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E/16/156

CO542 – Neural Networks and Fuzzy Systems

Lab2 – Fuzzy Logic

1. **Define the rule-base for the scenario.**

	Angle(Θ)					
Angular Velocity (ω)		NH	NL	Z	PL	PH
	NH	NH	NH	NH	NL	Z
	NL	NH	NH	NL	Z	PL
	Z	NH	NL	Z	PL	PH
	PL	NL	Z	PL	PH	PH
	PH	Z	PL	PH	PH	PH

2. **Membership values**

Angle

- Zero 0.75
- Positive Low 0.25

Angular Velocity

- Zero 0.4
- Negative Low 0.6

Step 1:

1. If angle(Θ) is zero and velocity(ω) is zero then force is zero
   Zero(Angle)^Zero(Velocity) => Zero(Force)

2. If angle(Θ) is zero and velocity(ω) is NL then force is NL
   NegativeLow(Angle)^Zero(Velocity) => NegativeLow(Force)

3. If angle(Θ) is PL and velocity(ω) is zero then force is PL
   PositiveLow(Angle)^Zero(Velocity) => PositiveLow(Force)

4. If angle(Θ) is PL and velocity(ω) is NL then force is zero
   PositiveLow(Angle)^ NegativeLow(Velocity) => Zero(Force)

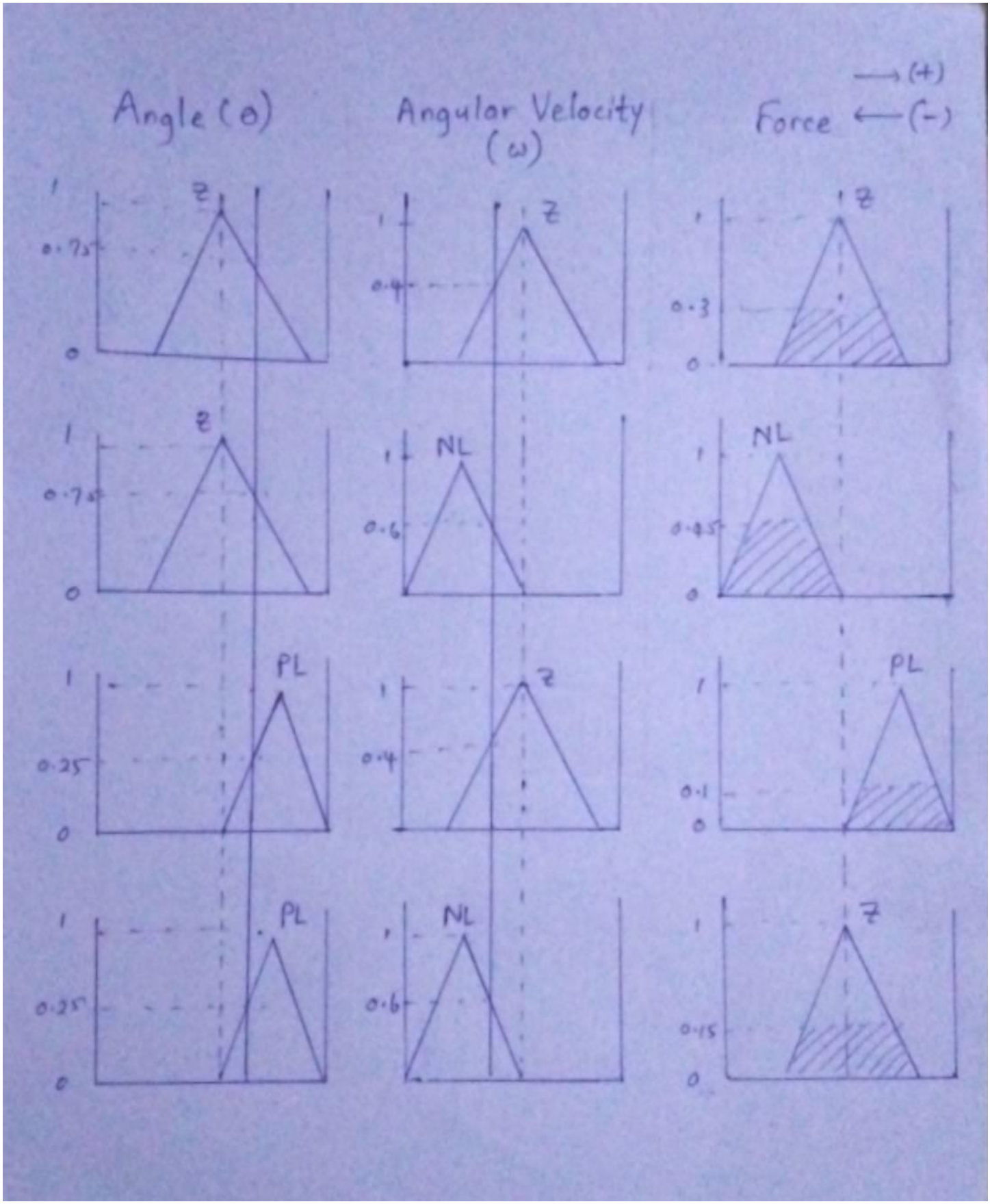
Step 2:

Membership function value calculation

$\mu ij = \mu i(X) . \mu j(X)$

μ_{23} = 0.75 x 0.6 = 0.45
μ_{24} = 0.25 x 0.6 = 0.15
μ_{33} = 0.75 x 0.4 = 0.3
μ_{34} = 0.25 x 0.4 = 0.1

Illustrate each μij with the help of the figure



Step 3:

Defuzzification using the Centroid Defuzzification Method

$$f(x)=\frac{\sum_{i=1}^{N} z^{i} \prod_{j=1}^{n} \mu_{ij}(x_j)}{\sum_{i=1}^{N} \prod_{j=1}^{n} \mu_{ij}(x_j)}$$

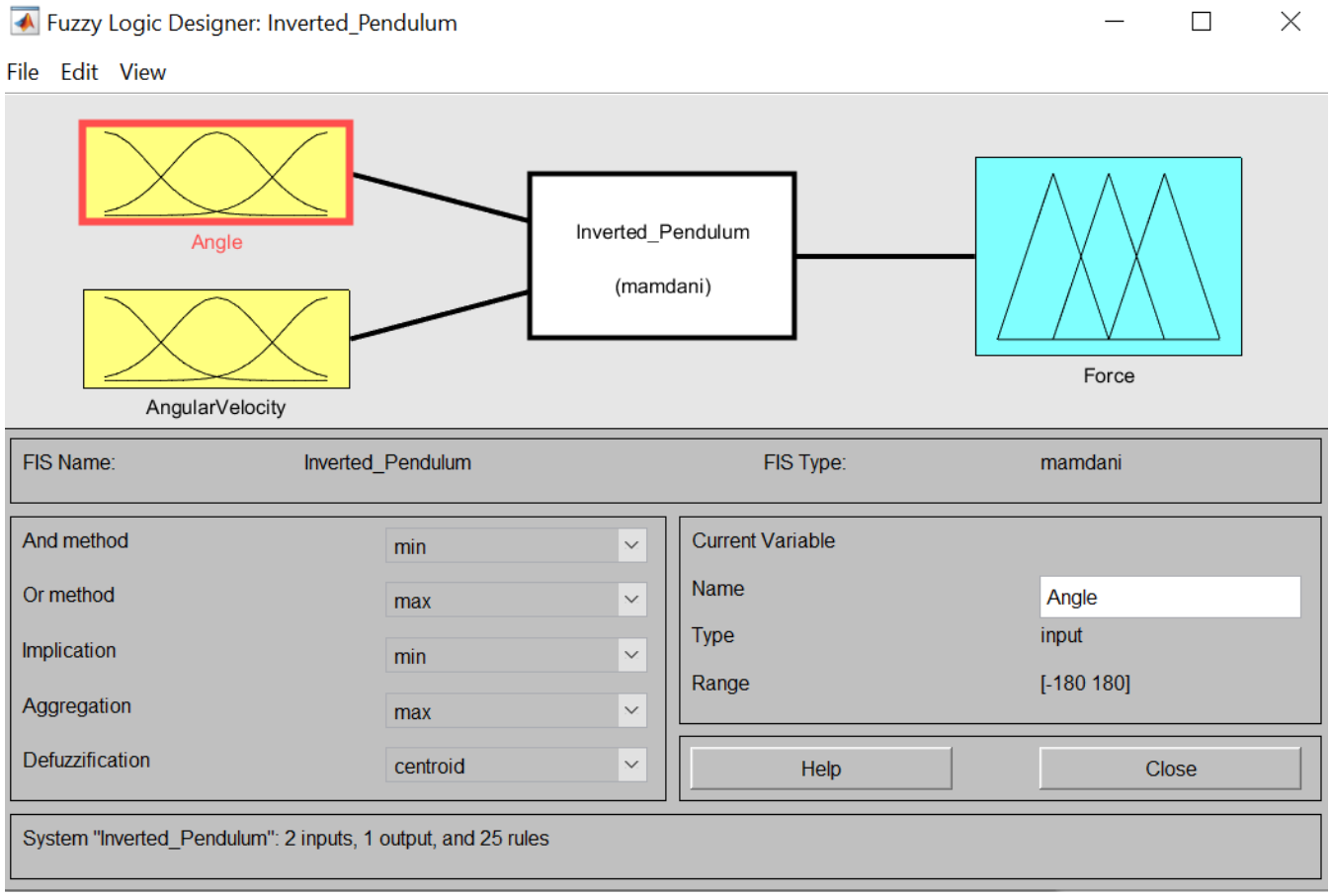
From the above formula,

$$\text{Force} = \frac{[NL \times (\mu_{23})] + [Z \times (\mu_{24})] + [Z \times (\mu_{33})] + [PL \times (\mu_{34})]}{(\mu_{23} + \mu_{24} + \mu_{33} + \mu_{34})}$$

$$= \frac{[-0.45] + [0] + [0] + [0.1]}{(0.45 + 0.15 + 0.3 + 0.1)}$$

$$= \underline{-0.35\ N}$$

3. Use Fuzzy Logic tool box in MATLAB



Command Window

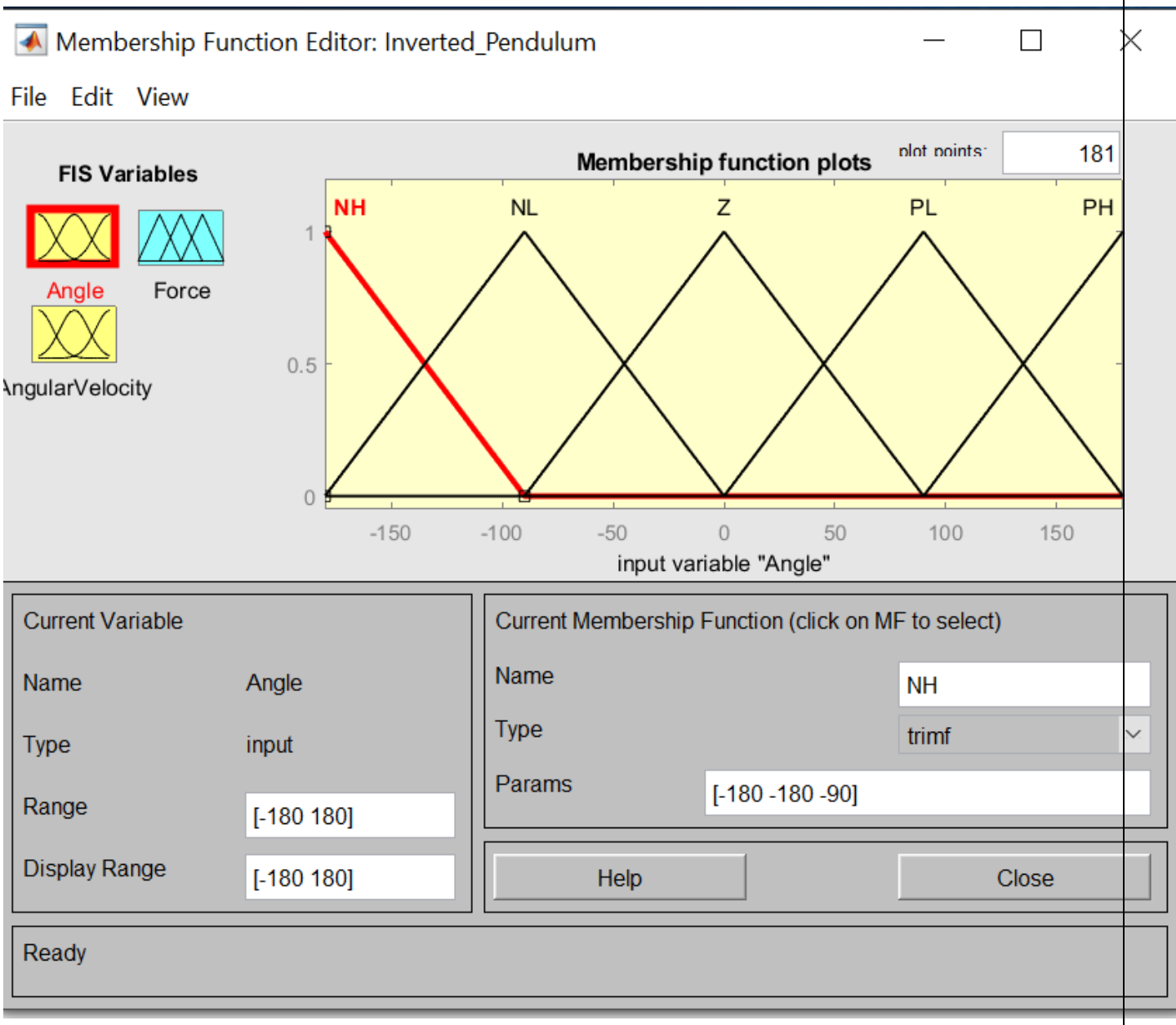
```
>>
>> fuzzy
>> fis =readfis('Inverted_Pendulum');
>> out = evalfis([65 -0.1],fis)

out =

    0.3873

>> surfview(fis)
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
>>
```

Input Membership Function


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
1
0.5
0
-150
-100
-50
0
50
100
150
input variable "Angle"
Current Variable
Name
Angle
Type
input
Range
[-180 180]
Display Range
[-180 180]
Current Membership Function (click on MF to select)
Name
NH
Type
trimf
Params
[-180 -180 -90]
Help
Close
Ready


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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0.5
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-150
-100
-50
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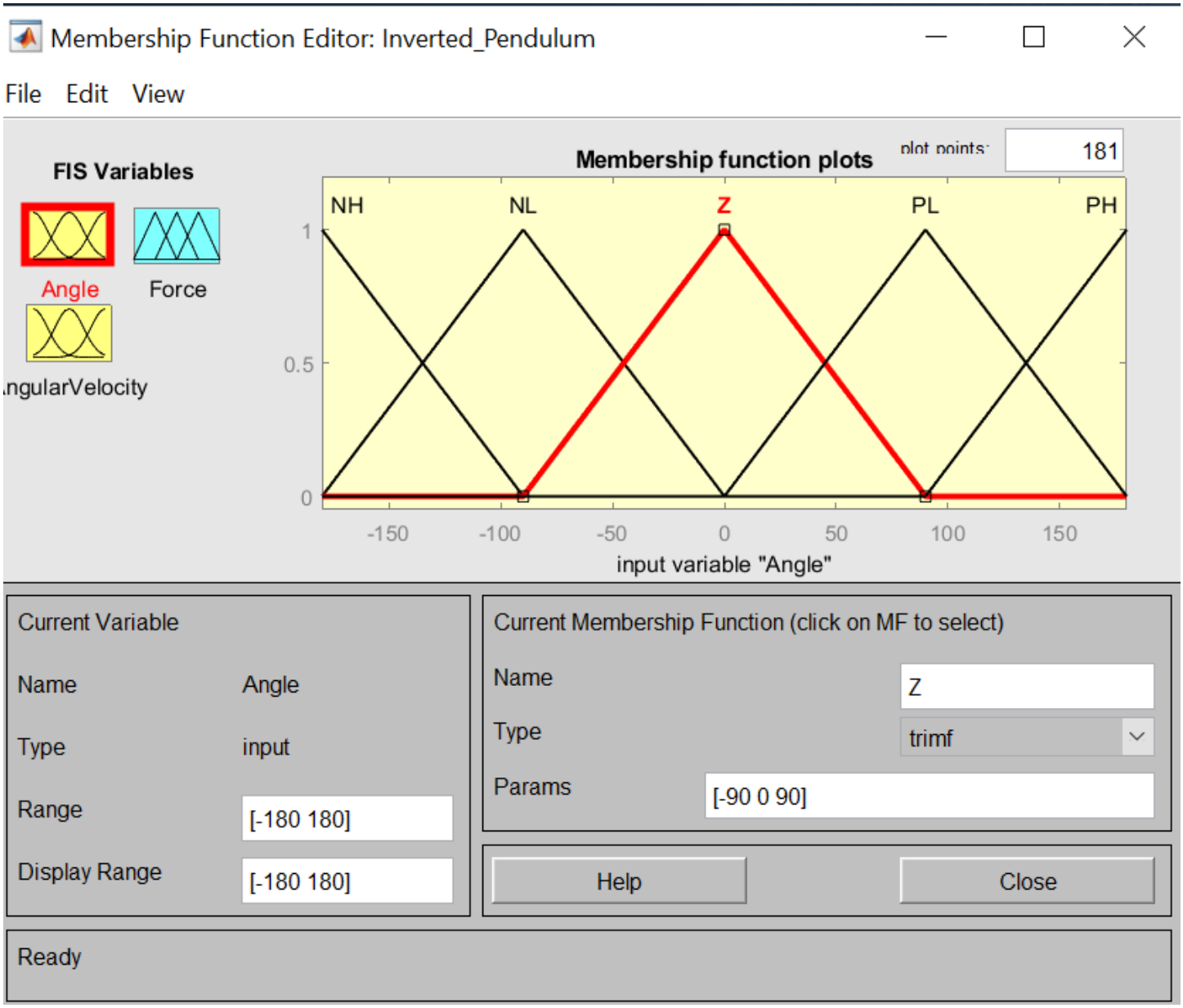
100
150
input variable "Angle"
Current Variable
Name
Angle
Type
input
Range
[-180 180]
Display Range
[-180 180]
Current Membership Function (click on MF to select)
Name
NL
Type
trimf
Params
[-180 -90 0]
Help
Close
Ready


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
ngularVelocity
Membership function plots
plot points:
181
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PH
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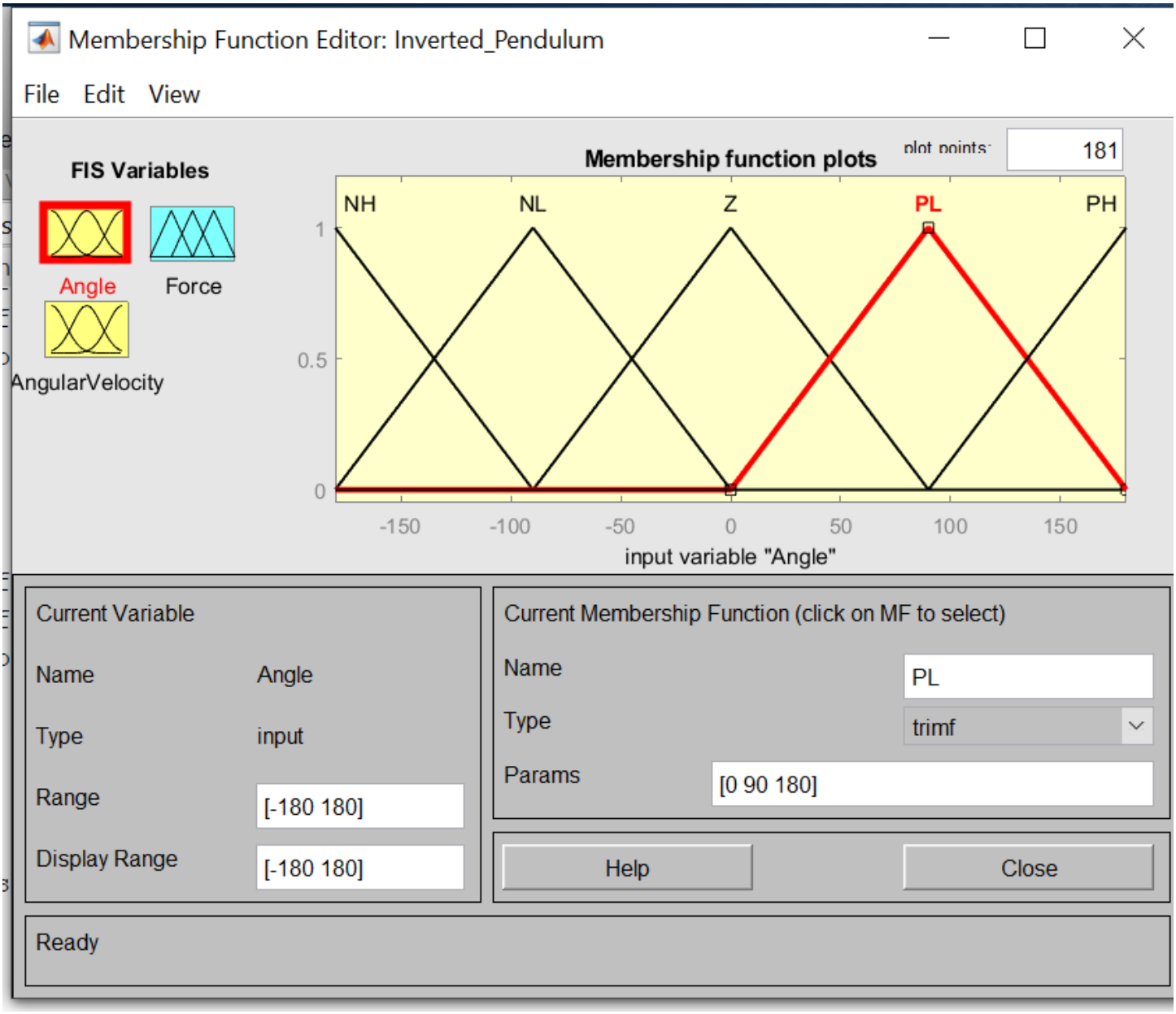
input variable "Angle"
Current Variable
Name
Angle
Type
input
Range
[-180 180]
Display Range
[-180 180]
Current Membership Function (click on MF to select)
Name
Z
Type
trimf
Params
[-90 0 90]
Help
Close
Ready


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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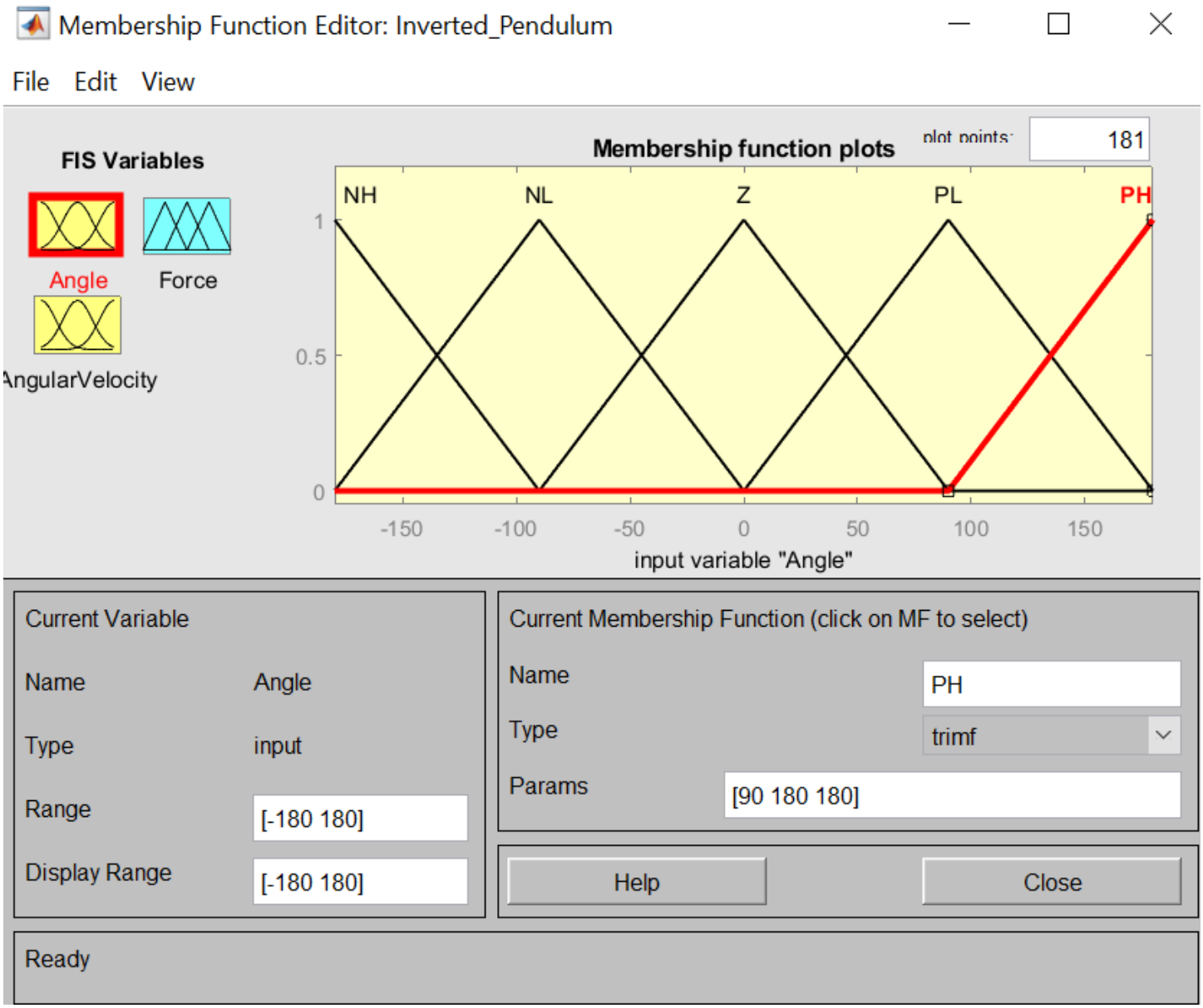
-150
-100
-50
0
50
100
150
input variable "Angle"
Current Variable
Name
Angle
Type
input
Range
[-180 180]
Display Range
[-180 180]
Current Membership Function (click on MF to select)
Name
PL
Type
trimf
Params
[0 90 180]
Help
Close
Ready


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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-150
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-50
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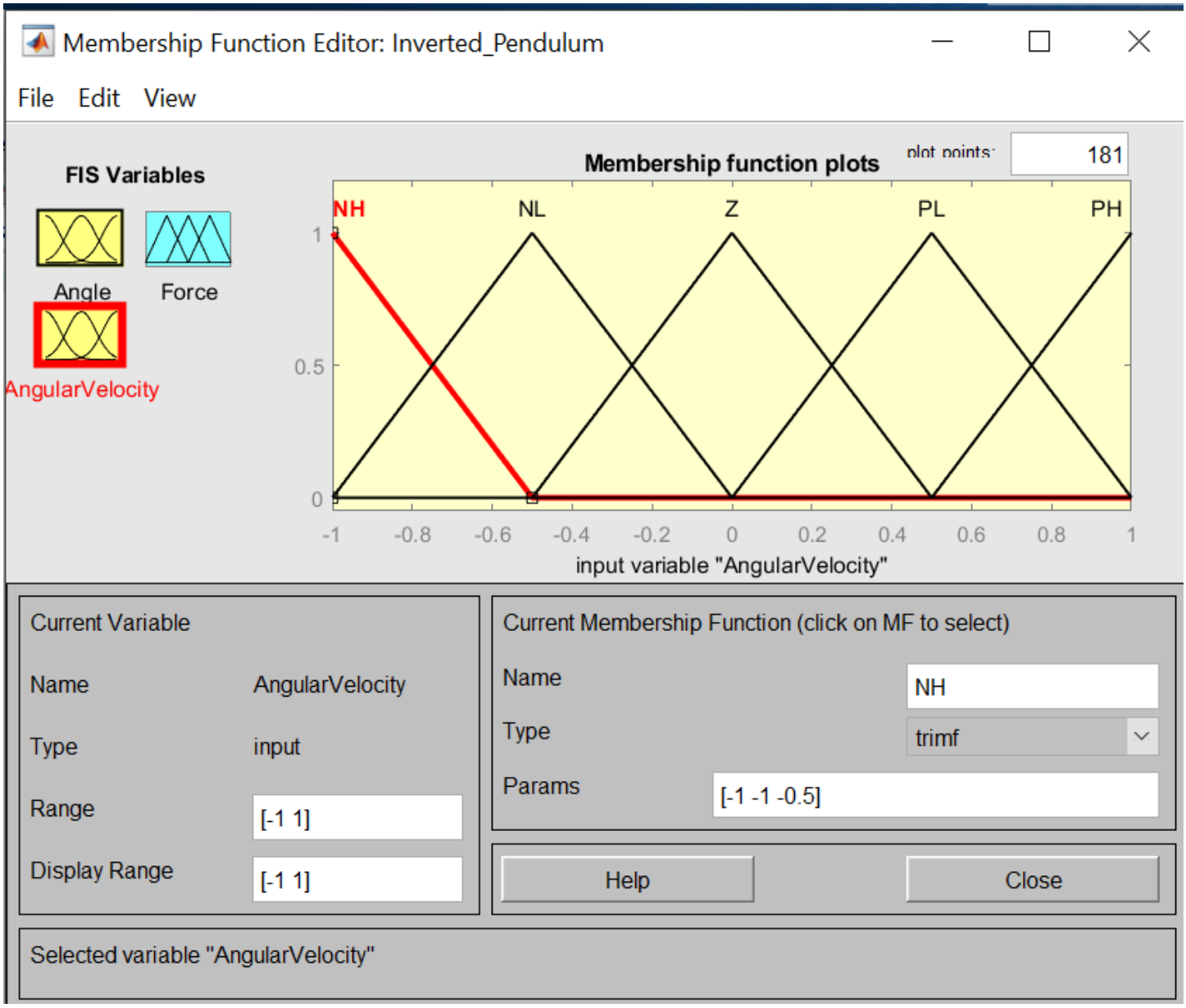
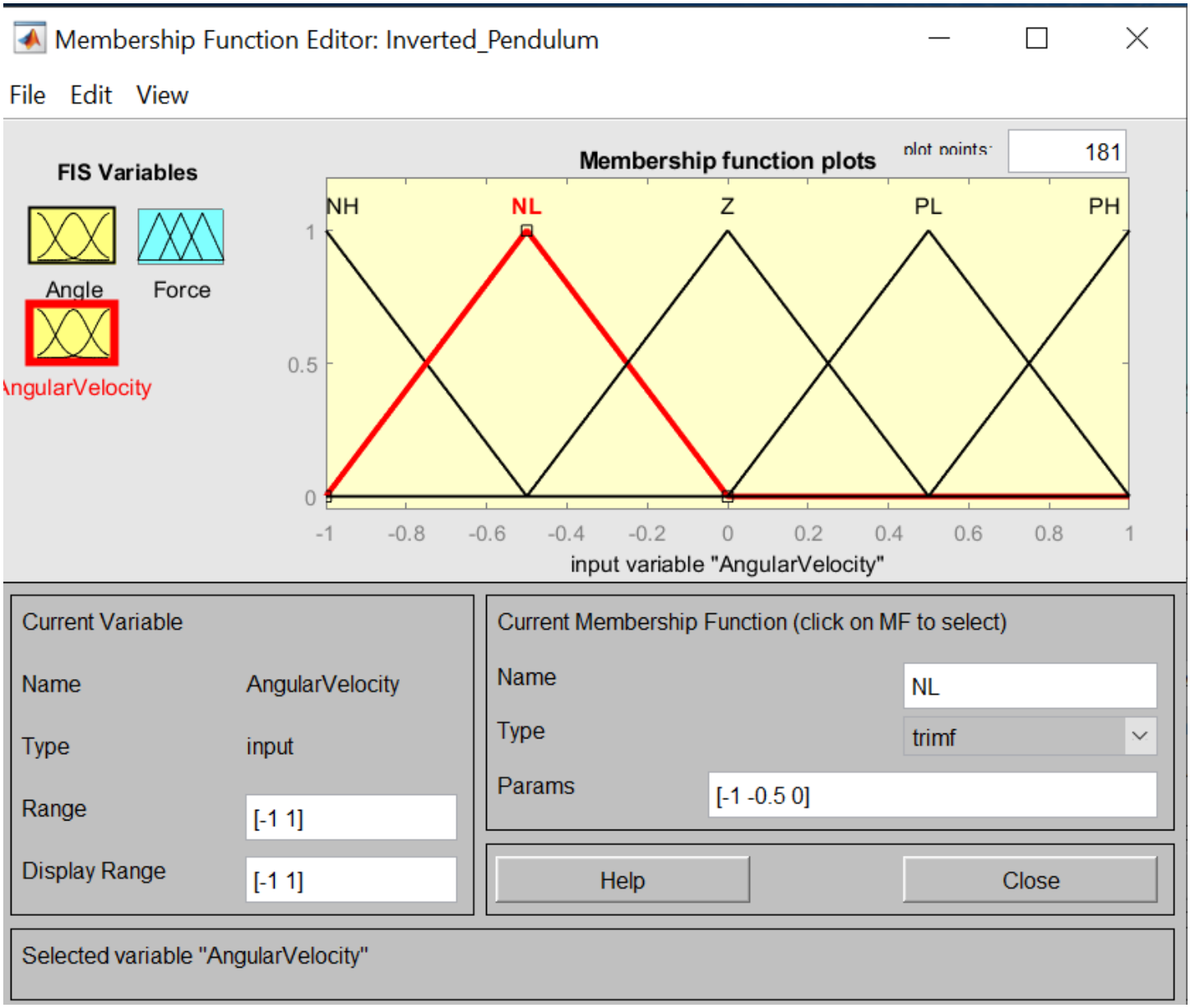
50
100
150
input variable "Angle"
Current Variable
Name
Angle
Type
input
Range
[-180 180]
Display Range
[-180 180]
Current Membership Function (click on MF to select)
Name
PH
Type
trimf
Params
[90 180 180]
Help
Close
Ready


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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 "AngularVelocity"
Current Variable
Name AngularVelocity
Type input
Range [-1 1]
Display Range [-1 1]
Current Membership Function (click on MF to select)
Name NH
Type trimf
Params [-1 -1 -0.5]
Help
Close
Selected variable "AngularVelocity"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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-0.8
-0.6
-0.4
-0.2
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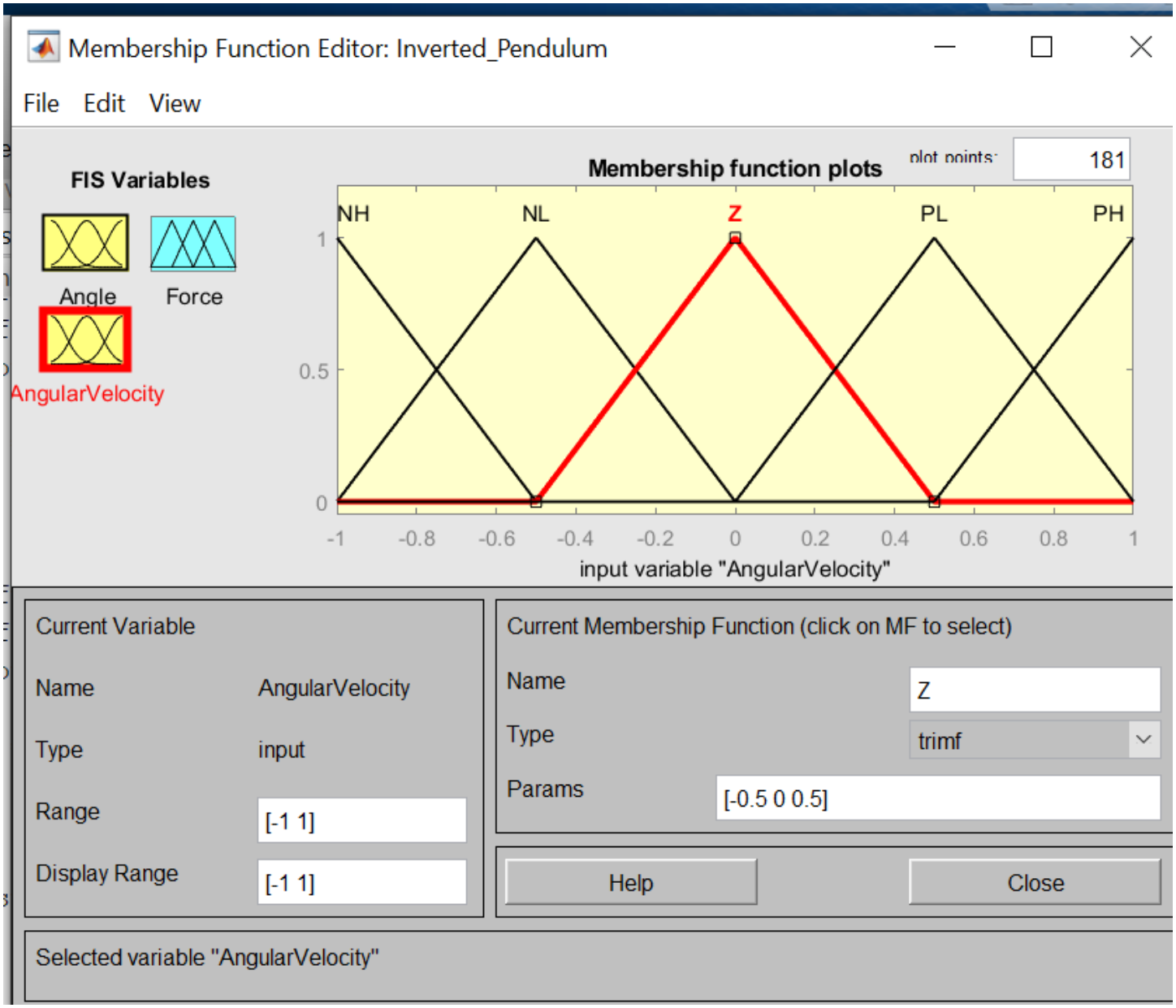
0.2
0.4
0.6
0.8
1
input variable "AngularVelocity"
Current Variable
Name
AngularVelocity
Type
input
Range
[-1 1]
Display Range
[-1 1]
Current Membership Function (click on MF to select)
Name
NL
Type
trimf
Params
[-1 -0.5 0]
Help
Close
Selected variable "AngularVelocity"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
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NH
NL
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PL
PH
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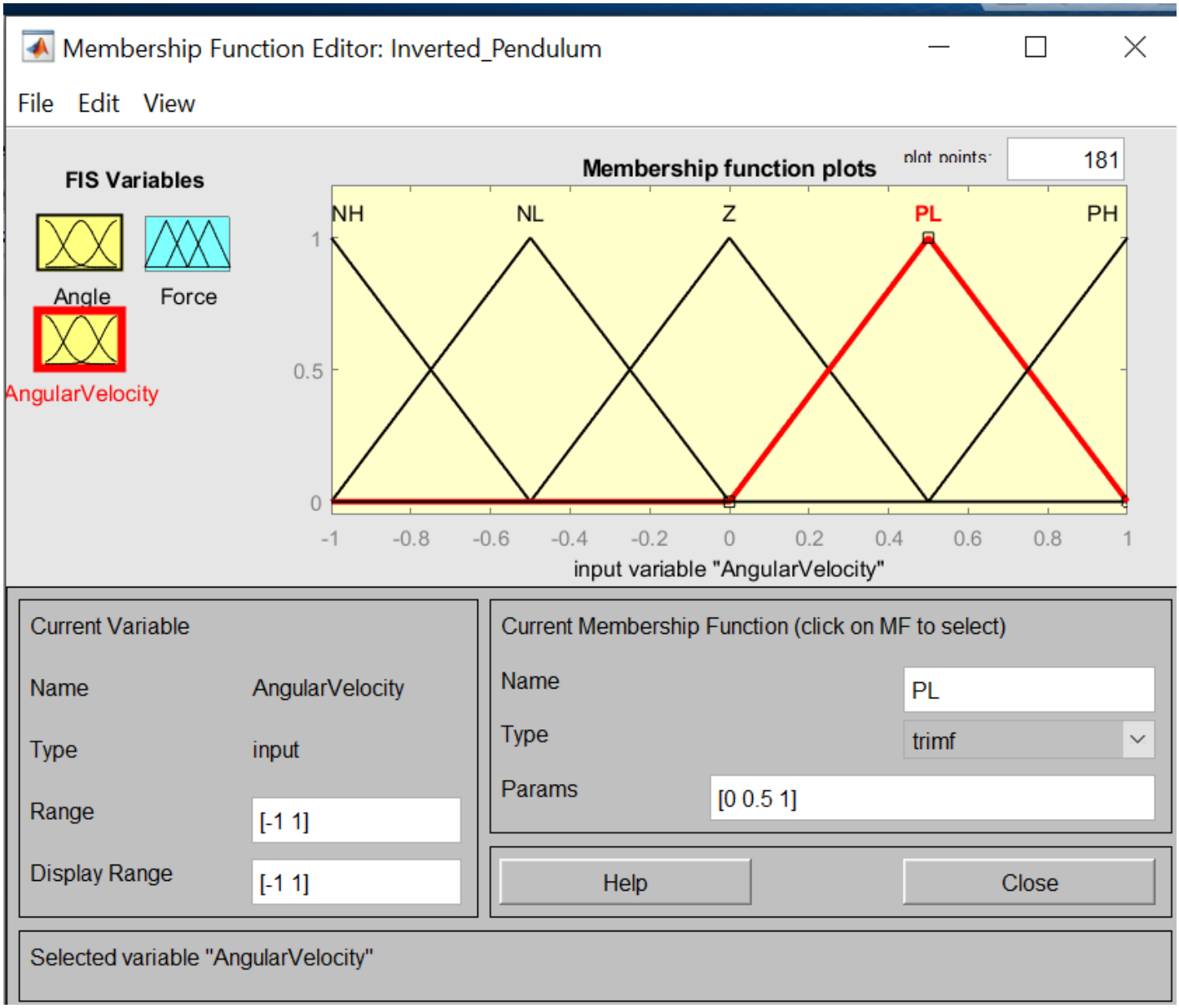
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
input variable "AngularVelocity"
Current Variable
Name
AngularVelocity
Type
input
Range
[-1 1]
Display Range
[-1 1]
Current Membership Function (click on MF to select)
Name
Z
Type
trimf
Params
[-0.5 0 0.5]
Help
Close
Selected variable "AngularVelocity"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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-0.6
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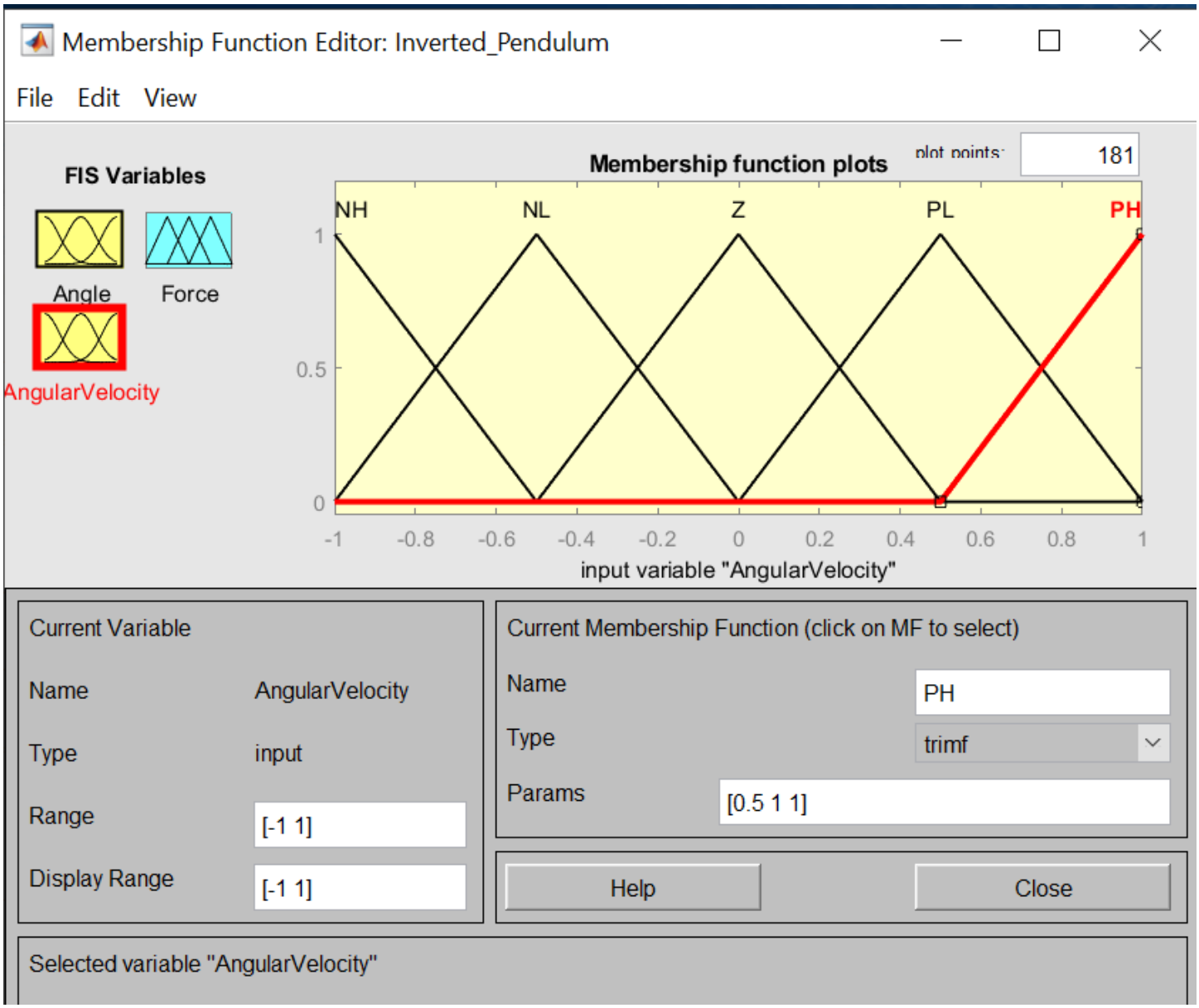
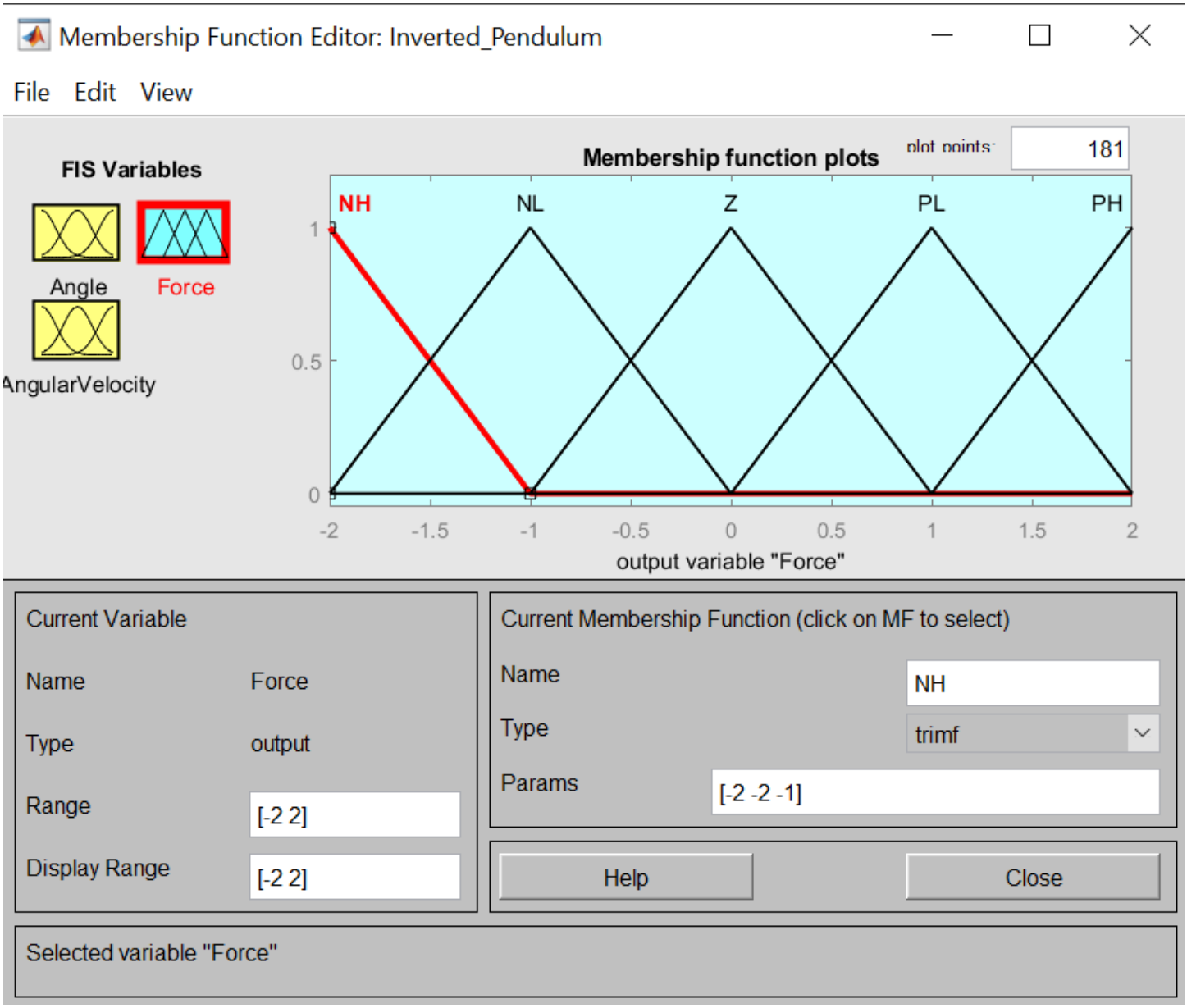
0.2
0.4
0.6
0.8
1
input variable "AngularVelocity"
Current Variable
Name
AngularVelocity
Type
input
Range
[-1 1]
Display Range
[-1 1]
Current Membership Function (click on MF to select)
Name
PL
Type
trimf
Params
[0 0.5 1]
Help
Close
Selected variable "AngularVelocity"



Output Membership Function


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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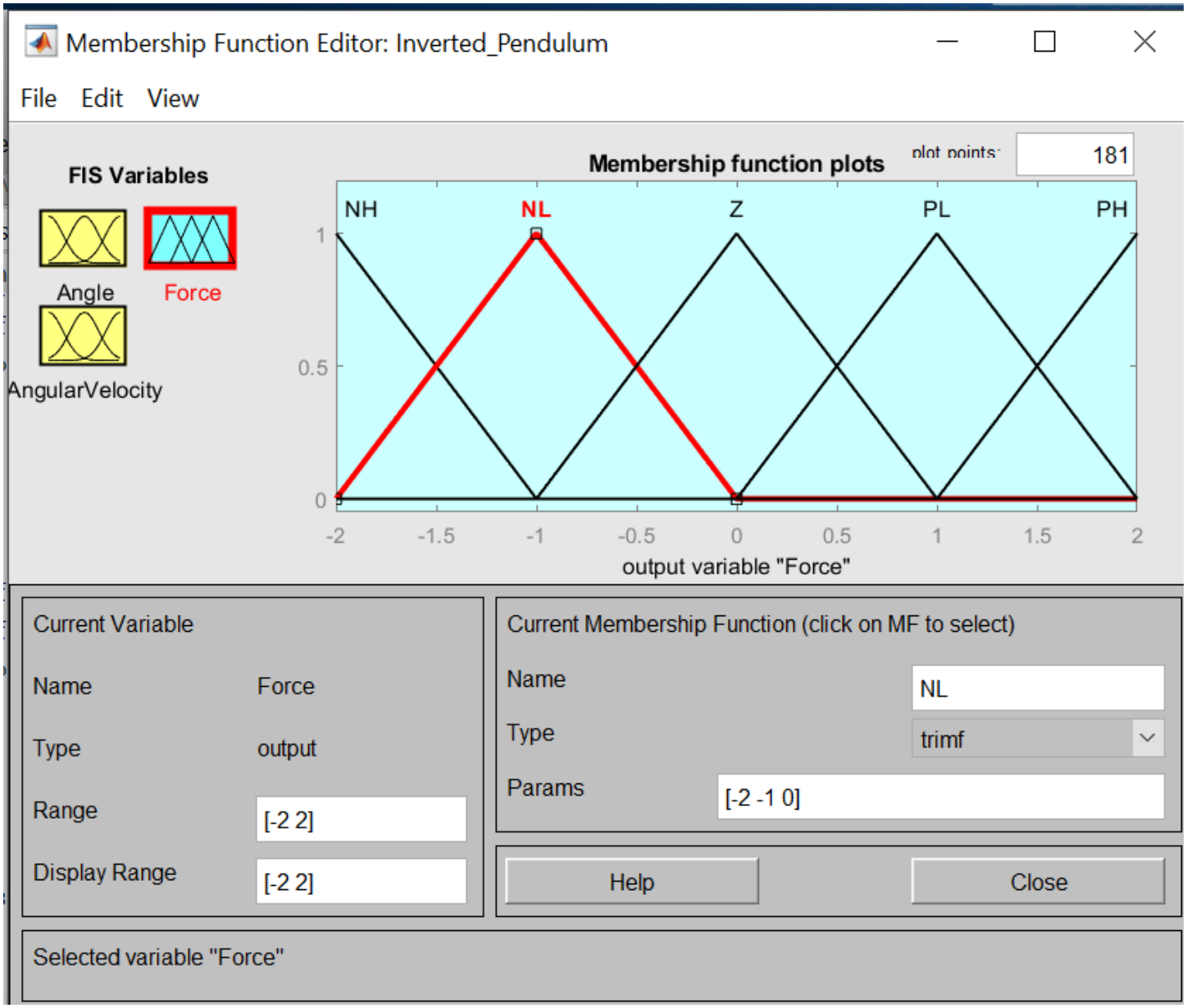
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
output variable "Force"
Current Variable
Name
Force
Type
output
Range
[-2 2]
Display Range
[-2 2]
Current Membership Function (click on MF to select)
Name
NH
Type
trimf
Params
[-2 -2 -1]
Help
Close
Selected variable "Force"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
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NL
Z
PL
PH
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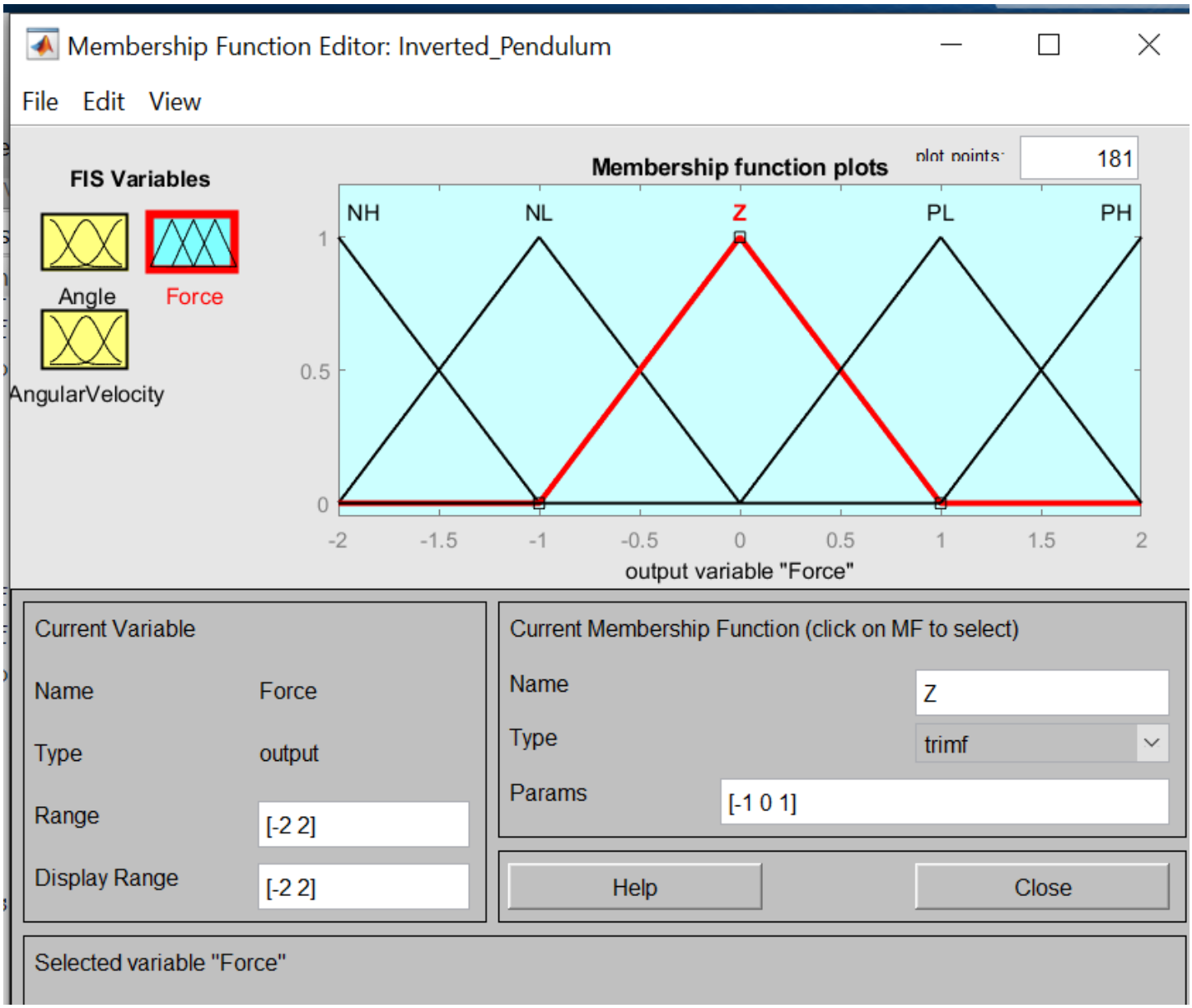
-1.5
-1
-0.5
0
0.5
1
1.5
2
output variable "Force"
Current Variable
Name
Force
Type
output
Range
[-2 2]
Display Range
[-2 2]
Current Membership Function (click on MF to select)
Name
NL
Type
trimf
Params
[-2 -1 0]
Help
Close
Selected variable "Force"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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-1.5
-1
-0.5
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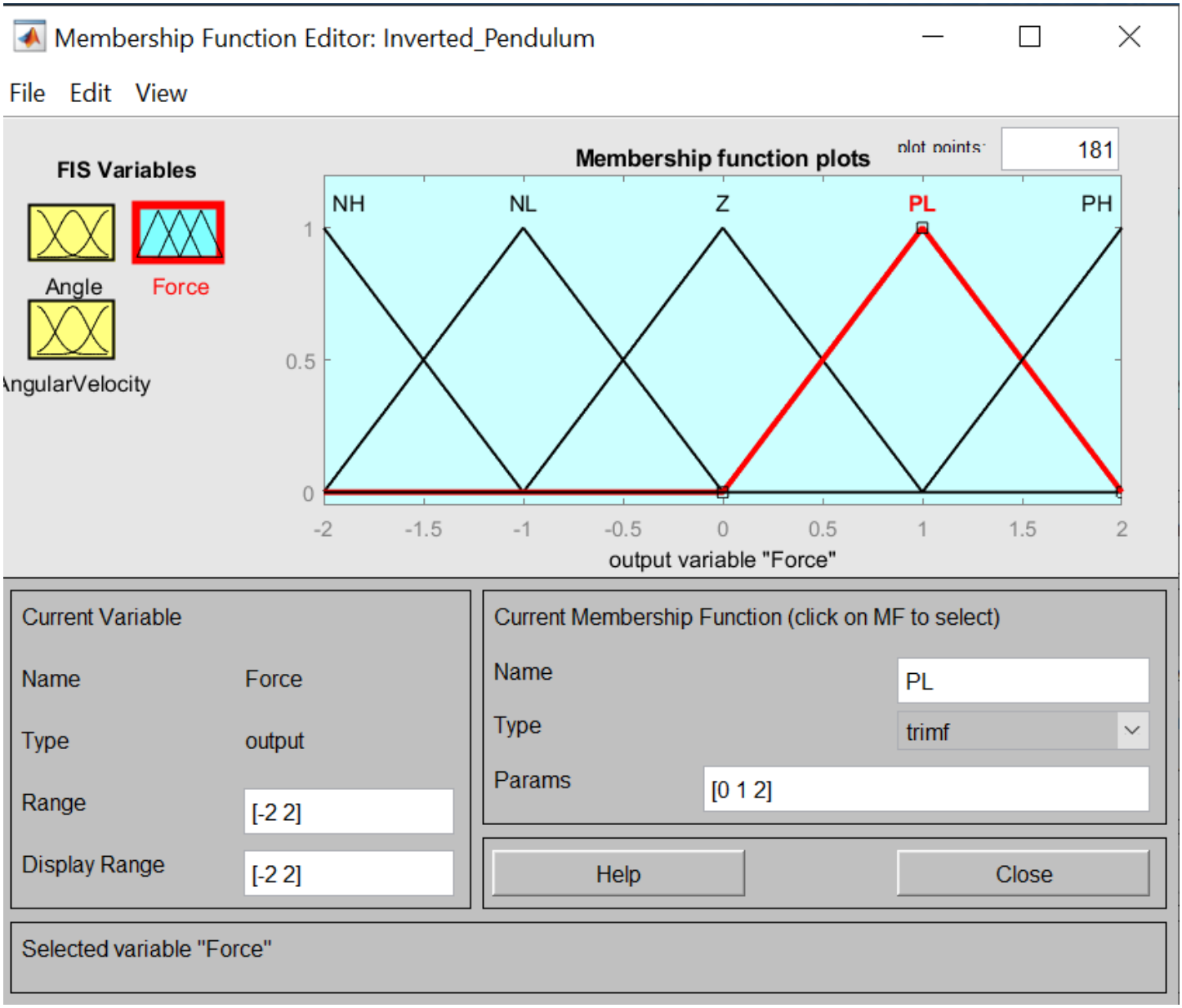
0.5
1
1.5
2
output variable "Force"
Current Variable
Name
Force
Type
output
Range
[-2 2]
Display Range
[-2 2]
Current Membership Function (click on MF to select)
Name
Z
Type
trimf
Params
[-1 0 1]
Help
Close
Selected variable "Force"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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0.5
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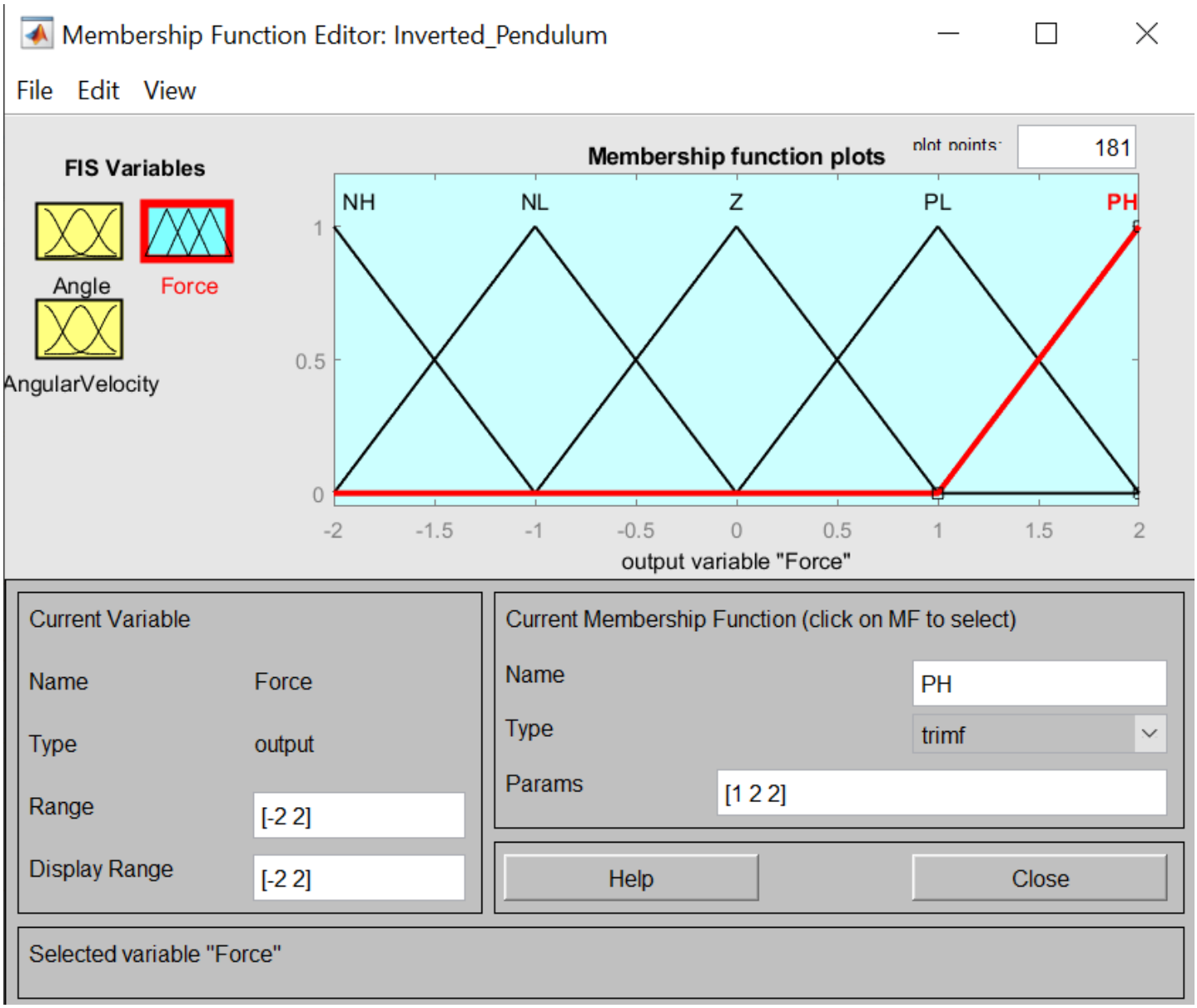
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
output variable "Force"
Current Variable
Name
Force
Type
output
Range
[-2 2]
Display Range
[-2 2]
Current Membership Function (click on MF to select)
Name
PL
Type
trimf
Params
[0 1 2]
Help
Close
Selected variable "Force"


Membership Function Editor: Inverted_Pendulum
File Edit View
FIS Variables
Angle
Force
AngularVelocity
Membership function plots
plot points:
181
NH
NL
Z
PL
PH
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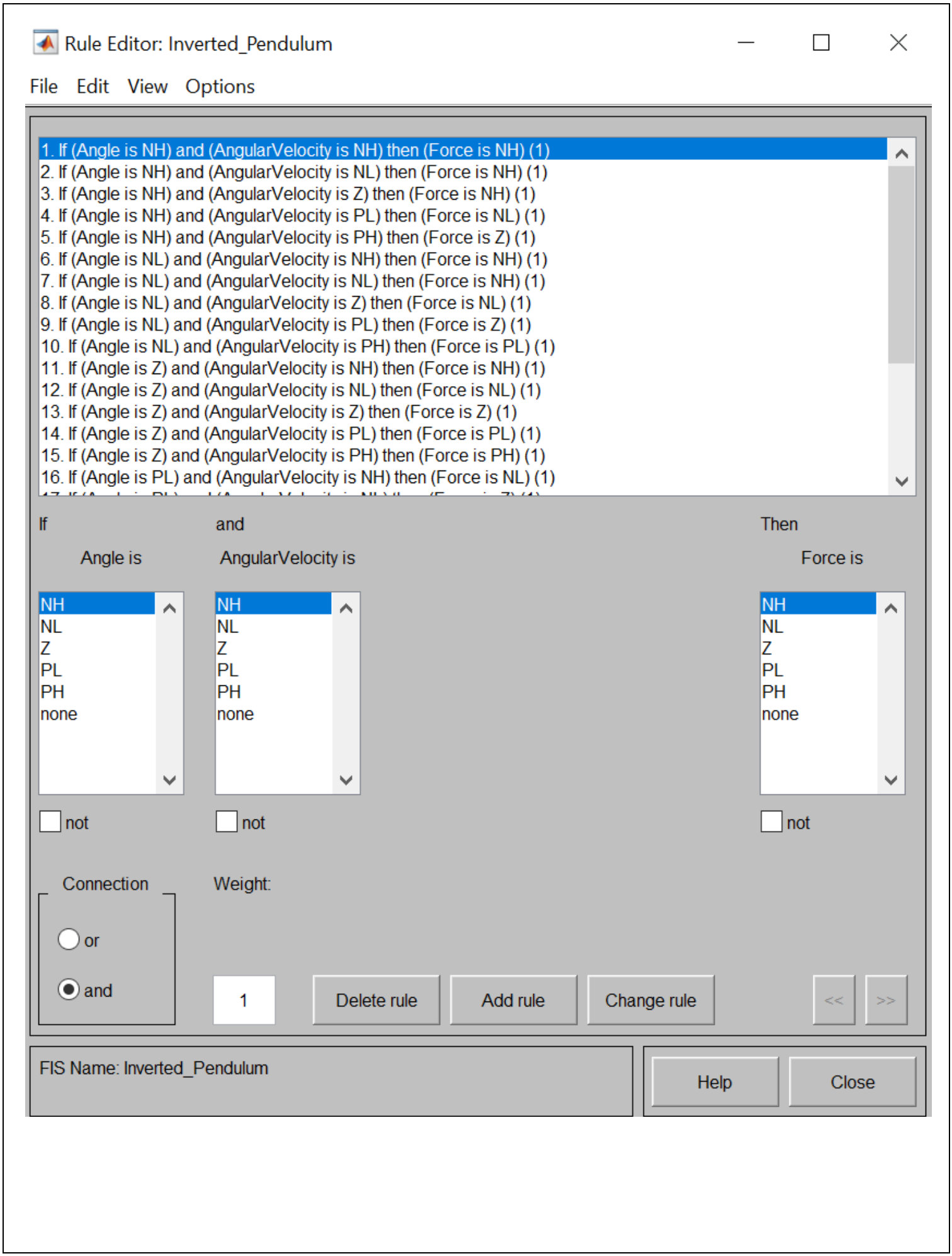
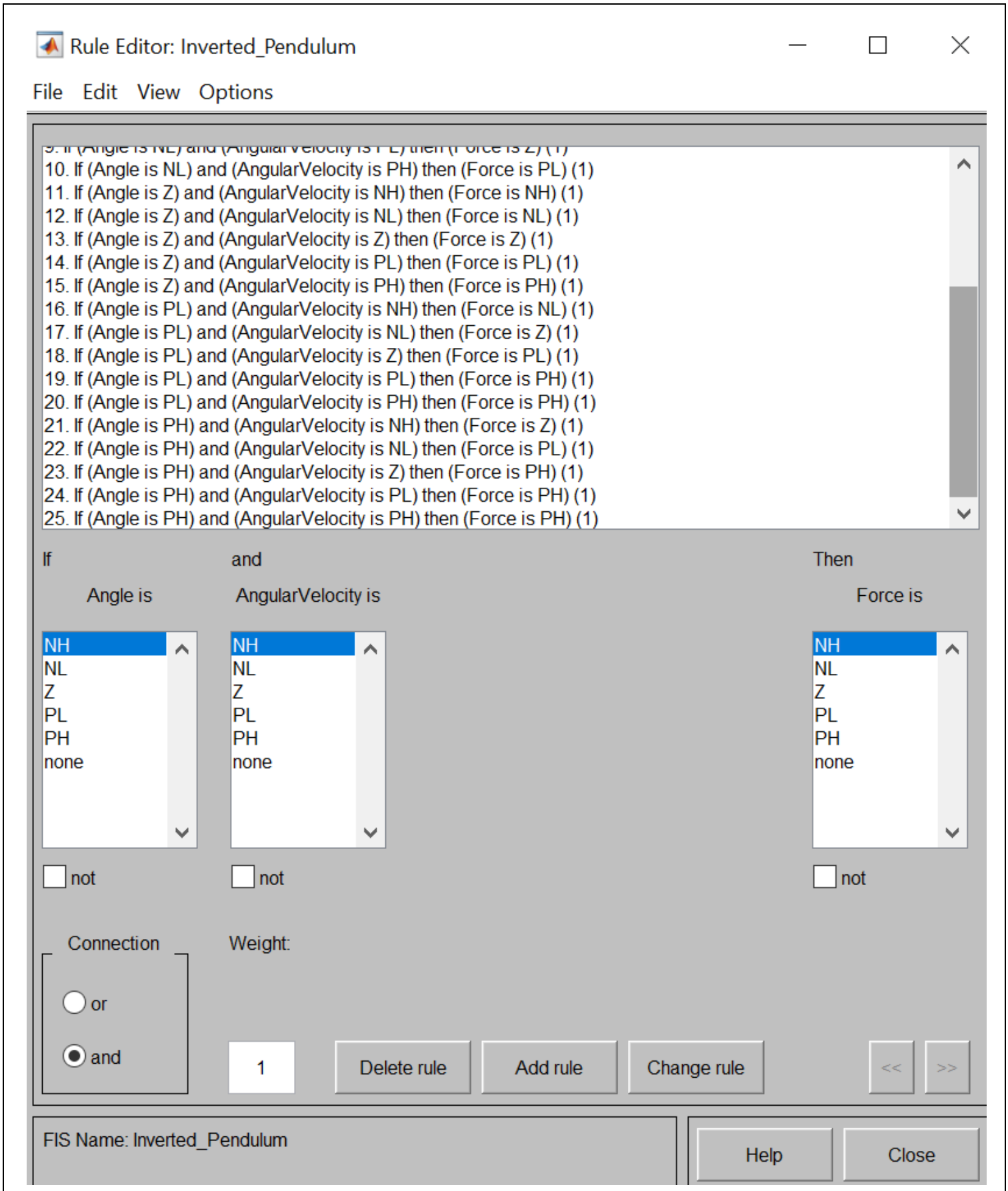
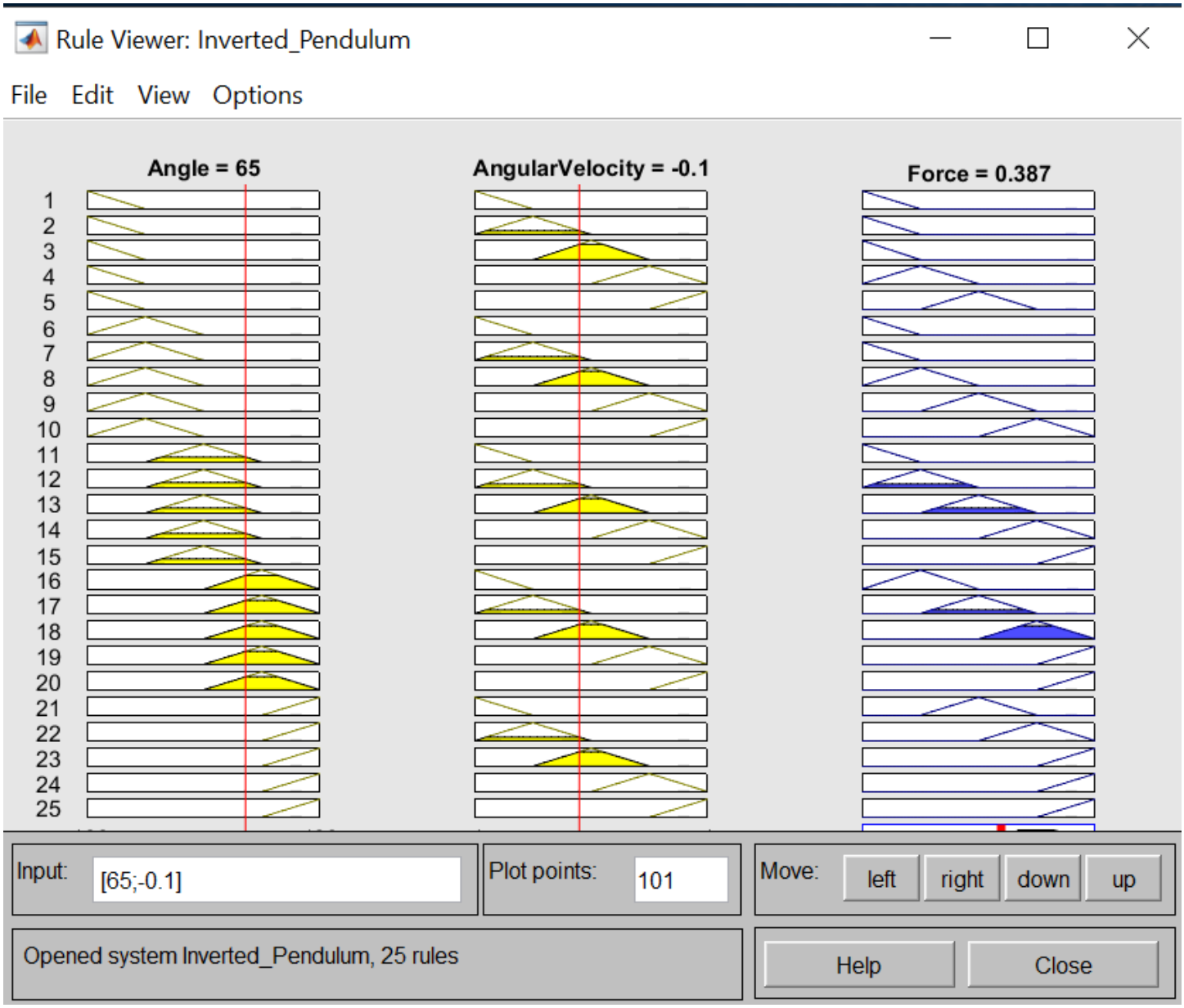
output variable "Force"
Current Variable
Name
Force
Type
output
Range
[-2 2]
Display Range
[-2 2]
Current Membership Function (click on MF to select)
Name
PH
Type
trimf
Params
[1 2 2]
Help
Close
Selected variable "Force"

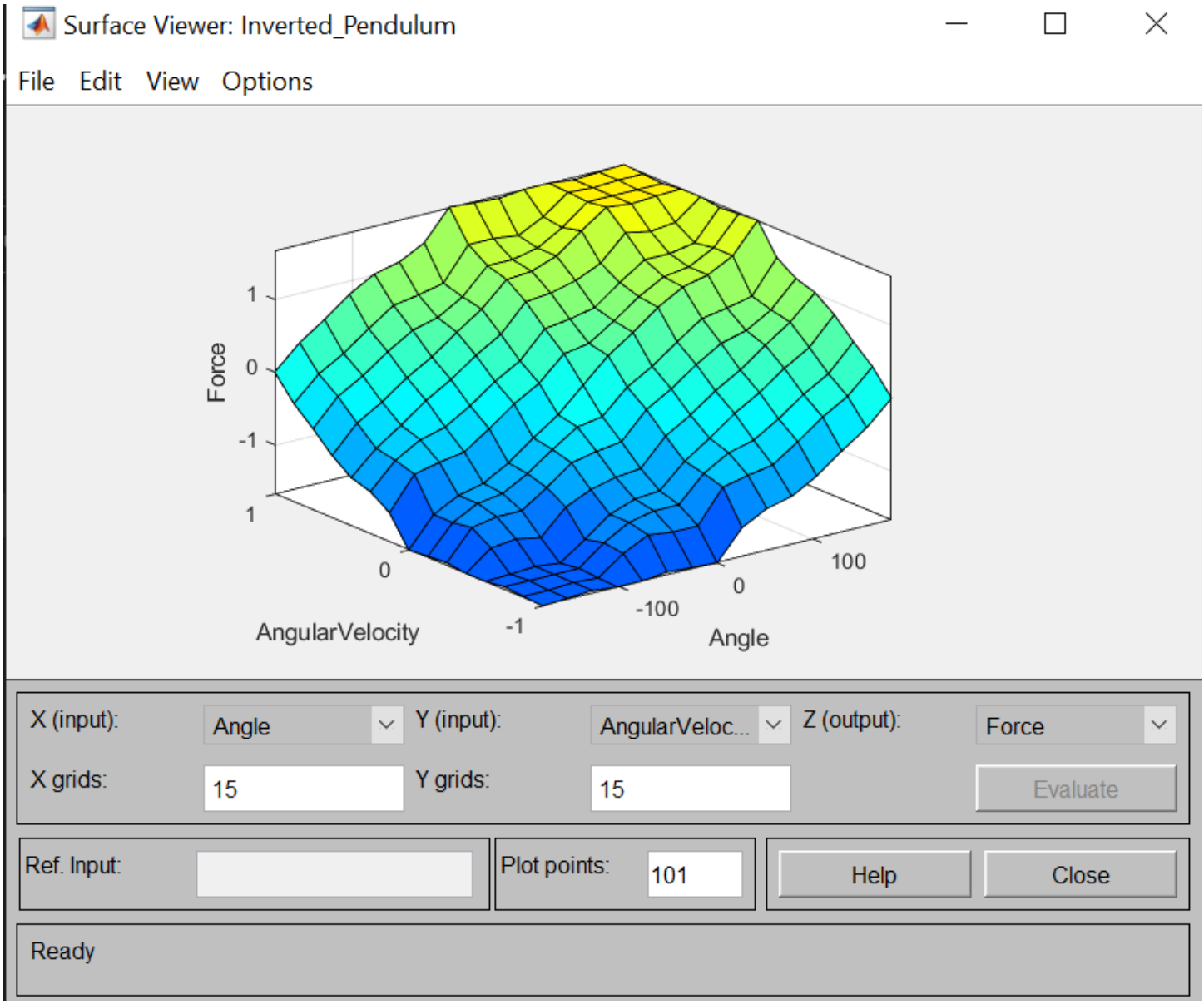
Rule Base


Rule Editor: Inverted_Pendulum
File Edit View Options
1. If (Angle is NH) and (AngularVelocity is NH) then (Force is NH) (1)
2. If (Angle is NH) and (AngularVelocity is NL) then (Force is NH) (1)
3. If (Angle is NH) and (AngularVelocity is Z) then (Force is NH) (1)
4. If (Angle is NH) and (AngularVelocity is PL) then (Force is NL) (1)
5. If (Angle is NH) and (AngularVelocity is PH) then (Force is Z) (1)
6. If (Angle is NL) and (AngularVelocity is NH) then (Force is NH) (1)
7. If (Angle is NL) and (AngularVelocity is NL) then (Force is NH) (1)
8. If (Angle is NL) and (AngularVelocity is Z) then (Force is NL) (1)
9. If (Angle is NL) and (AngularVelocity is PL) then (Force is Z) (1)
10. If (Angle is NL) and (AngularVelocity is PH) then (Force is PL) (1)
11. If (Angle is Z) and (AngularVelocity is NH) then (Force is NH) (1)
12. If (Angle is Z) and (AngularVelocity is NL) then (Force is NL) (1)
13. If (Angle is Z) and (AngularVelocity is Z) then (Force is Z) (1)
14. If (Angle is Z) and (AngularVelocity is PL) then (Force is PL) (1)
15. If (Angle is Z) and (AngularVelocity is PH) then (Force is PH) (1)
16. If (Angle is PL) and (AngularVelocity is NH) then (Force is NL) (1)
If
Angle is
and
AngularVelocity is
Then
Force is
NH
NL
Z
PL
PH
none
not
not
not
Connection
or
and
Weight:
1
Delete rule
Add rule
Change rule
<<
>>
FIS Name: Inverted_Pendulum
Help
Close


Rule Editor: Inverted_Pendulum
File Edit View Options
10. If (Angle is NL) and (AngularVelocity is PH) then (Force is PL) (1)
11. If (Angle is Z) and (AngularVelocity is NH) then (Force is NH) (1)
12. If (Angle is Z) and (AngularVelocity is NL) then (Force is NL) (1)
13. If (Angle is Z) and (AngularVelocity is Z) then (Force is Z) (1)
14. If (Angle is Z) and (AngularVelocity is PL) then (Force is PL) (1)
15. If (Angle is Z) and (AngularVelocity is PH) then (Force is PH) (1)
16. If (Angle is PL) and (AngularVelocity is NH) then (Force is NL) (1)
17. If (Angle is PL) and (AngularVelocity is NL) then (Force is Z) (1)
18. If (Angle is PL) and (AngularVelocity is Z) then (Force is PL) (1)
19. If (Angle is PL) and (AngularVelocity is PL) then (Force is PH) (1)
20. If (Angle is PL) and (AngularVelocity is PH) then (Force is PH) (1)
21. If (Angle is PH) and (AngularVelocity is NH) then (Force is Z) (1)
22. If (Angle is PH) and (AngularVelocity is NL) then (Force is PL) (1)
23. If (Angle is PH) and (AngularVelocity is Z) then (Force is PH) (1)
24. If (Angle is PH) and (AngularVelocity is PL) then (Force is PH) (1)
25. If (Angle is PH) and (AngularVelocity is PH) then (Force is PH) (1)
If
Angle is
NH
NL
Z
PL
PH
none
not
and
AngularVelocity is
NH
NL
Z
PL
PH
none
not
Then
Force is
NH
NL
Z
PL
PH
none
not
Connection
or
and
Weight:
1
Delete rule
Add rule
Change rule
<<
>>
FIS Name: Inverted_Pendulum
Help
Close


Rule Viewer: Inverted_Pendulum
File Edit View Options
Angle = 65
AngularVelocity = -0.1
Force = 0.387
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
Input: [65;-0.1]
Plot points: 101
Move: left right down up
Opened system Inverted_Pendulum, 25 rules
Help Close

Surface Map


Surface Viewer: Inverted_Pendulum
File Edit View Options
Force
1
0
-1
1
0
-1
AngularVelocity
100
0
-100
Angle
X (input):
Angle
Y (input):
AngularVeloc...
Z (output):
Force
X grids:
15
Y grids:
15
Evaluate
Ref. Input:
Plot points:
101
Help
Close
Ready