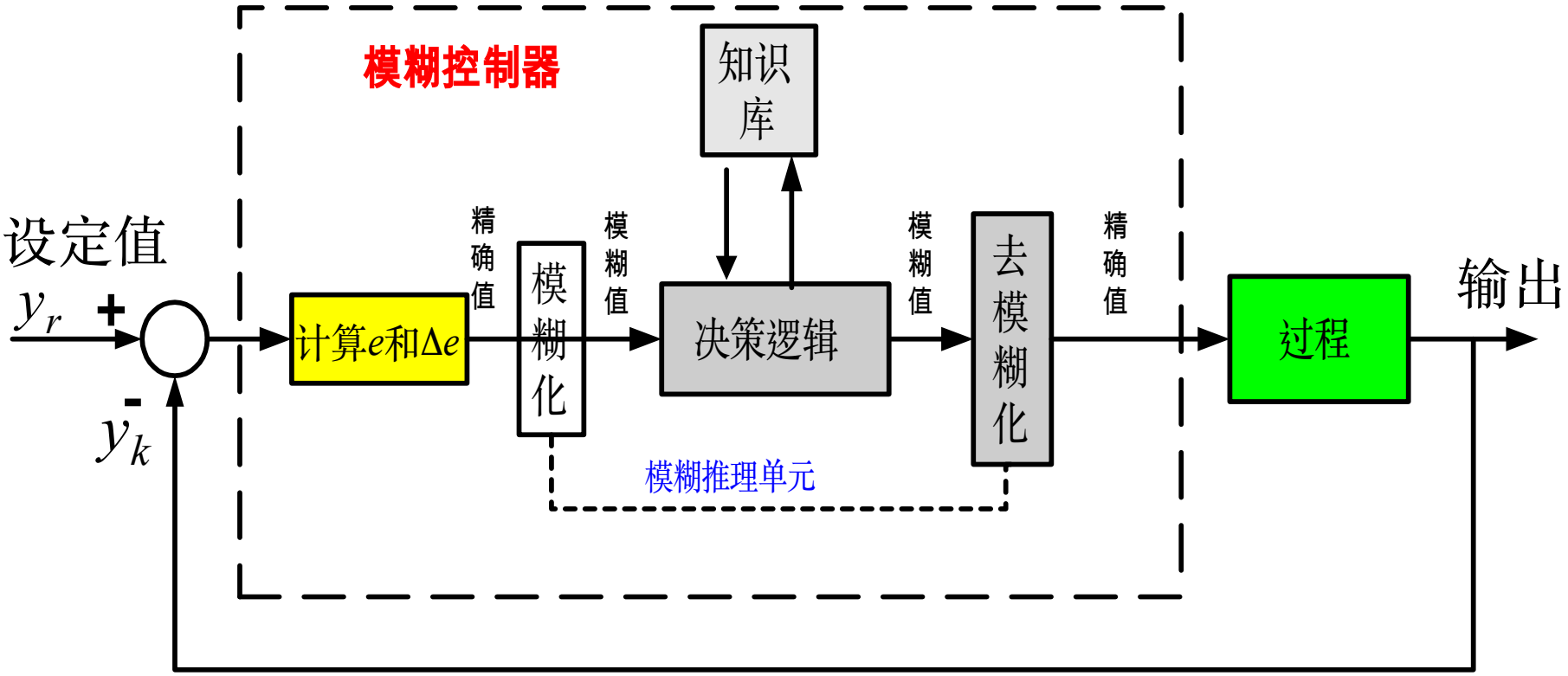
模糊控制的基本原理和方法

- 模糊逻辑控制器的基本结构
- 模糊控制系统的设计
- PID 模糊控制器模糊
- 利用 MATLAB 设计模糊控制器

模糊逻辑控制器的基本结构



在采样时刻k,误差和误差的变化定义为

$$e_k = y_r - y_k$$

$$\Delta e_k = e_k - e_{k-1}$$

▲模糊化部件

▲知识库

▲推理逻辑—模糊控制系统的核心

▲去模糊化部件

模糊控制中，推理逻辑按专家知识，以语言规则描述：

一般规则表示如下：

$$R_1: if\ x_1 \text{ 是 } A_1^1, x_2 \text{ 是} A_2^1, \cdots\cdots, x_n \text{ 是 } A_n^1, then\ y \text{ 是 } C_1$$

$$R_2: if\ x_1 \text{ 是 } A_1^2, x_2 \text{ 是} A_2^2, \cdots\cdots, x_n \text{ 是 } A_n^2, then\ y \text{ 是 } C_2$$

$$\cdots\cdots$$

$$R_n: if\ x_1 \text{ 是 } A_1^n, x_2 \text{ 是} A_2^n, \cdots\cdots, x_n \text{是 } A_n^n, then\ y \text{ 是 } C_n$$

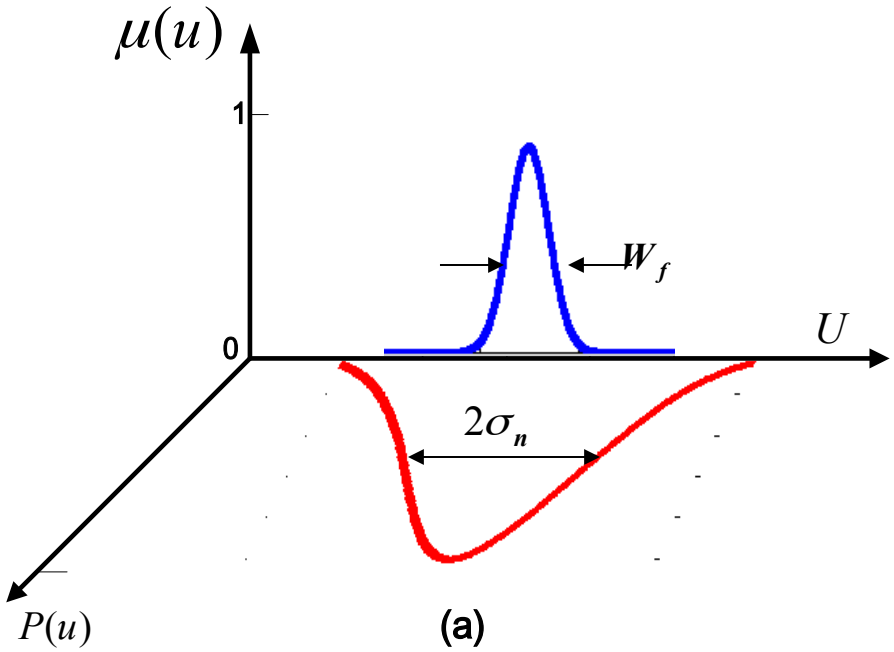
● 模糊控制系统的设计

1. 模糊化的策略

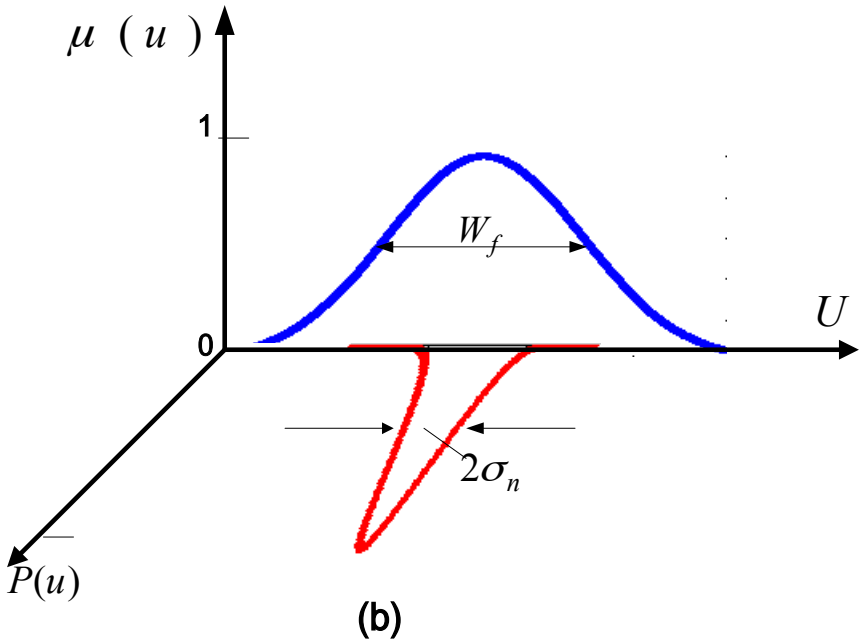
▲ 采用单点模糊化

▲ 选择合适的模糊函数

☆ 考虑噪声的概率密度函数。使 $W_f > 5\sigma_n$

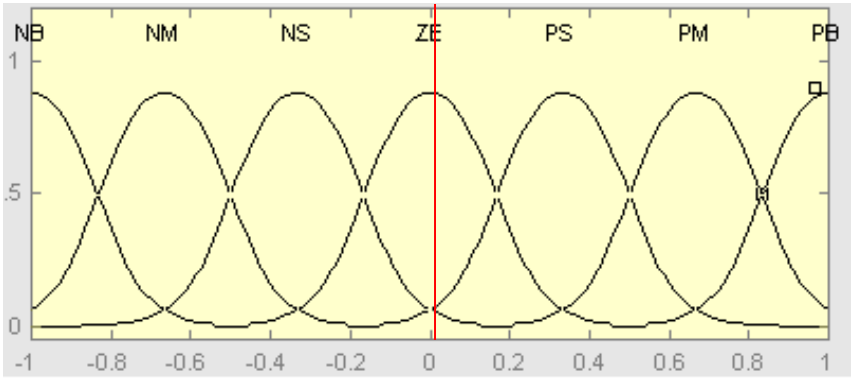


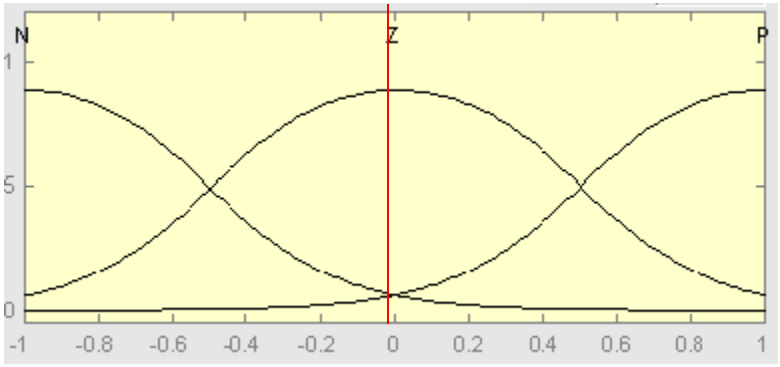
(a)

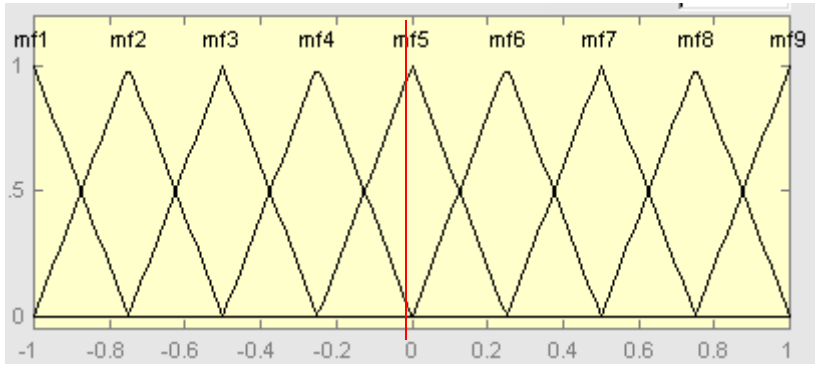


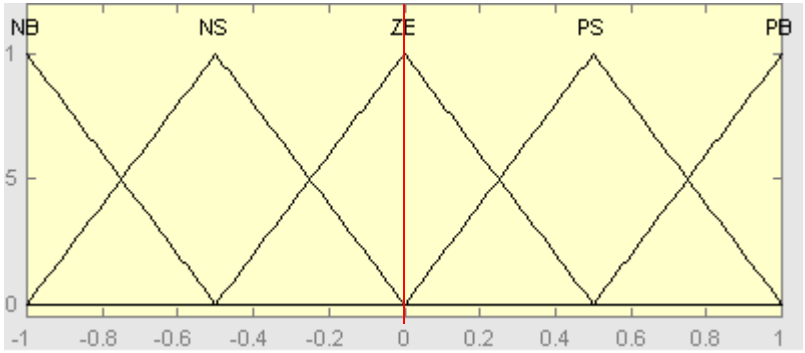
(b)

☆ 模糊变量术语集合的数目选取。在细分和粗分之间进行折中。一般为 2~10 。



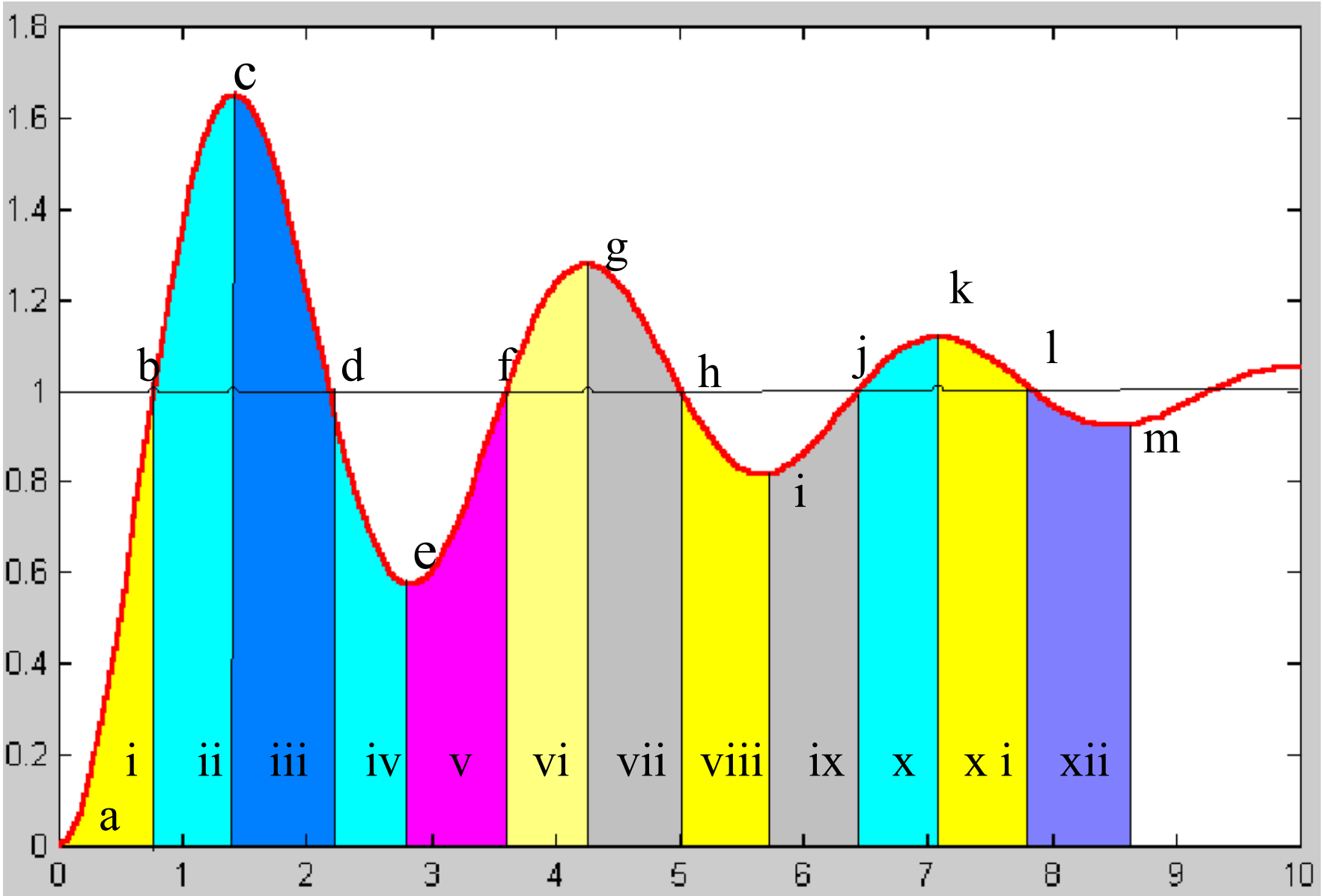






2. 模糊规则的合理调整

按照系统的动态行为可以合理地选择和确定模糊规则：



根据 e 和△ e 的方向和大小，选择控制量的增量△ u 的大小和方向。

有四种情况：

1. $e>0\ \Delta e<0$ (相当于i 、v 、ix区);
2. $e<0\ \Delta e<0$ (相当于ii 、vi 、x 区);
3. $e<0\ \Delta e>0$ (相当于iii 、vii 、xi区);
4. $e>0\ \Delta e>0$ (相当于iv 、viii 、xii区);

有交叉点和峰、谷点。

交叉点 1. $e>0 \rightarrow e<0,\ \Delta e<0\ (b,f,j)$

2. $e<0 \rightarrow e>0,\ \Delta e>0\ (d,h,l)$

峰点：$\Delta e=0$，$e<0\ (c,g,k)$

谷点：$\Delta e=0$，$e>0\ (e,i,m)$

控制规则：

1 。如果 e 和△ e 二者都为零，△ u=0, 保持现状。

2 。如果 e 以满意的速率趋向零， △ u=0, 保持现状。

3 。如果 e 不是自校正， △ u 不为零，取决于 e 和△ e 的符号和大小

●对交叉点， △ u 符号和△ e 符号一样。

对b, f, j，$\Delta u < 0$

对d, h, l，$\Delta u > 0$

●对峰、谷点，△ u 符号和 e 符号一样。

对c, g, k，$\Delta u < 0$

对e, i, m，$\Delta u > 0$

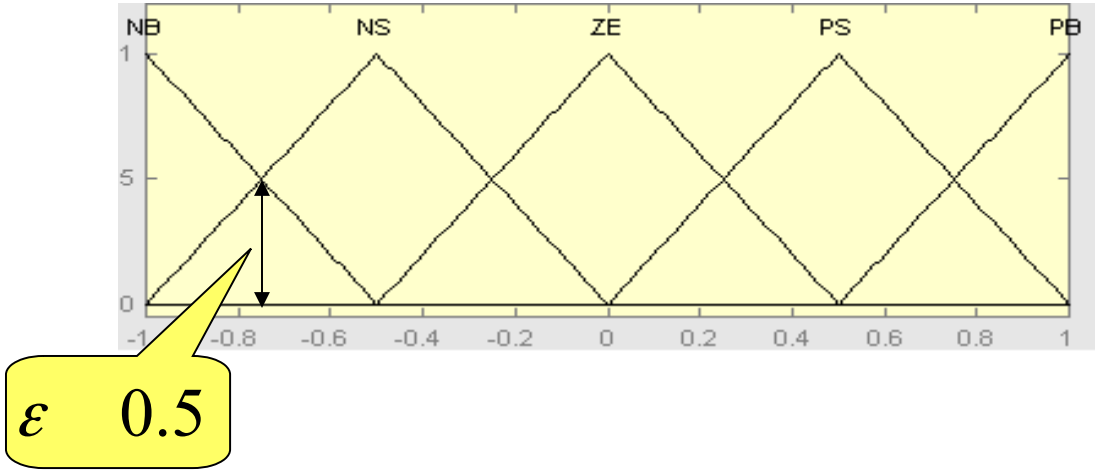
- 对i、v、ix区，当e大时，要缩短上升时间，$\Delta u > 0$；当接近设定值时，$\Delta u = 0$或≈ 0。
- 对ii、vi、x区，应防止超调，$\Delta u < 0$
- 对iii、vii、xi区，当e大时，要缩短上升时间，$\Delta u < 0$；当接近设定值时，$\Delta u = 0$或> 0。
- 对iv、viii、xii区，应防止超调，减小谷点的峰值，$\Delta u > 0$。

根据以上规则，我们可以选择和设计模糊控制器的规则表

规则号	e	△e	△u	参考点
1	PB	ZE	PB	a
2	PM	ZE	PM	e
3	PS	ZE	PS	i
4	ZE	NB	NB	b
5	ZE	NM	NM	f
6	ZE	NS	NS	j
7	NB	ZE	NB	c
8	NM	ZE	NM	g
9	NS	ZE	NS	k
10	ZE	PB	PB	d
11	ZE	PM	PM	h
12	ZE	PS	PS	i
13	ZE	ZE	ZE	设置点

3．模糊规则的完整性、一致性

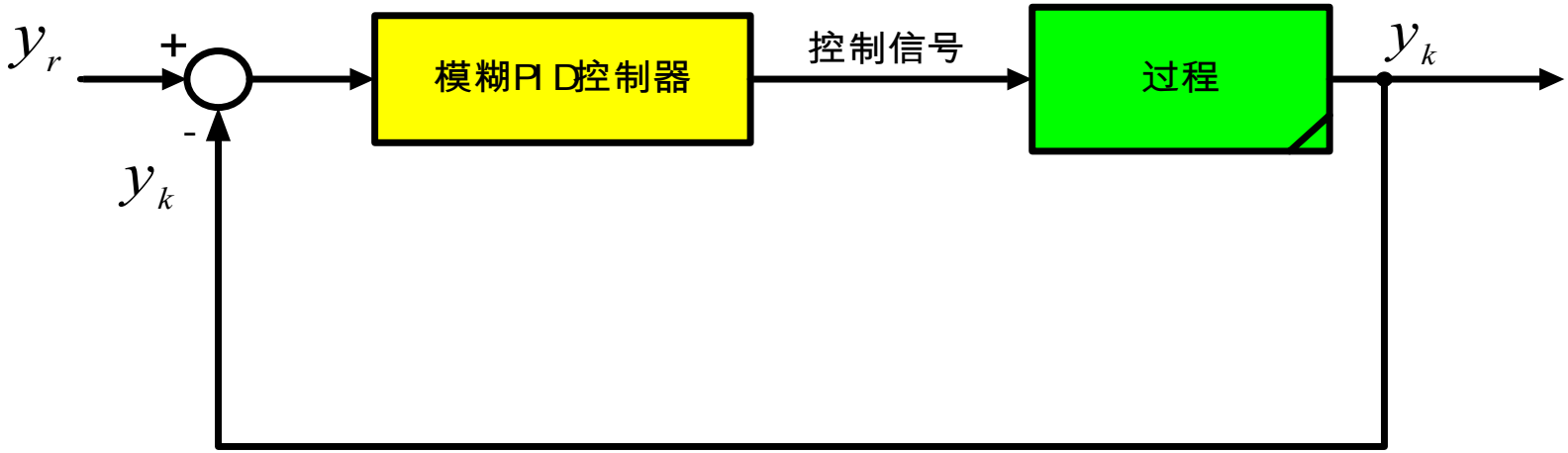
- 对过程的每一状态，都能推导出一个合适的控制规则，——控制规则的完整性。
- 子集的并，应该以一定程度ε覆盖有关论域——控制规则的ε 完整性。 ε　0.5.



- 规则之间不存在矛盾 .

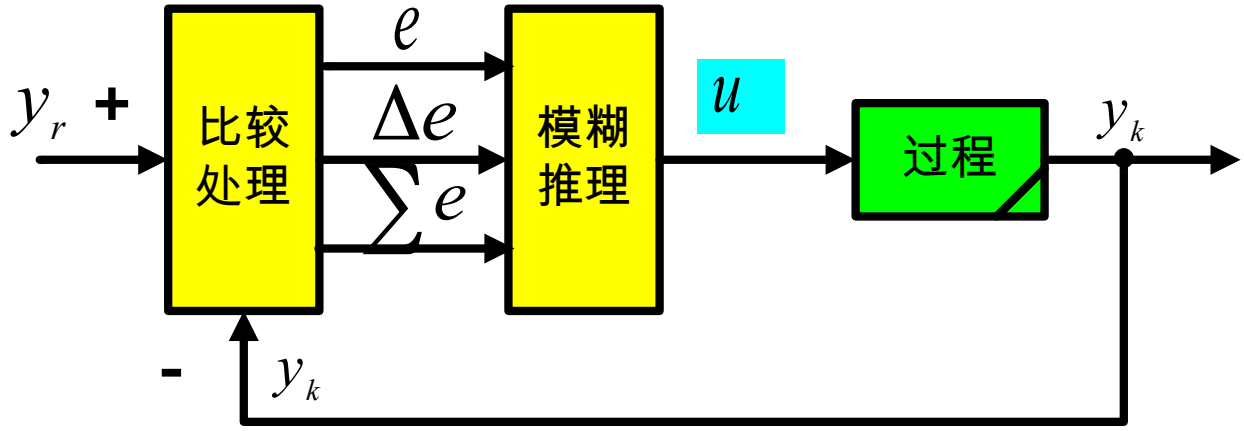
模糊控制器应用的模式

- 模糊 PID 控制器

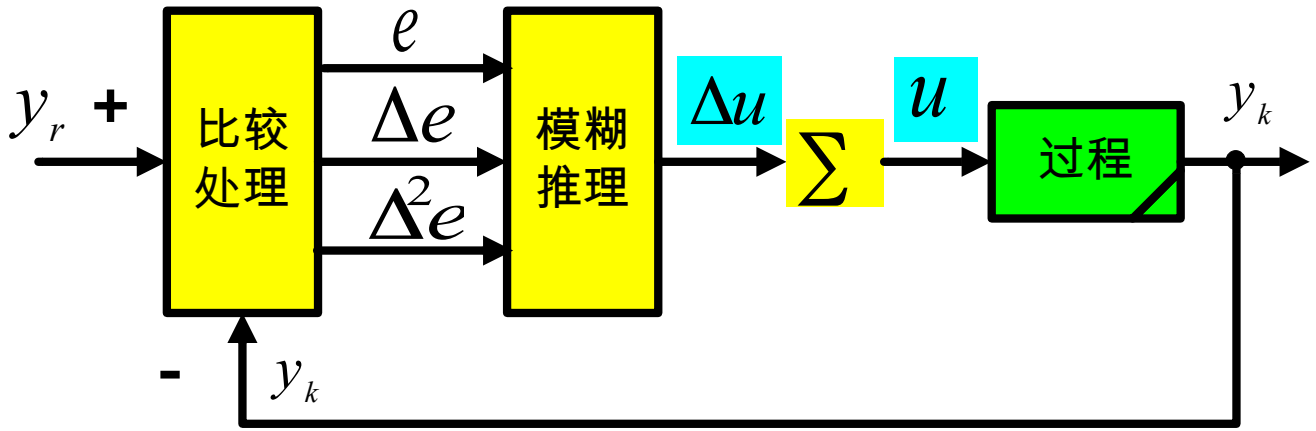


●模糊 PID 控制器

常规模糊 PID 控制器



增量模糊 PID 控制器



- 模糊控制在 MATLAB 中的实现

假定被控对象的传递函数为：

$$G_2 = \frac{4.228}{(s+0.5)(s^2+1.64s+8.456)}$$

- 设计一模糊控制器，查看其阶跃响应。
- **步骤**

1. 确定 e ， de 和 u 的论域
2. e ， de 和 u 语言变量的选取
3. 规则的制定
4. 推理方法的确定

利用 MATLAB 的 Toolbox 工具

- 1. 根据系统实际情况，选择 e ， de 和 u 的论域

  e range : [-1 1]

  de range: [-0.1 0.1]

  u range: [0 2]

- 2. e ， de 和 u 语言变量的选取

  e 8 个： NB,NM,NS,NZ,PZ,PS,PM,PB

  de 7 个： NB,NM,NS,Z,PS,PM,PB

  U 7 个： NB,NM,NS,Z,PS,PM,PB

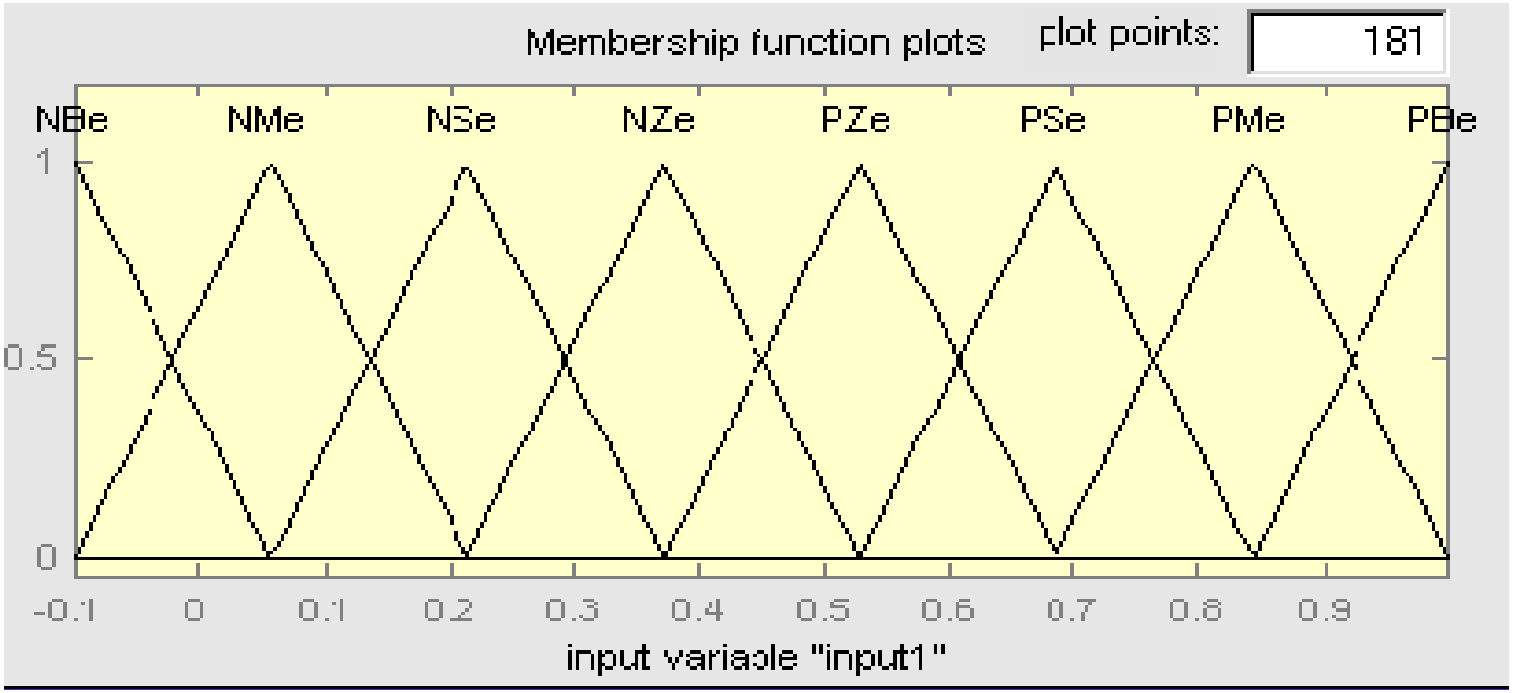
3. 模糊规则确定

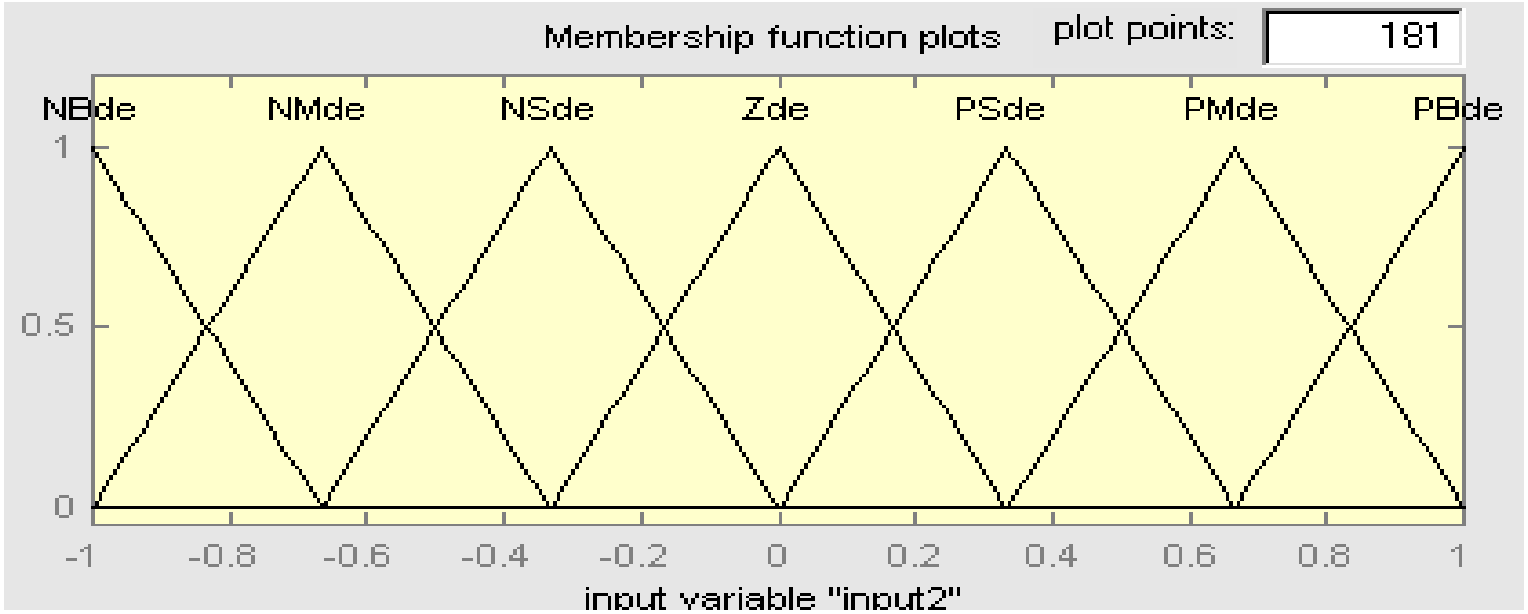
U		e							
		NB	NM	NS	NZ	PZ	PS	PM	PB
de	PB	PL	PM	NM	NM	NM	NL	NL	NB
	PM	PL	PM	NM	NM	NM	NS	NS	NB
	PS	PL	PM	NS	NS	NS	NS	NM	NB
	Z	PL	PM	PS	Z	Z	NS	NM	NB
	NS	PL	PM	PS	PS	PS	PS	NM	NB
	NM	PL	PL	PS	PS	PM	PM	NM	NB
	NB	PL	PL	PL	PM	PM	PM	NM	NB

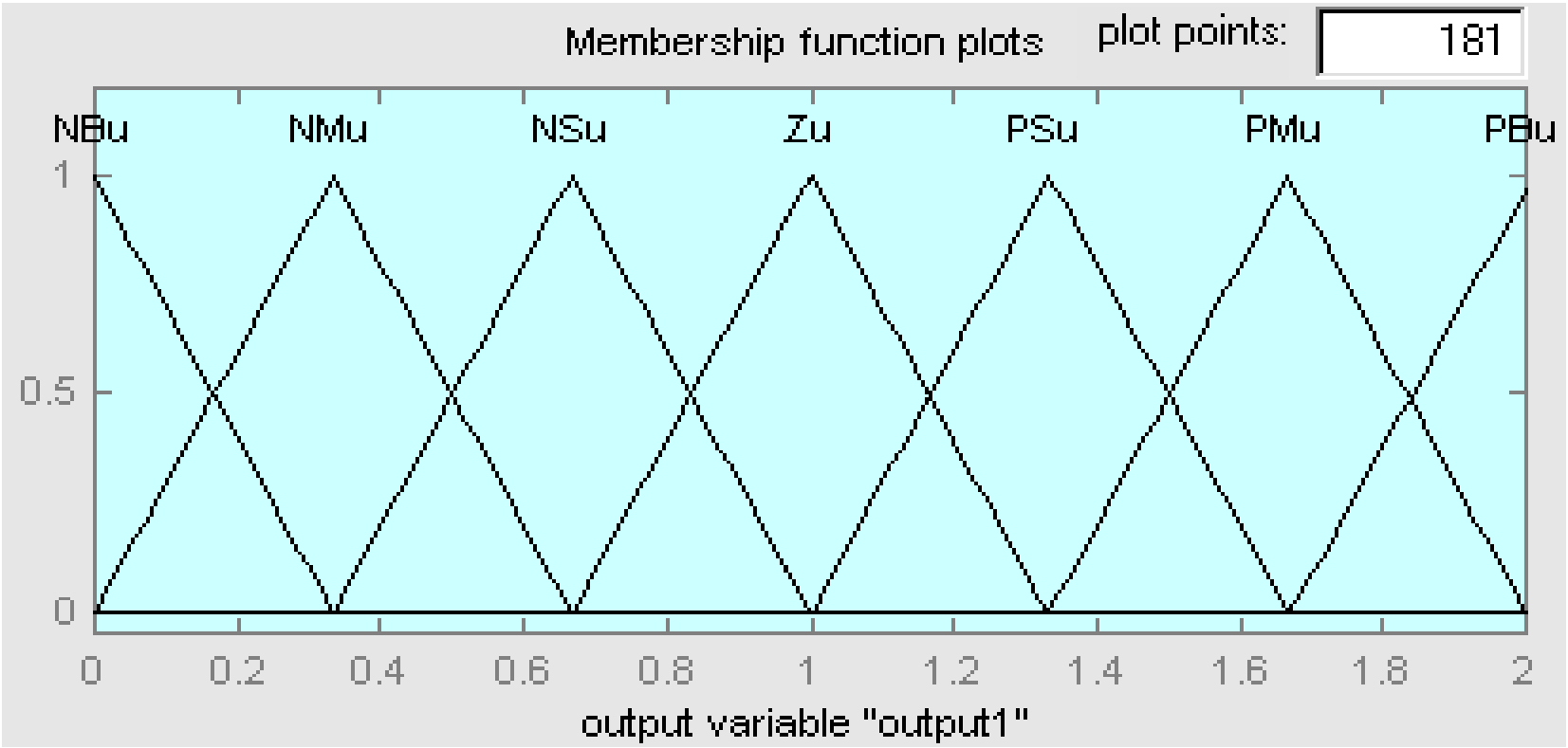
4. 隐含和推理方法的制定

- 隐含采用‘mamdani’方法：‘max-min‘
- 推理方法，即‘min‘方法
- 去模糊方法：重心法。
- 选择隶属函数的形式：三角型

MATLAB


Membership function plots
plot points:
181
NBe
NMe
NSe
NZe
PZe
PSe
PMe
PBe
1
0.5
0
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
input variable "input1"

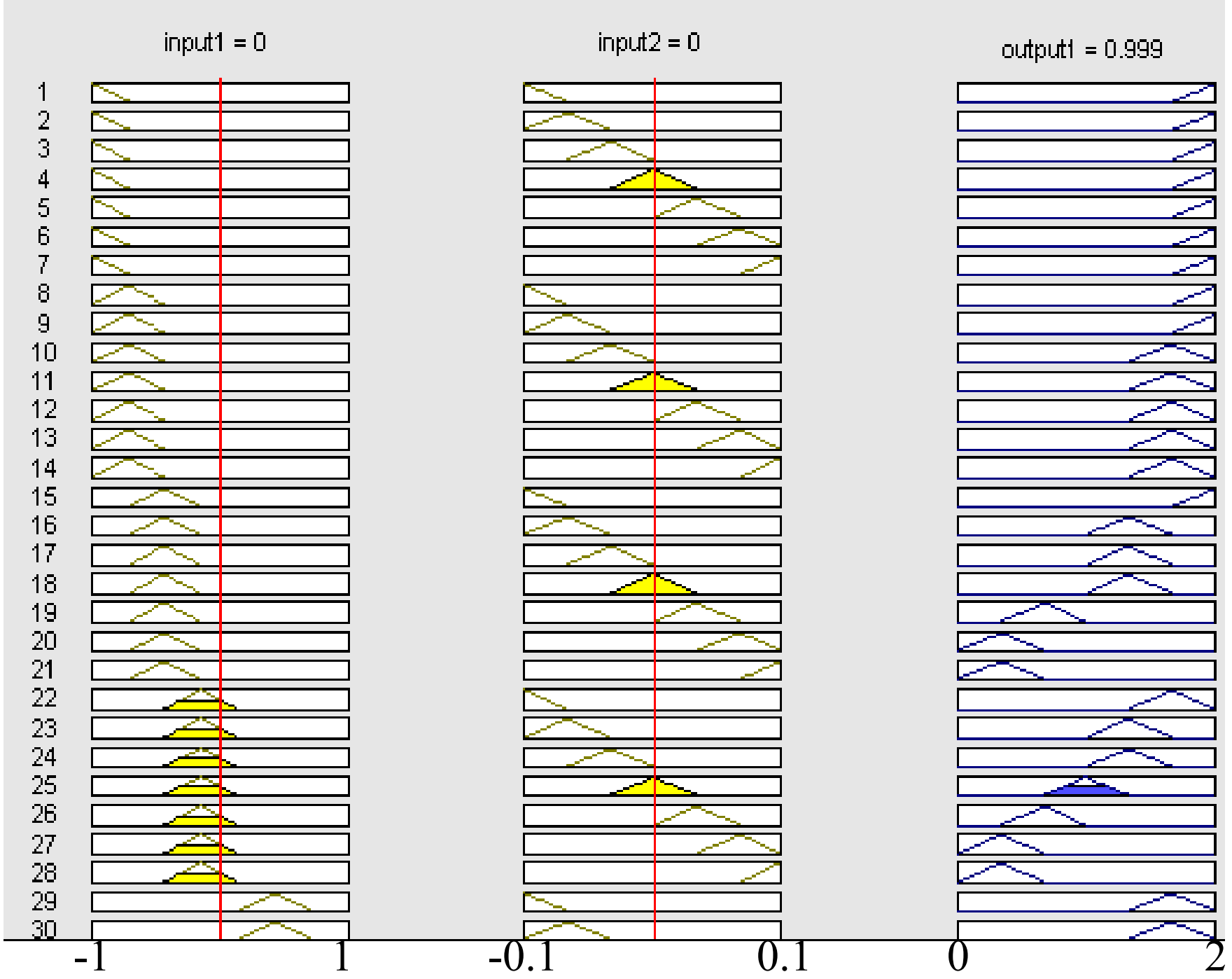

Membership function plots
plot points:
181
NBde
NMde
NSde
Zde
PSde
PMde
PBde
1
0.5
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
input variable "input2"

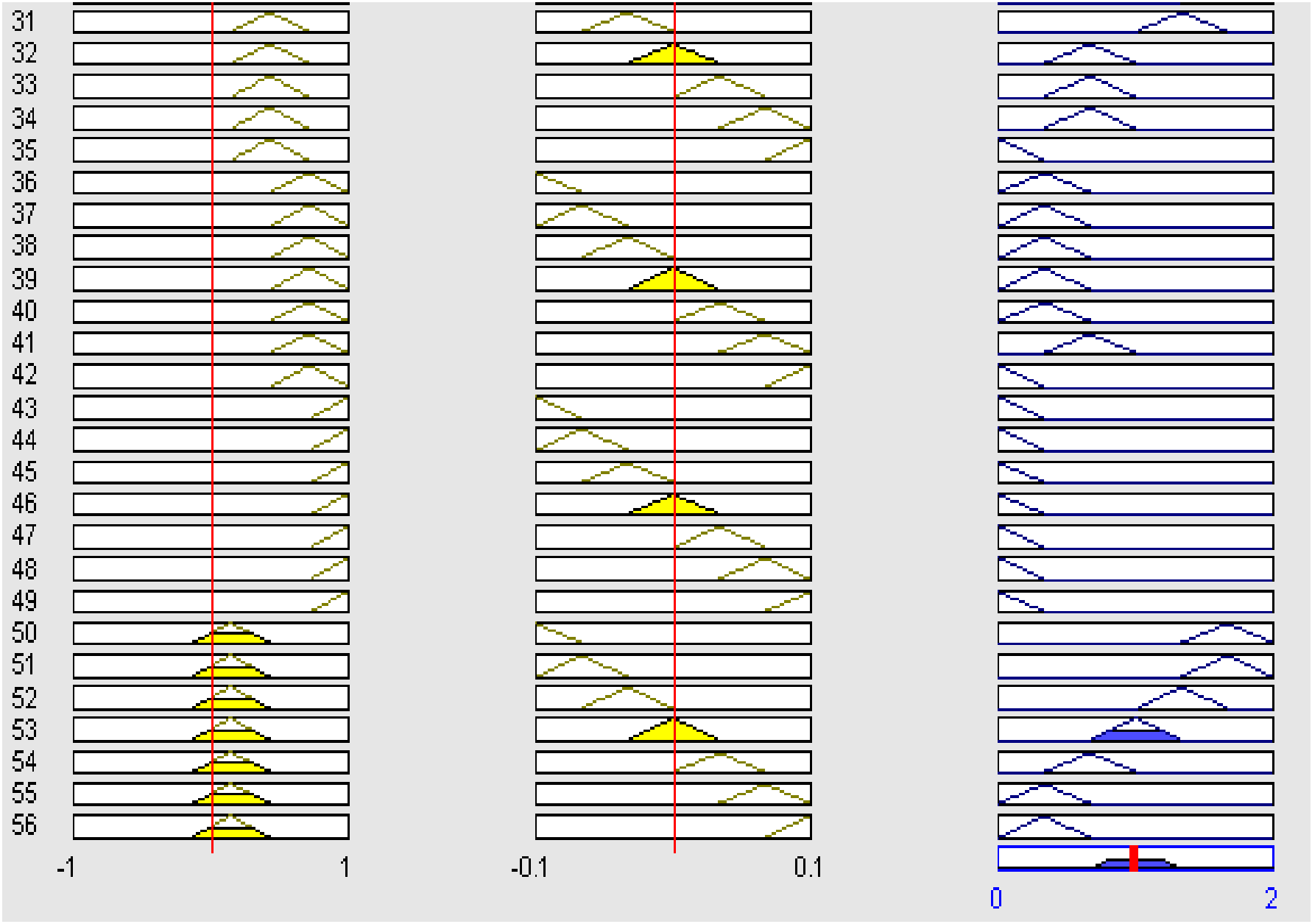

Membership function plots
plot points:
181
NBu
NMu
NSu
Zu
PSu
PMu
PBu
1
0.5
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
output variable "output1"

1. If (input1 is NBe) and (input2 is NBde) then (output1 is PBu) (1)
2. If (input1 is NBe) and (input2 is NMde) then (output1 is PBu) (1)
3. If (input1 is NBe) and (input2 is NSde) then (output1 is PBu) (1)
4. If (input1 is NBe) and (input2 is Zde) then (output1 is PBu) (1)
5. If (input1 is NBe) and (input2 is PSde) then (output1 is PBu) (1)
6. If (input1 is NBe) and (input2 is PMde) then (output1 is PBu) (1)
7. If (input1 is NBe) and (input2 is PBde) then (output1 is PBu) (1)
8. If (input1 is NMe) and (input2 is NBde) then (output1 is PBu) (1)
9. If (input1 is NMe) and (input2 is NMde) then (output1 is PBu) (1)
10. If (input1 is NMe) and (input2 is NSde) then (output1 is PMu) (1)
11. If (input1 is NMe) and (input2 is Zde) then (output1 is PMu) (1)
12. If (input1 is NMe) and (input2 is PSde) then (output1 is PMu) (1)
13. If (input1 is NMe) and (input2 is PMde) then (output1 is PMu) (1)
14. If (input1 is NMe) and (input2 is PBde) then (output1 is PMu) (1)
15. If (input1 is NSe) and (input2 is NBde) then (output1 is PBu) (1)
16. If (input1 is NSe) and (input2 is NMde) then (output1 is PSu) (1)
17. If (input1 is NSe) and (input2 is NSde) then (output1 is PSu) (1)
18. If (input1 is NSe) and (input2 is Zde) then (output1 is PSu) (1)
19. If (input1 is NSe) and (input2 is PSde) then (output1 is NSu) (1)
20. If (input1 is NSe) and (input2 is PMde) then (output1 is NMu) (1)
21. If (input1 is NSe) and (input2 is PBde) then (output1 is NMu) (1)
22. If (input1 is NZe) and (input2 is NBde) then (output1 is PMu) (1)
23. If (input1 is NZe) and (input2 is NMde) then (output1 is PSu) (1)
24. If (input1 is NZe) and (input2 is NSde) then (output1 is PSu) (1)
25. If (input1 is NZe) and (input2 is Zde) then (output1 is Zu) (1)
26. If (input1 is NZe) and (input2 is PSde) then (output1 is NSu) (1)
27. If (input1 is NZe) and (input2 is PMde) then (output1 is NMu) (1)
28. If (input1 is NZe) and (input2 is PBde) then (output1 is NMu) (1)
29. If (input1 is PSe) and (input2 is NBde) then (output1 is PMu) (1)
30. If (input1 is PSe) and (input2 is NMde) then (output1 is PMu) (1)
31. If (input1 is PSe) and (input2 is NSde) then (output1 is PSu) (1)
32. If (input1 is PSe) and (input2 is Zde) then (output1 is NSu) (1)
33. If (input1 is PSe) and (input2 is PSde) then (output1 is NSu) (1)

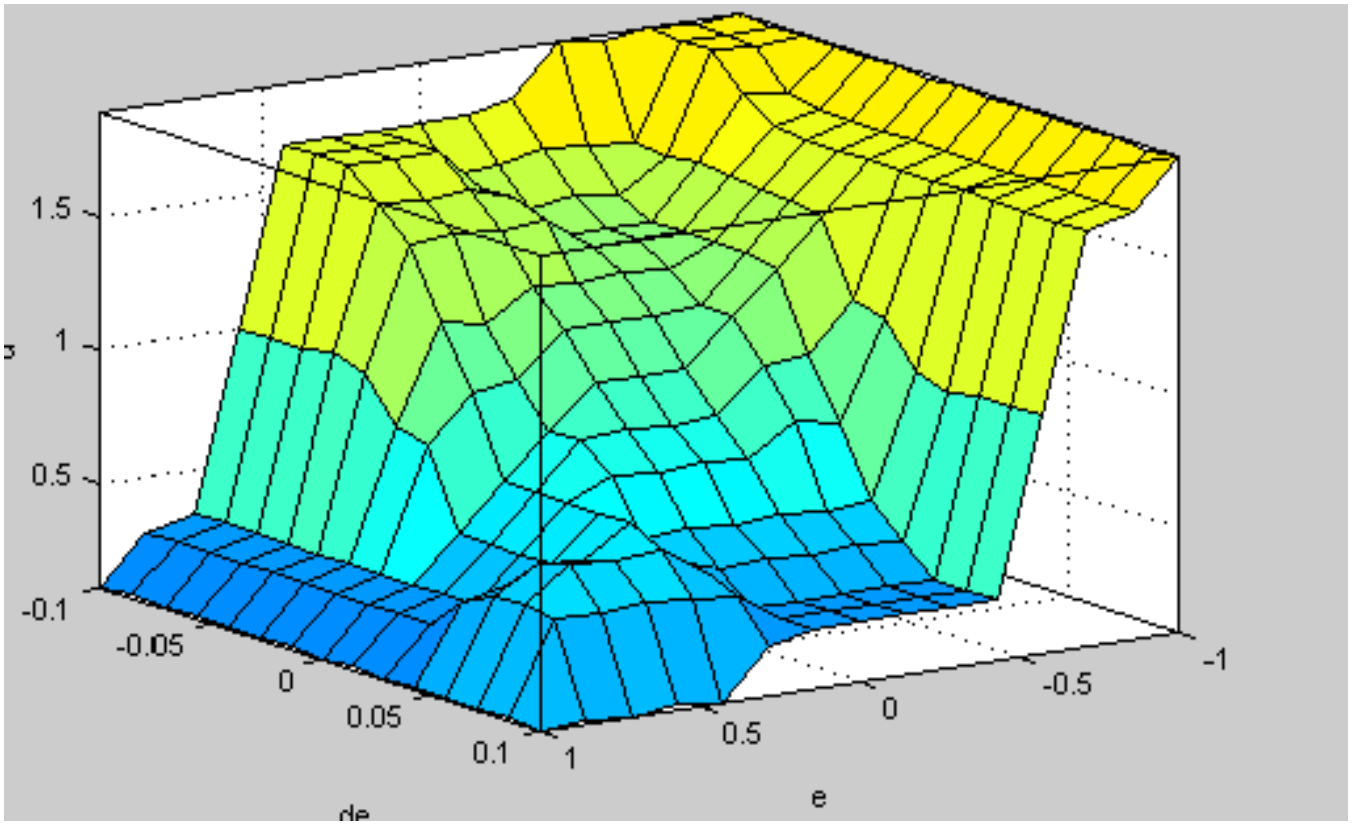
34. If (input1 is PSe) and (input2 is PMde) then (output1 is NSu) (1)
35. If (input1 is PSe) and (input2 is PBde) then (output1 is NBu) (1)
36. If (input1 is PMe) and (input2 is NBde) then (output1 is NMu) (1)
37. If (input1 is PMe) and (input2 is NMde) then (output1 is NMu) (1)
38. If (input1 is PMe) and (input2 is NSde) then (output1 is NMu) (1)
39. If (input1 is PMe) and (input2 is Zde) then (output1 is NMu) (1)
40. If (input1 is PMe) and (input2 is PSde) then (output1 is NMu) (1)
41. If (input1 is PMe) and (input2 is PMde) then (output1 is NSu) (1)
42. If (input1 is PMe) and (input2 is PBde) then (output1 is NBu) (1)
43. If (input1 is PBe) and (input2 is NBde) then (output1 is NBu) (1)
44. If (input1 is PBe) and (input2 is NMde) then (output1 is NBu) (1)
45. If (input1 is PBe) and (input2 is NSde) then (output1 is NBu) (1)
46. If (input1 is PBe) and (input2 is Zde) then (output1 is NBu) (1)
47. If (input1 is PBe) and (input2 is PSde) then (output1 is NBu) (1)
48. If (input1 is PBe) and (input2 is PMde) then (output1 is NBu) (1)
49. If (input1 is PBe) and (input2 is PBde) then (output1 is NBu) (1)
50. If (input1 is PZe) and (input2 is NBde) then (output1 is PMu) (1)
51. If (input1 is PZe) and (input2 is NMde) then (output1 is PMu) (1)
52. If (input1 is PZe) and (input2 is NSde) then (output1 is PSu) (1)
53. If (input1 is PZe) and (input2 is Zde) then (output1 is Zu) (1)
54. If (input1 is PZe) and (input2 is PSde) then (output1 is NSu) (1)
55. If (input1 is PZe) and (input2 is PMde) then (output1 is NMu) (1)

56. If (input1 is PZe) and (input2 is PBde) then (output1 is NMu) (1)

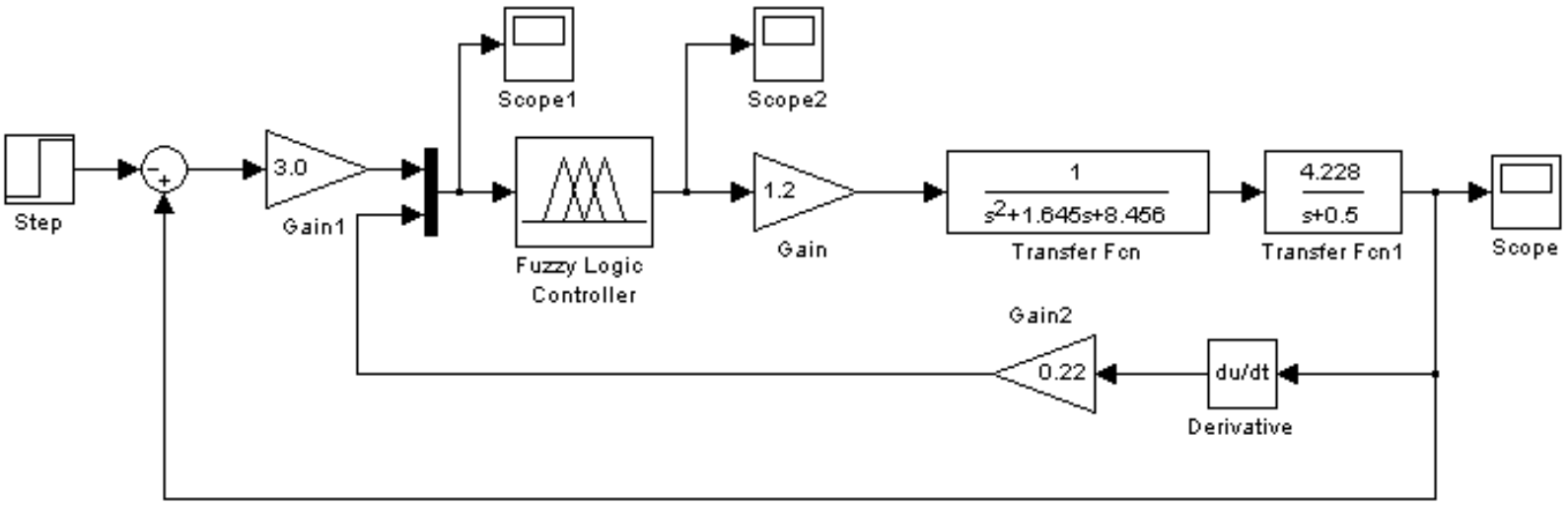

input1 = 0
input2 = 0
output1 = 0.999
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
-1
1
-0.1
0.1
0
2

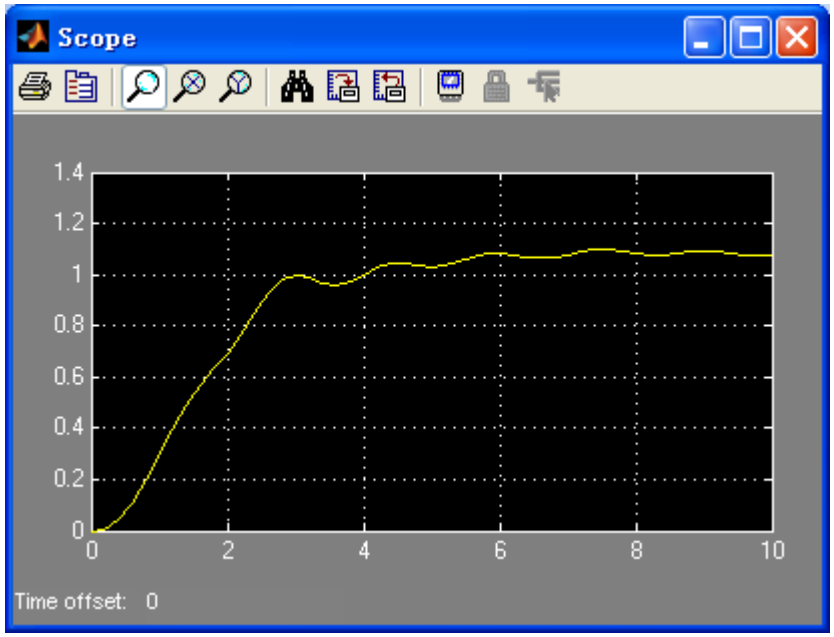

31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
-1
1
-0.1
0.1
0
2

也可以用 viewsurf 菜单命令看模糊控制器的输出量

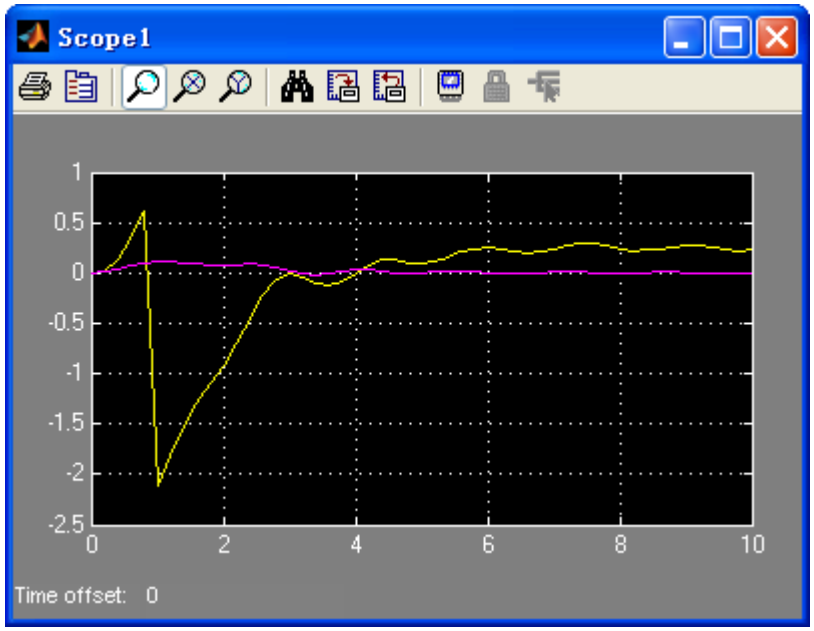


仿真程序：

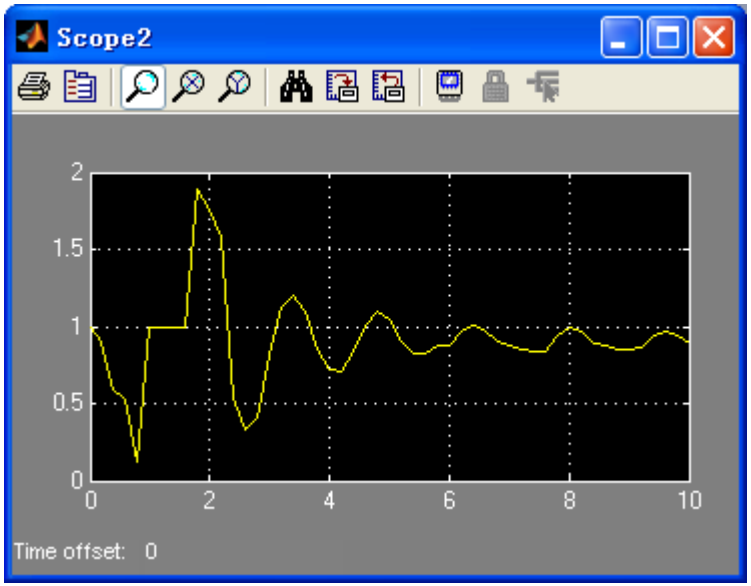

Scope1
Scope2
Step
3.0
Gain1
Fuzzy Logic
Controller
1.2
Gain
1
s2+1.645s+8.456
Transfer Fcn
4.228
s+0.5
Transfer Fcn1
Scope
Gain2
0.22
du/dt
Derivative



系统输出



误差及其变化率



模糊控制器输出