

## Examples on Mamdani FIS system

**Ex1:** Design a fuzzy lighting controller system, in which the control system dim the bulb light automatically according to the environmental Light. Assume that the inputs to the system are the environmental light  $x_1$  and the changing rate of the environmental light  $x_2$ . While the output variable which represents the control value to the dimmer is  $DM$ . Consider the following assumption:

Assume that  $x_1$  can be *Dark (D)*, *Medium (M)*, and *Light (L)* and its range between 120 and 220, with three membership functions:  $L(130,150)$ ,  $\Pi(130, 150\ 190,210)$ , and  $\Gamma(190, 210)$  for  $D$ ,  $M$ , and  $L$  respectively.

$x_2$  ranges between -10 and +10 and is divided into *Negative-Small (NS)*, *Zero (ZE)*, and *Positive-Small (PS)*, with three membership functions:  $\Lambda(-20, -10, 0)$ ,  $\Lambda(-10, 0, 10)$ , and  $\Lambda(0,10,20)$  for  $NS$ ,  $ZE$ , and  $PS$  respectively.

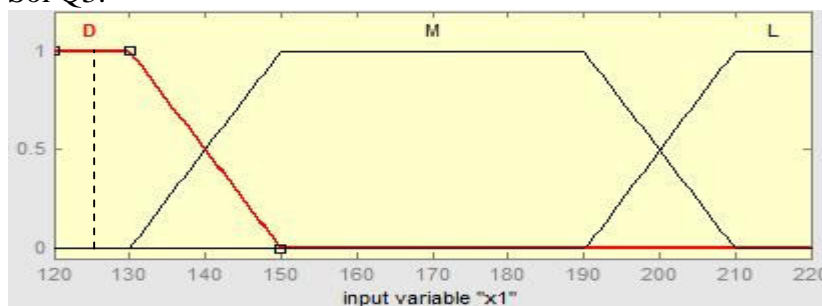
The output  $DM$  ranges between 0 and 10 and is divided into *Very-small (VS)*, *Small (S)*, *Big(B)*, and *Very-big (VB)*, with four membership functions:  $L(2,4)$ ,  $\Lambda(2,4,6)$ ,  $\Lambda(4,6,8)$ , and  $\Gamma(6,8)$  for  $VS$ ,  $S$ ,  $B$ , and  $VB$  respectively.

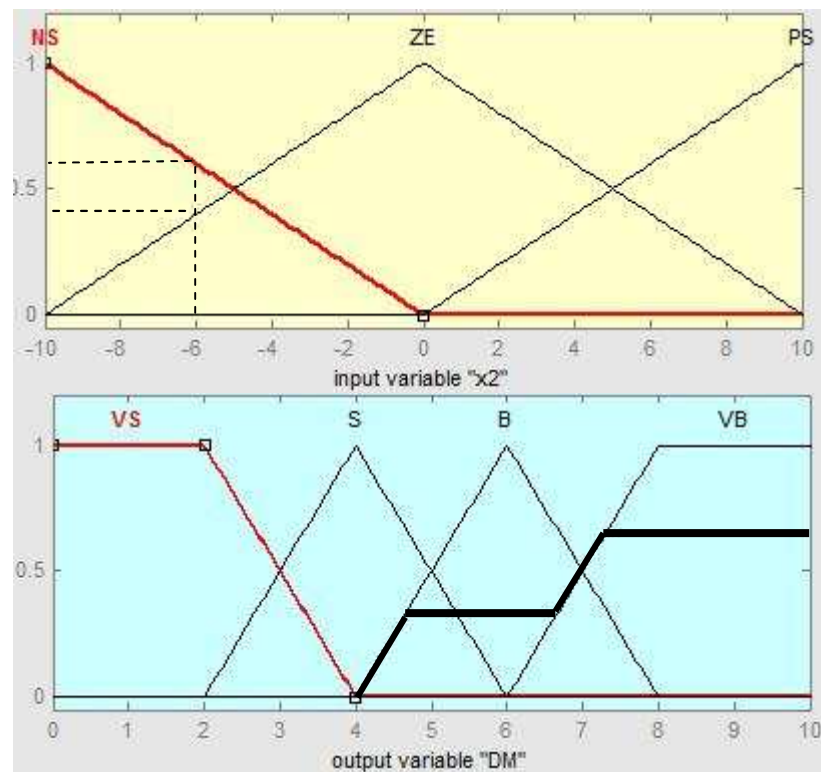
Evaluate the output for  $x_1 = 125$  and  $x_2 = -6$ , having the following fuzzy rule base:

$x_2 \backslash x_1$	D	M	L
PS	B	S	VS
ZE	B	B	S
NS	VB	B	B

### Solution:

Sol Q3:





X1=125 then it is D

X2= -6 then it is ZE and NS

Therefore two rules will be fired:

IF X1 IS D AND X2 IS ZE THEN DM IS B

IF X1 IS D AND X2 IS PS THEN DM IS VB

For the first rule  $\mu_{X1} = 1$  and  $\mu_{X2} = 0.4$  thus,  $\mu_{DM} = 0.4$

For the second rule  $\mu_{X1} = 1$  and  $\mu_{X2} = 0.6$  thus,  $\mu_{DM} = 0.6$

Now, the control action will be:

$dm = \{0, 0, 0, 0, .4, .4, .5, .6, .6, .6\}$

Finally, we apply center of gravity (CoG) defuzzification in order to obtain final crisp output:

$$DM = \frac{(0*0) + (0*1) + \dots + (0*4) + (.4*5) + (.4*6) + (.5*7) + (.6*8) + \dots + (.6*10)}{0+0+\dots+.4+.4+.5+.6+.6+.6} = \frac{24.1}{3.1} = 7.77$$

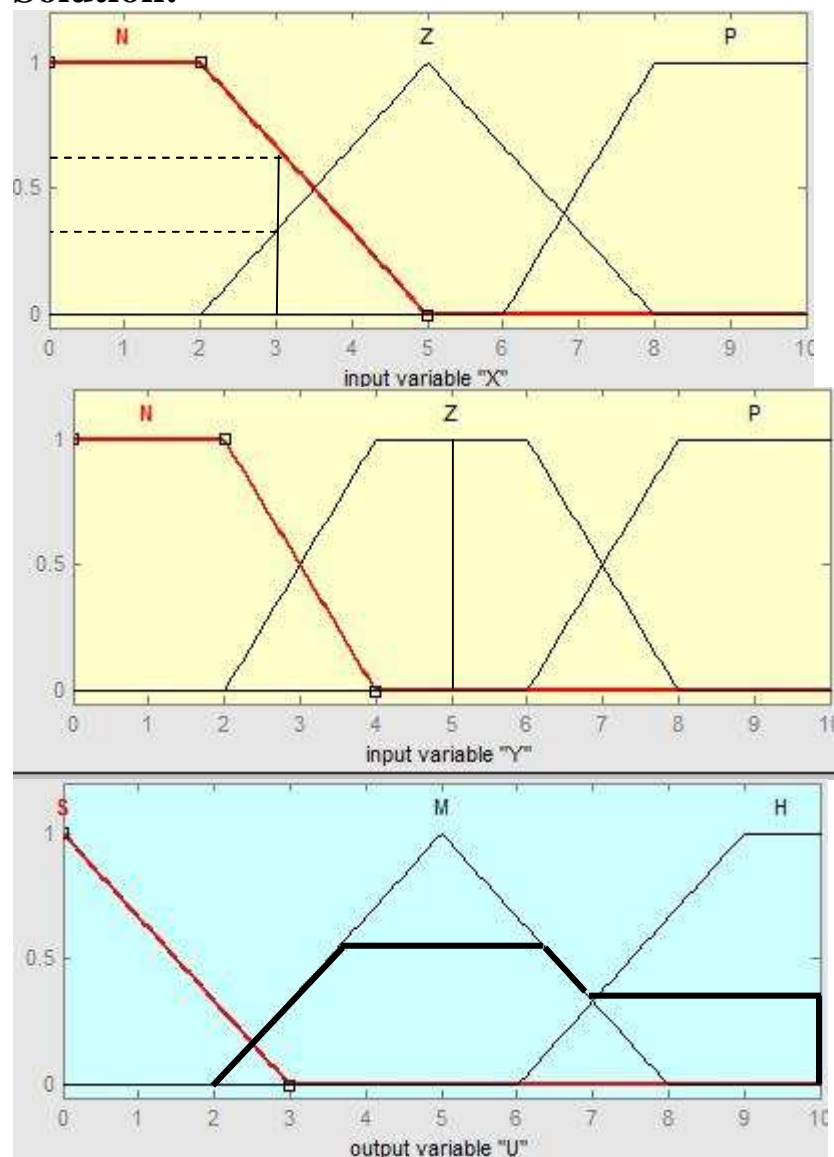
**Ex2:** Consider a fuzzy logic controller with two inputs x, y and a single output u, in which each of the inputs/output variables is quantified into three fuzzy sets with membership functions as illustrated in the table bellow. Suppose that the range of each variable is [0, 10] with number of intervals = 10.

X		Y		U	
Fuzzy terms	Membership function	Fuzzy terms	Membership function	Fuzzy terms	Membership function
N	$L(x; 2,5)$	N	$L(y; 2,4)$	S	$L(u; 0,3)$
Z	$(x; 2,5,8)$	Z	$\Pi(y; 2,4,6,8)$	M	$(u; 2,5,8)$
P	$\Gamma(x; 6,8)$	P	$\Gamma(y; 6,8)$	H	$\Gamma(u; 6,8)$

Find the control action if  $x=3$  and  $y=5$ , knowing that the fuzzy rules are

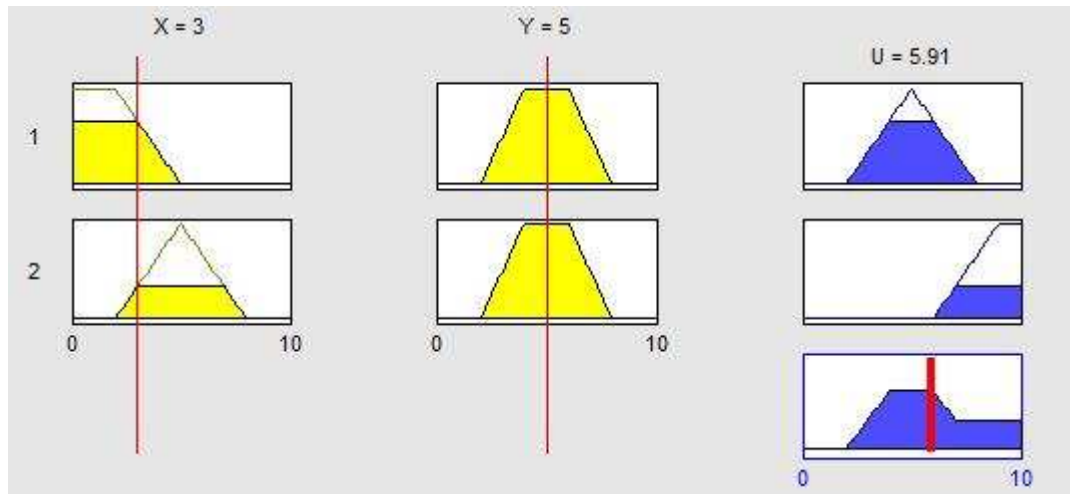
$\wedge$	N	Z	P
N	S	M	M
Z	M	H	H
P	M	H	H

**Solution:**



1. If (X is N) and (Y is Z) then (U is M)  $\rightarrow \mu_N(x) = .66; \mu_Z(y)=1 \rightarrow; \mu_M(u)=0.66$

2. If (X is Z) and (Y is Z) then (U is H)  $\rightarrow \mu_Z(x) = .33; \mu_Z(y)=1 \rightarrow; \mu_M(u)=0.66$



$$u = \frac{\sum_{n=1}^N I_n \mu_n}{\sum_{n=1}^N \mu_n}$$

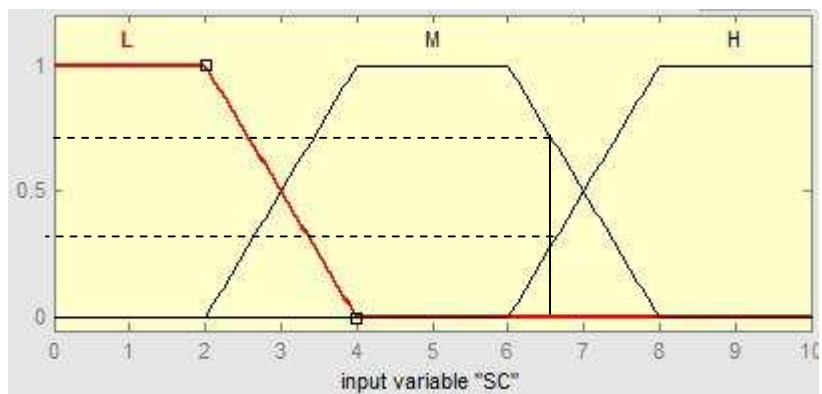
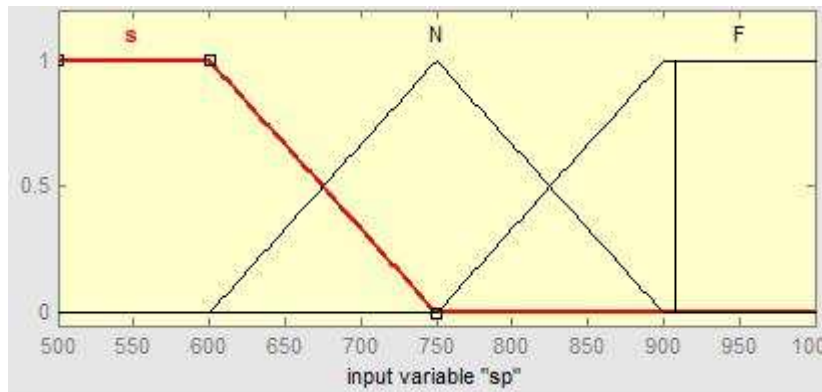
$$u = (0+0+0.333*3+0.666*(4+5+6)+0.333*(7+8+9+10))/(0.333*5+0.666*3) \approx 6$$

**Ex3:** Consider a fuzzy logic controller is used to control the speed of a motor by changing its input voltage (V) according to two input variables; speed (SP), and speed change rate SC. Let the fuzzy set of SP be {*Slow (S)*, *Normal (N)*, *Fast (F)*}, and the fuzzy set for SC be {*Low (L)*, *Medium (M)*, *High (H)*}, and for the control action be {*Slow Down (DN)*, *No Change (NC)*, *Speed Up (Up)*}, where, (SP  $\in$  [500, 1000]), (SC  $\in$  [0, 10]), and (V  $\in$  [2, 3]) with step = 0.1. The membership functions for the input/output variables are described in table 1. Find the control action if SP=910 And SC= 6.5 based on the fuzzy rules shown in table 2.

Table 1					
SP		SC		V	
Term	MF	Term	MF	Term	MF
S	L(600,750 )	L	L(2 ,4 )	DN	L(2.2 ,2.5)
N	$\Lambda$ (600,750,900)	M	$\Pi$ ( 2,4 ,6, 8)	NC	$\Lambda$ (2.4, 2.5,2.6)
F	$\Gamma$ (750,900 )	H	$\Gamma$ (6 ,8 )	Up	$\Gamma$ ( 2.5, 2.8 )

Table 2			
$\wedge$	S	N	F
L	Up	NC	NC
M	Up	NC	NC
H	NC	DN	DN

**Solution:**

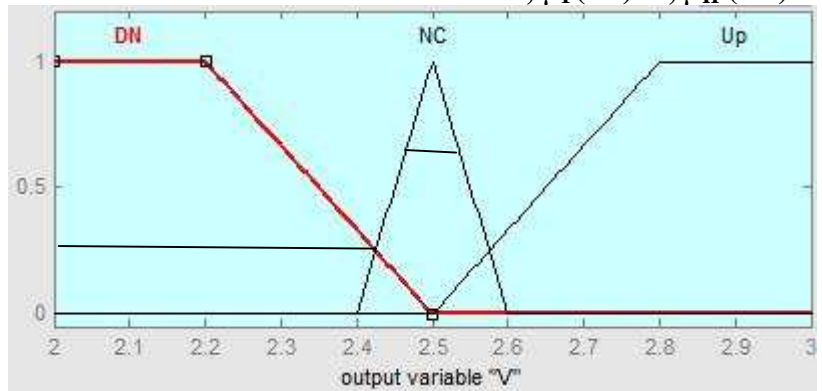


$$\mu_M(SC) = (8 - 6.5) / (8 - 6) = 0.75$$

$$\mu_H(SC) = (6.5 - 6) / (8 - 6) = 0.25$$

If SP is F AND SC is M Then V is NC;  $\mu_F(SP)=1$ ,  $\mu_M(SC)=0.75$ ,  $\mu_{NC}(V)=0.75$

IF SP is F AND SC is H Then V is DN;  $\mu_F(SP)=1$ ,  $\mu_H(SC)=0.25$ ,  $\mu_{DN}(V)=0.25$



$$u = \frac{\sum_{n=1}^N I_n \mu_n}{\sum_{n=1}^N \mu_n}$$

$$V = [0.25 * (2.1 + 2.2 + 2.3 + 2.4) + 0.75 * 2.5] / [0.25 * 4 + 0.75] = 4.125 / 1.75 = 2.357$$