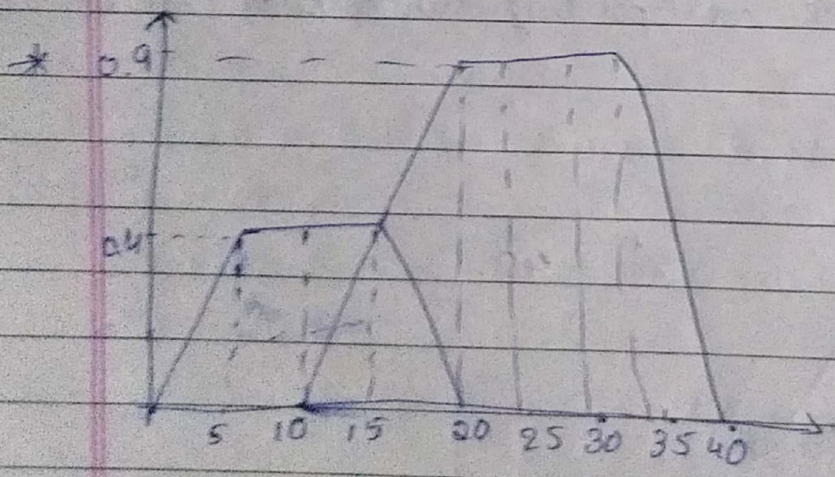
$$z^* = \frac{\sum \mu_c(z) \cdot z}{\sum \mu_c(z)}$$



$$z^* = \frac{(a \times 0.6) + (1 \times b)}{0.6 + 1}$$

$$= \frac{(0.6 \times 15) + (1 \times 27)}{0.6 + 1}$$

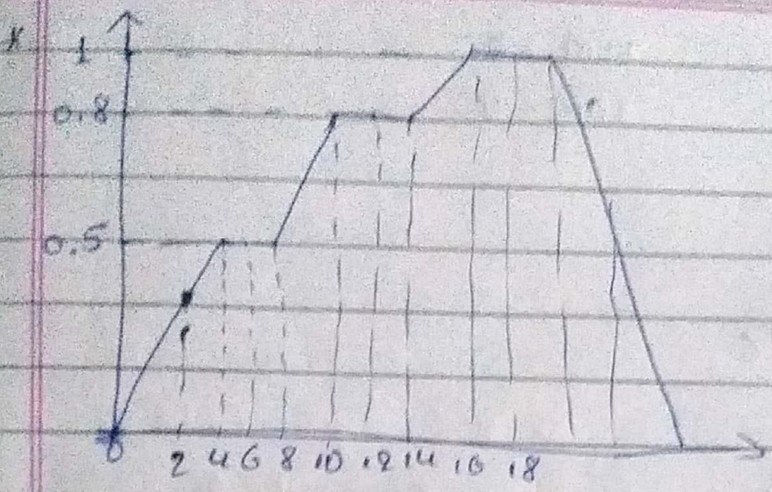
$$z^* = 22.5$$



$$z^* = \frac{\sum \mu_c(z) \cdot z}{\sum \mu_c(z)}$$

$$= \frac{(0.4 \times 10) + (0.9 \times 25)}{0.4 + 0.9}$$

$$z^* = 20.38$$

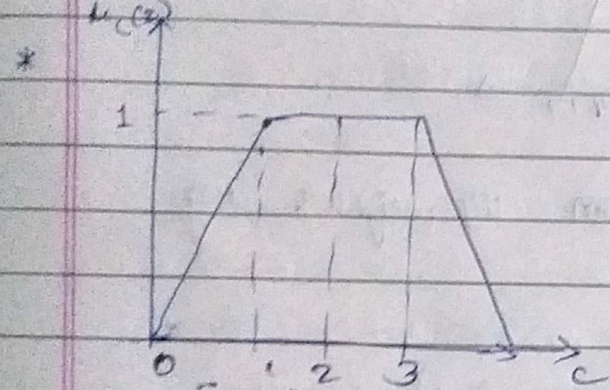


$$z^* = \frac{(0.5\times \overset{5}{6}) + (0.8\times 9) + (1\times 13)}{0.5+0.8+1}$$

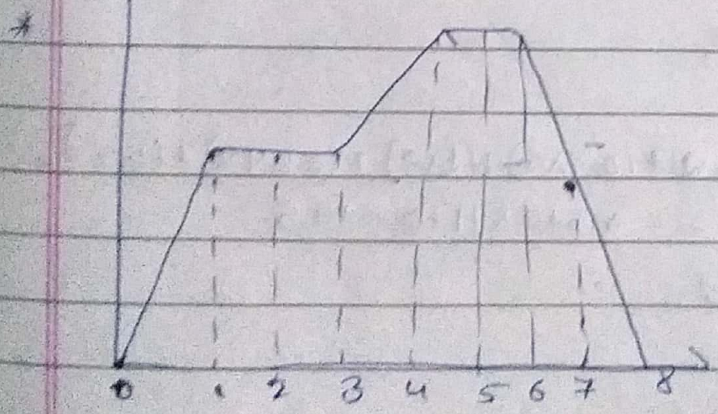
$$= 9.86.$$

iii) Middle of max (MOM) / Mean of maximum:

only applicable for flat function.

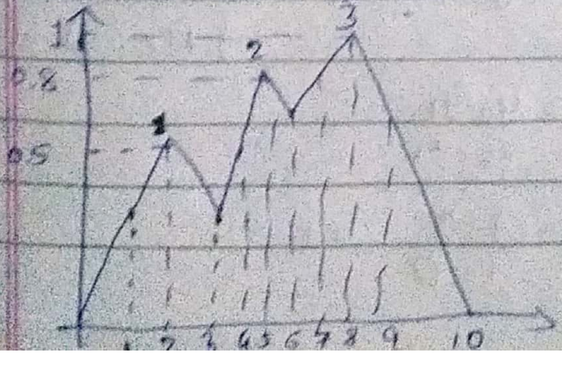


$$z^* = \frac{1+3}{2} = 2$$



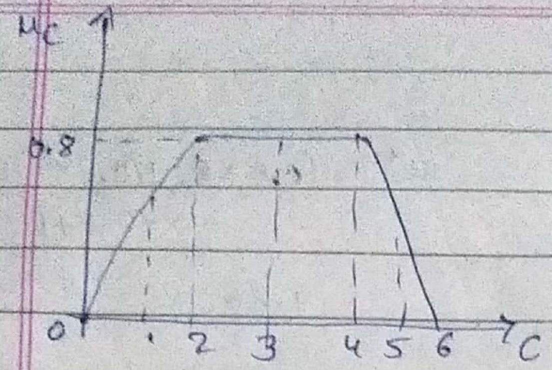
$$z^* = \frac{4+6}{2} = 5$$

iv) First of max (FOM) & last of max (LOM)



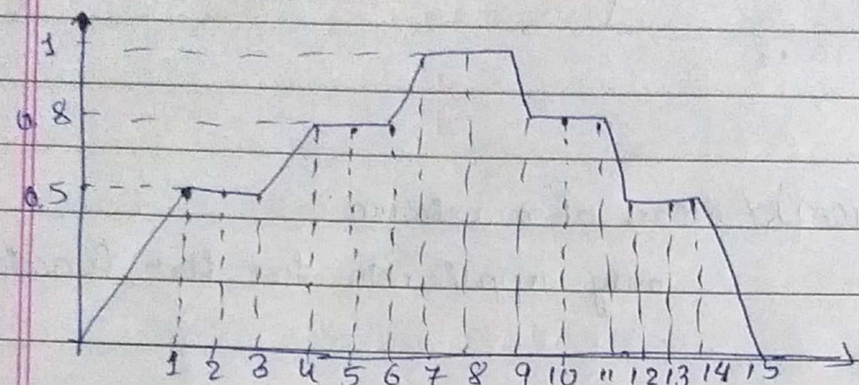
FOM, $z^* = 7$

LOM $= z^* = 7$



FOM = 2

LOM = 4



Find z^* using i) height ii) MOM iii) weighted avg iv) fom v) LOM.

=> i) Height method is not applicable.

ii) MOM = 8

iii) FOM = 7

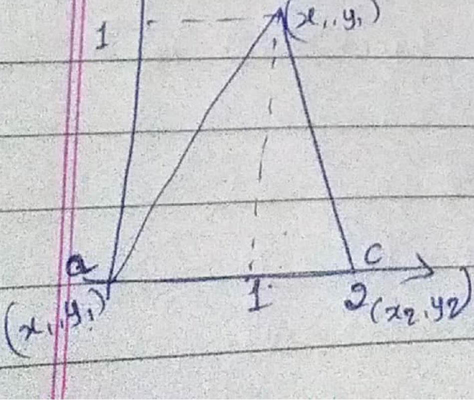
iv) LOM = 9

v) weighted avg : $z^* = \dfrac{(0.5\times 2)+(0.8\times 5)+(1\times 8)+(0.8\times 12)+(0.5\times 16)}{0.5+0.8+1+0.8+0.5}$

$= 8.5$

v) Centre of gravity : (COG) :

*



1) for ab : $y = mx + c \Rightarrow \dfrac{\int \mu_c(z).\, z\, dz}{\int \mu_c(z)\, dz}$

$m = \dfrac{y_2 - y_1}{x_2 - x_1}$

$= \dfrac{1-0}{1-0} = 1$

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let $x = 1$, $y = 1$

$1 = 1 \times 1 + c$

$c = 0$

$\mu(z) = mz + c$

$\mu(z_1) = 1 \times z + 0$

$\mu(z_1) = z \rightarrow 1$

2) for bc: $y = mx + c$

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0 - 1}{2 - 1} = \frac{-1}{1} = -1$

let, $x = 2$, $y = 0$

$0 = (-1)2 + c$

$c = 2$

$\mu(z_2) = mz + c$

$\mu(z_2) = (-1)z + 2$

$\mu(z_2) = -z + 2 \rightarrow 2$

3) $z^* = \frac{\int_0^2 \mu_c(z) . z\, dz}{\int_0^2 \mu_c(z)\, dz}$

$= \frac{\int_0^1 \mu_c(z_1) . z\, dz + \int_1^2 \mu_c(z_2) . z\, dz}{\int_0^1 \mu_c(z_1)\, dz + \int_1^2 \mu_c(z_2)\, dz}$

$= \frac{\int_0^1 z . z\, dz + \int_1^2 (-z+2) . z\, dz}{\int_0^1 z\, dz + \int_1^2 (-z+2)\, dz}$

$= \frac{\int_0^1 z^2\, dz + \int_1^2 (-z^2 + 2z)\, dz}{\int_0^1 z\, dz + \int_1^2 (-z+2)\, dz}$

$= \frac{1}{1} = 1$

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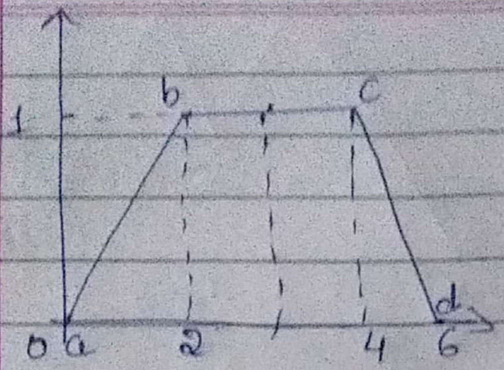


1 for ab, $y = mx + C$

$m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{1-0}{2-0} = 0.5$

at b, $(x, y) = (2, 1)$

$x = 2, \quad y = 1$

$1 = 0.5 \times 2 + C$

$C = 0$

~~for~~ $\mu(z) = mz + C$

$\mu(z_1) = (0.5)z + 0$

$\mu_c(z_1) = (0.5)z. \rightarrow (1)$

2. for bc, ~~$y = mx + c$~~ $\mu_c(z_2) = mz + C$

for straight line, $m = 0$, at C, $(x, y) = (4, 1)$

$y = mx + C$

$1 = 0 \times 4 + C$

$C = 1.$

$\therefore \mu_c(z_2) = 0(z) + 1$

$\mu_c(z_2) = 1. \rightarrow (2)$

3. for cd, $y = mx + C$

$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0-1}{6-4} = \frac{-1}{2} = -0.5$

at C, $(x, y) = (6, 0)$

$0 = (-0.5)6 + C$

$C = 3.$

$\mu_c(z_3) = mz + C$

$\mu_c(z_3) = (-0.5)z + 3. \rightarrow (3).$

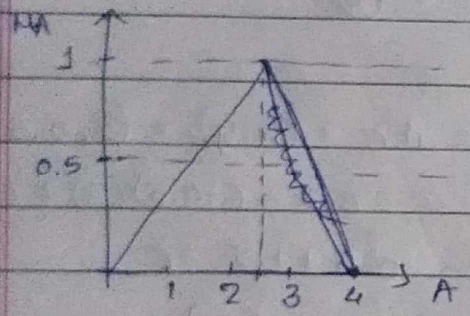
4) $$z^* = \frac{\int_0^6 \mu(z) \cdot z\,dz}{\int_0^6 \mu(z)\,dz}$$

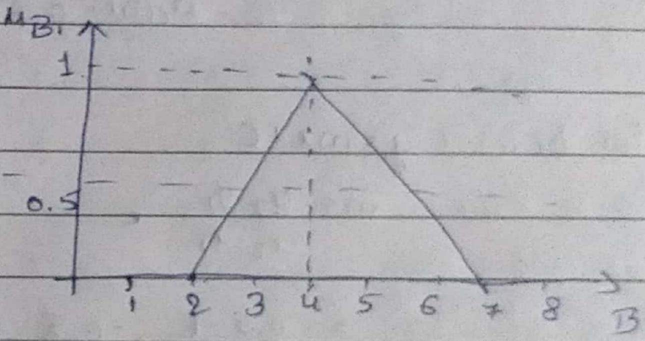
$$= \frac{\int_0^2 \mu_c(z_1) \cdot z\,dz + \int_2^4 \mu_c(z_2)\, z\,dz + \int_4^6 \mu_c(z_3) \cdot z\,dz}{\int_0^2 \mu_c(z_1)\,dz + \int_2^4 \mu_c(z_2)\,dz + \int_4^6 \mu_c(z_3)\,dz}$$

$$= \frac{\int_0^2 (0.5) z \cdot z\,dz + \int_2^4 1 \cdot z\,dz + \int_4^6 ((-0.5)z+3)\, z\,dz}{\int_0^2 (0.5 z)\,dz + \int_2^4 1\,dz + \int_4^6 (-0.5 z+3)\,dz}$$

$$= \frac{12}{4} = 3.$$

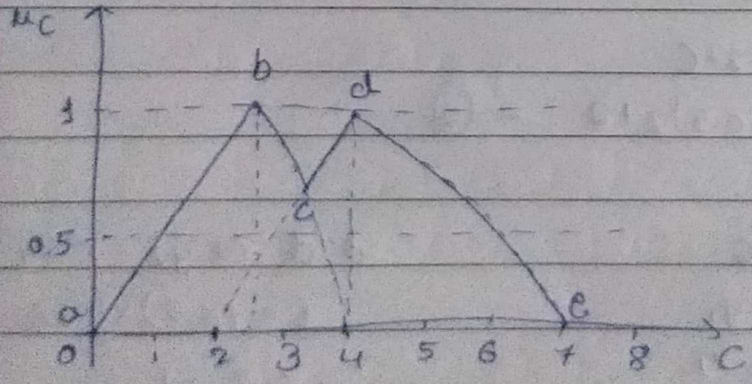
*





Find z^* using all the applicable methods for the union of A & B

⇒



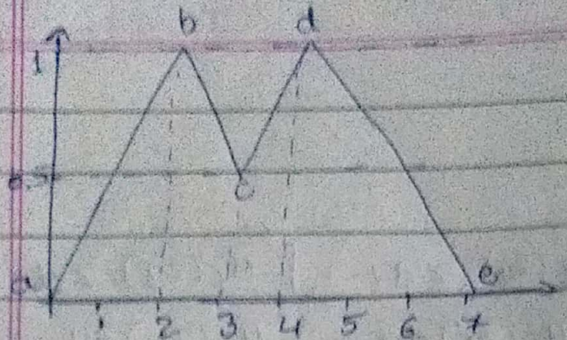
i) height method is not applicable bcz there are two peaks.

ii) weighted average is not applicable bcz there is no flat f^n.

iii) MOM is not applicable.

iv) FOM = 2

v) LOM = 4



i) for ab, $y = mx + c$

$m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{1-0}{2-0} = 0.5$

at b, $(x, y) = (2, 1)$

$1 = (0.5)(2) + C$

$C = 0$

$\mu(z_1) = mz + C \;=\; \mu_c(z_1) = 0.5z + 0$

$\mu_c(z_1) = 0.5z \rightarrow (1)$

ii) for bc, $y = mx + C$

$m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{0.5 - 1}{3 - 2} = \frac{-0.5}{1}$

$= -0.5$

at c $(x, y) = (3, 0.5)$

$0.5 = (-0.5)(3) + C$

$0.5 + 1.5 = C$

$C = 2$

$\mu_c(z_2) = mz + C$

$\mu_c(z_2) = (-0.5)z + 2 \rightarrow (2)$

iii) for cd, $y = mx + C$

$m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{1 - 0.5}{4 - 3} = 0.5$

at d $(x, y) = \cancel{0.5}\,(4, 1)$

$1 = (0.5) \times 4 + C$

$C = -1$

$\mu_c(z_3) = mz + C$

$\mu_c(z_3) = (0.5)z - 1 \rightarrow (3)$

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iv) for de, $y = mx + C$

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{0-1}{7-4} = \frac{-1}{3}$$

at e, $(x, y) = (7, 0)$

$0 = (-1/3)(7) + C$

$C = 2.333$

$\mu_C(z_4) = mz + C$

$\mu_C(z_4) = (-1/3) z + 2.333 \rightarrow (4).$

$$z^* = \frac{\int \mu_C(z).z\,dz}{\int \mu_C(z)\,dz}$$

$$= \frac{\int_0^2 (0.5z) z\,dz + \int_2^3 (-0.5z + 2) z\,dz + \int_3^4 (0.5z - 1) z\,dz + \int_4^7 (-1/3 z + 2.33) z\,dz}{\int_0^2 (0.5z)\,dz + \int_2^3 (-0.5z+2)\,dz + \int_3^4 (0.5z-1)\,dz + \int_4^7 (-1/3 z + 2.33)\,dz}$$

$$= \frac{13.327}{3.999}$$

$$= 3.33$$

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UNIT - 4

Applications:

1 Design a FKBC for washing machine

=> i/p | o/p

i/p	o/p
i) Type of cloths	i) Time for washing
ii) Dirt level	ii) qty of water
iii) Weight of cloths	iii) qty of detergent
	iv) Temp of water

2 : 1

By considering 2 i/p & 1 o/p.

i/p	o/p
i) Dirt level (D)	i) Time for washing (T)
[0 to 100%]	[0 to 60 min]
[0-40] - D_L	[0 - 30] - T_L
[30-70] - D_M	[20 - 50] - T_m
[60-100] - D_H	[40 - 60] - T_H

ii) Weight of cloths (W)

[0 to 7kg]

[0 to 3] - W_L

[2 to 5] - W_m

[4 to 7] - W_H

* Normalisation not needed
* Fuzzification:

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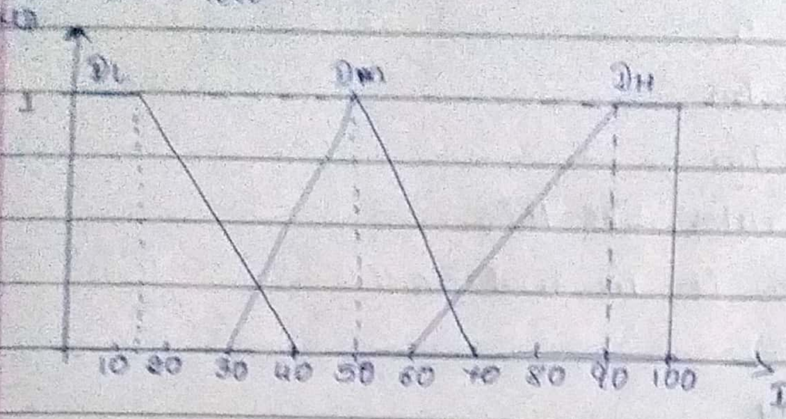
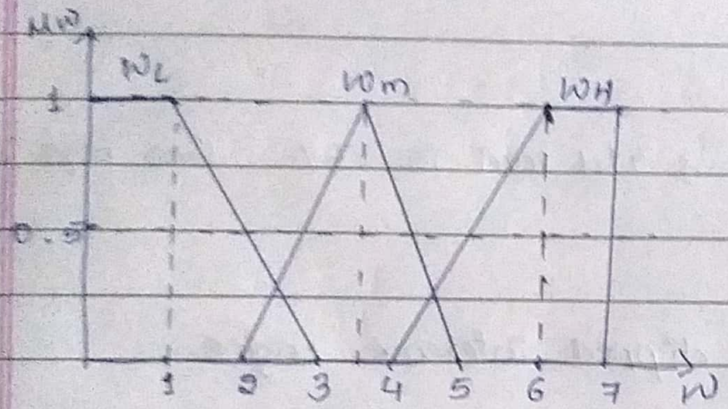
Fuzzification:-

* for dirt level



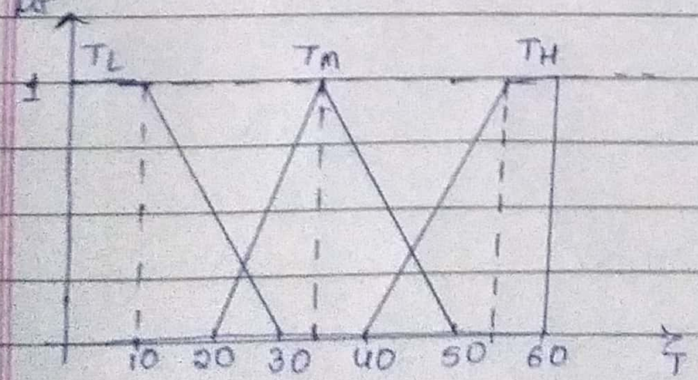
[0 to 100]
(0 - 40)
(30 - 70)
(60 - 100)

* for weight of cloths



[0 to 7]
[0 - 3]
[2 - 5]
[4 - 7]

* for ~~time for~~ washing



[0 to 60]
[0 to 30]
[20 - 50]
[40 - 60]

Rule base:

1. If D_L & W_L then T_L
2. If D_L & W_m then T_m
3. If D_L & W_H then T_m

We will get 9 rules like this.
So we can write it in matrix.

	W_L	W_m	W_H
D_L	T_L	T_m	T_m
D_m	T_L	T_m	T_m
D_H	T_m	T_H	T_H

Ex: weight of cloth is 4kg, & Dirt level is 40%. time reqd is to be calculated.

* We are using Mamdani clipped inference engine.

So, 4 kg lies W_m & 40% is D_M. so T is T_m