

CO542 - Neural Networks and Fuzzy Systems

Lab 02 - Fuzzy Logic

E/15/077

Scenario – Two Inputs One Output

Suppose you are assigned to design a fuzzy control system to determine the force needed to balance an inverted pendulum in a cart. Consider the inputs and output as given below. The angle (θ) between the platform and the pendulum and the angular velocity (ω) of this angle are chosen as the inputs of the system. The Force (F) to be applied on the platform to balance the pendulum is chosen as the corresponding output.

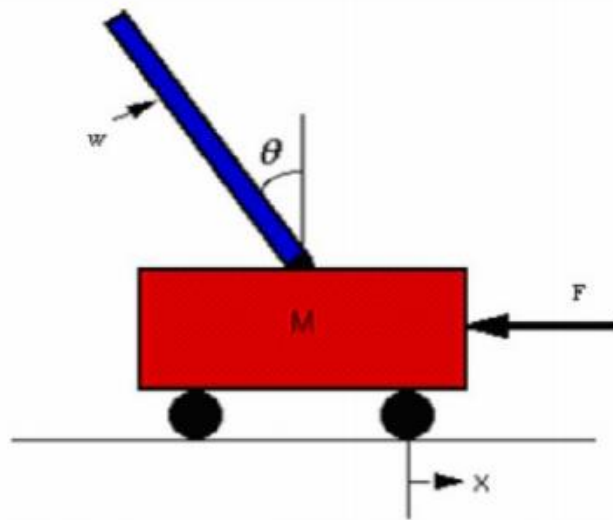


Figure 1: Inverted Pendulum in a cart

Input 1 : Angle (θ)

States of Input1 : (NH, NL, Z, PL, PH)

Input 2 : Angular Velocity (ω)

States of Input2 : (NH, NL, Z, PL, PH)

Output :

Force to be exerted to cart (F)

NH – Negative High (-2)

NL – Negative Low (-1)

Z – Zero (0)

PL – Positive Low (1)

PH – Positive High (2)

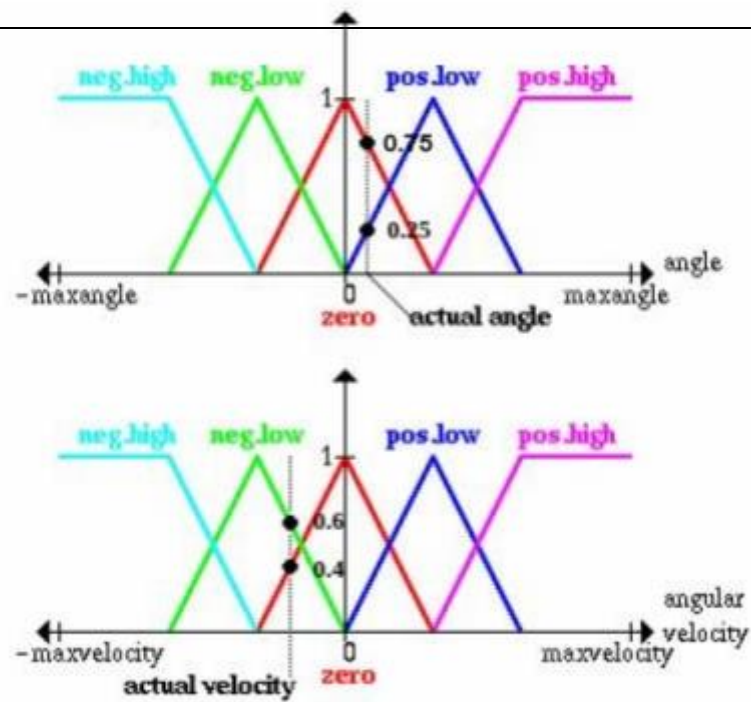


Figure 2: Membership for angle and angular velocity

Lab Tasks

1. Define all the fuzzy rules for the scenario.

- angle

	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. According to the figure 2, the corresponding rules can be listed below;

- If angle is zero and velocity is zero then force is zero
- If angle is zero and velocity is negative low then the force is negative low
- If angle is positive low and velocity is zero then force is positive low
- If angle is positive low and velocity is negative low then force is zero

- Calculating membership functions

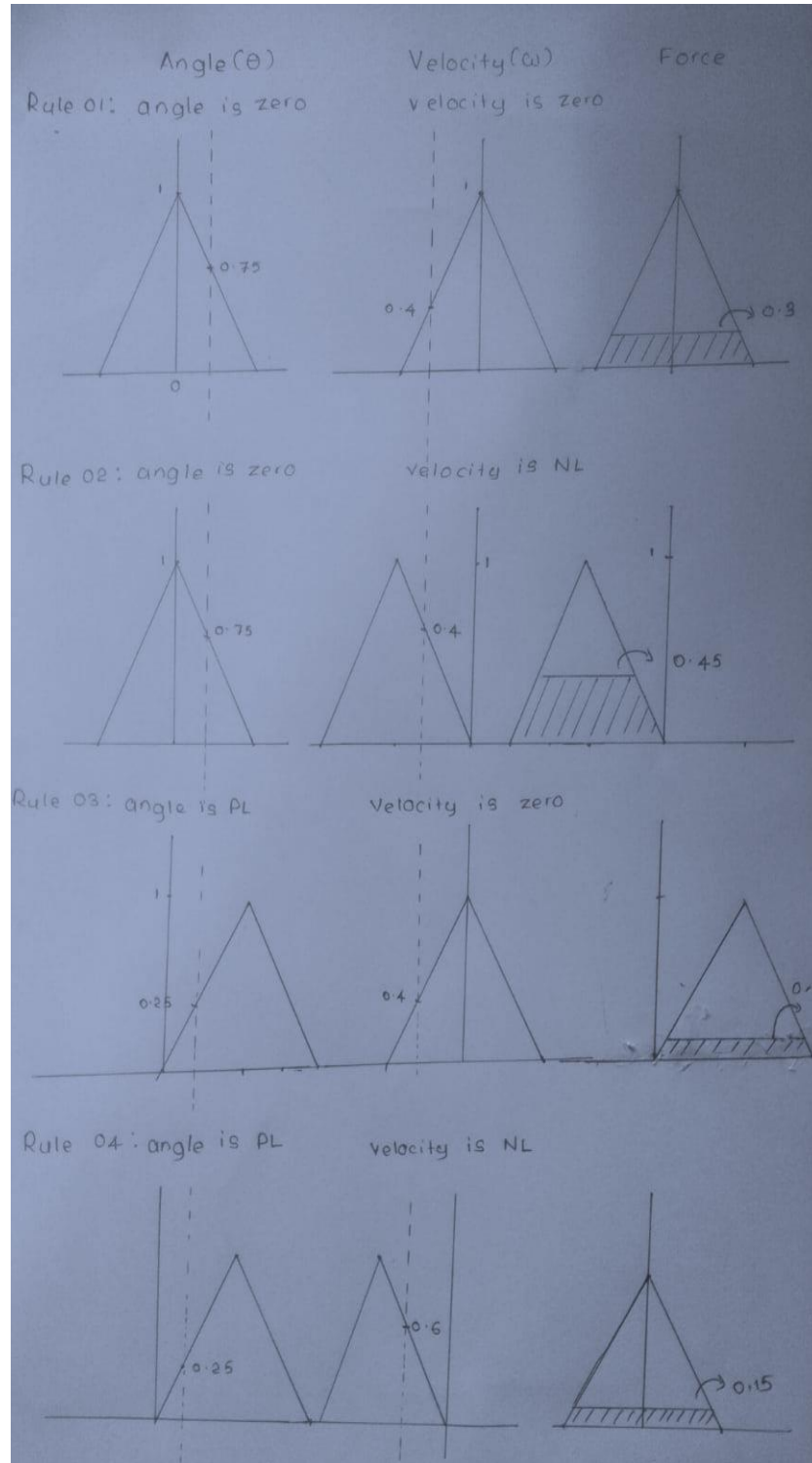


Figure 03: Graphical calculations

$$\mu_{33} = 0.75 \times 0.4 = 0.3$$

$$\mu_{23} = 0.75 \times 0.6 = 0.45$$

$$\mu_{34} = 0.4 \times 0.25 = 0.1$$

$$\mu_{24} = 0.6 \times 0.25 = 0.15$$

- Using centroid defuzzification method

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

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

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

3. Solving the same using Fuzzy Logic toolbox in MATLAB

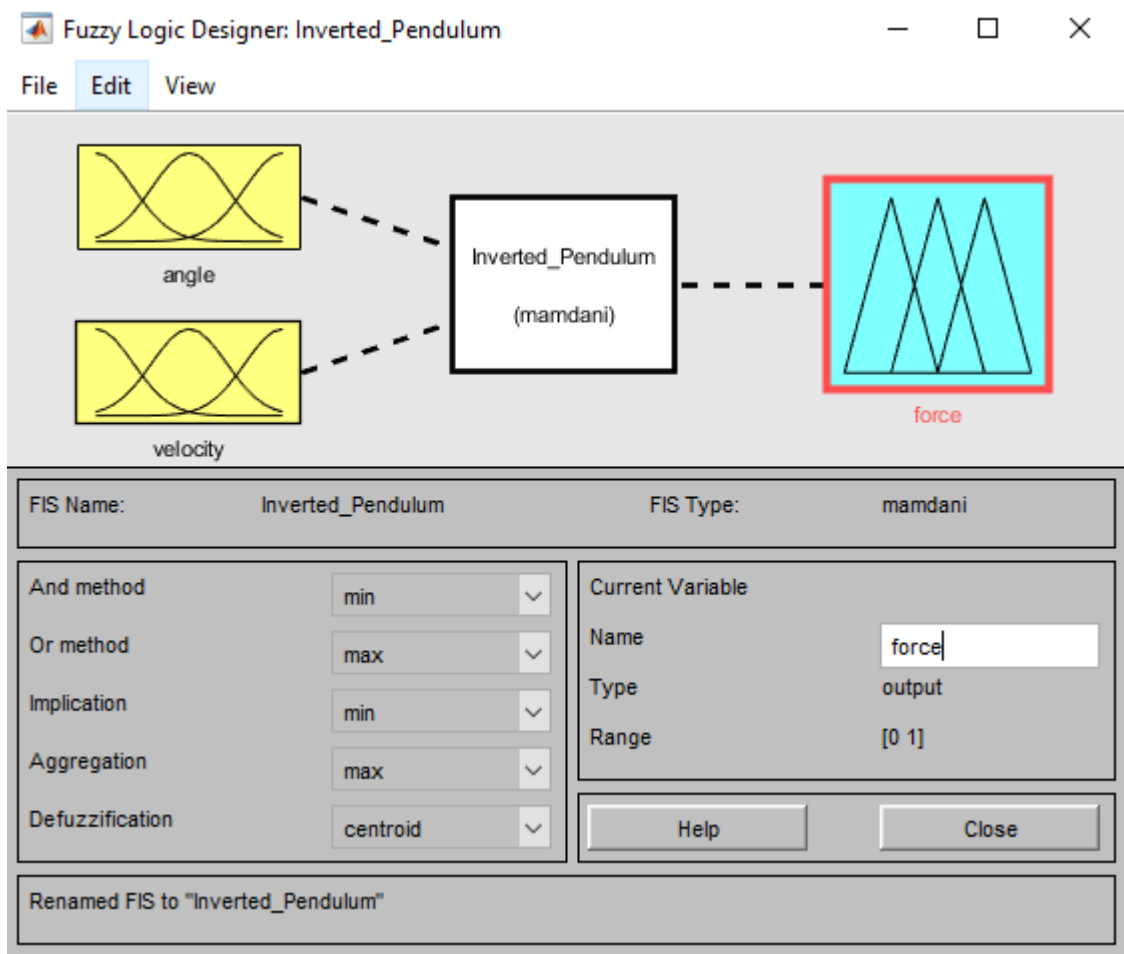


Figure 04 :Fuzzy Logic Editor

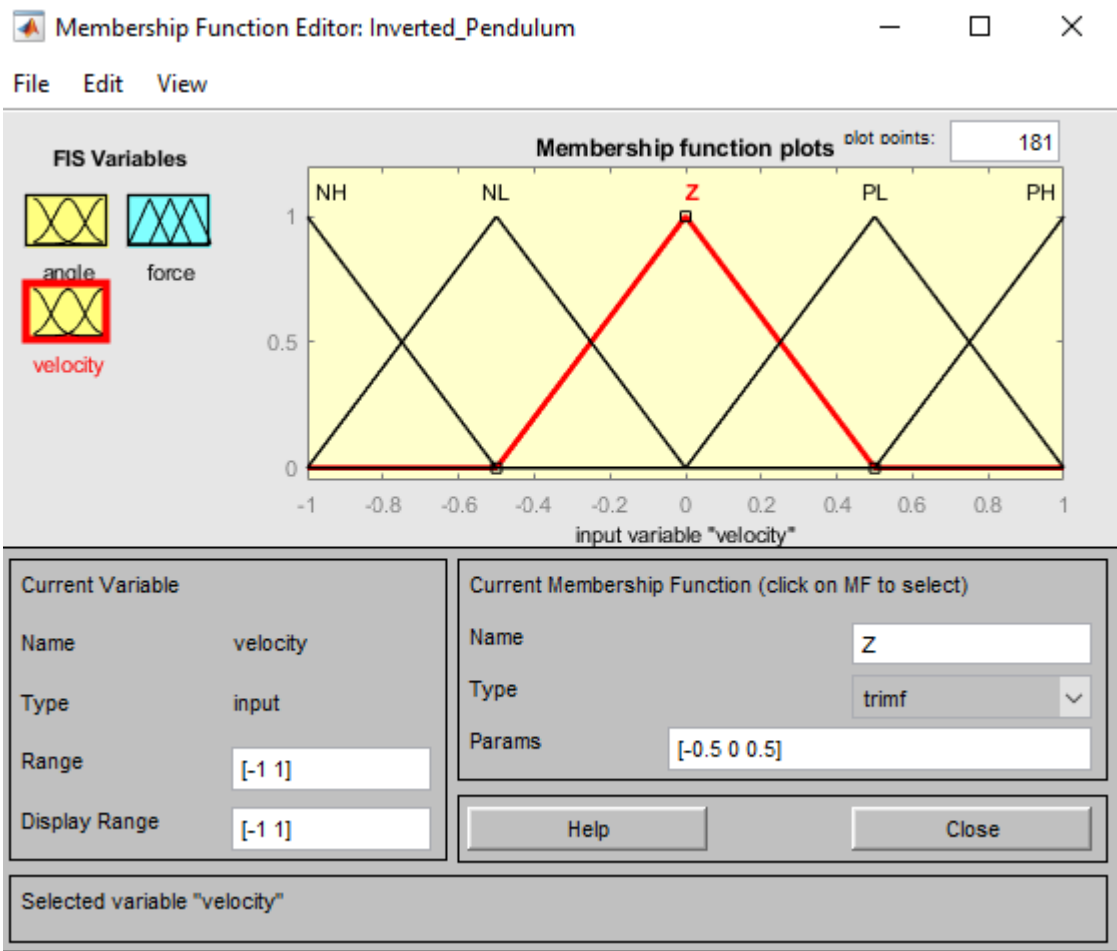


Figure 05 :input membership function-velocity

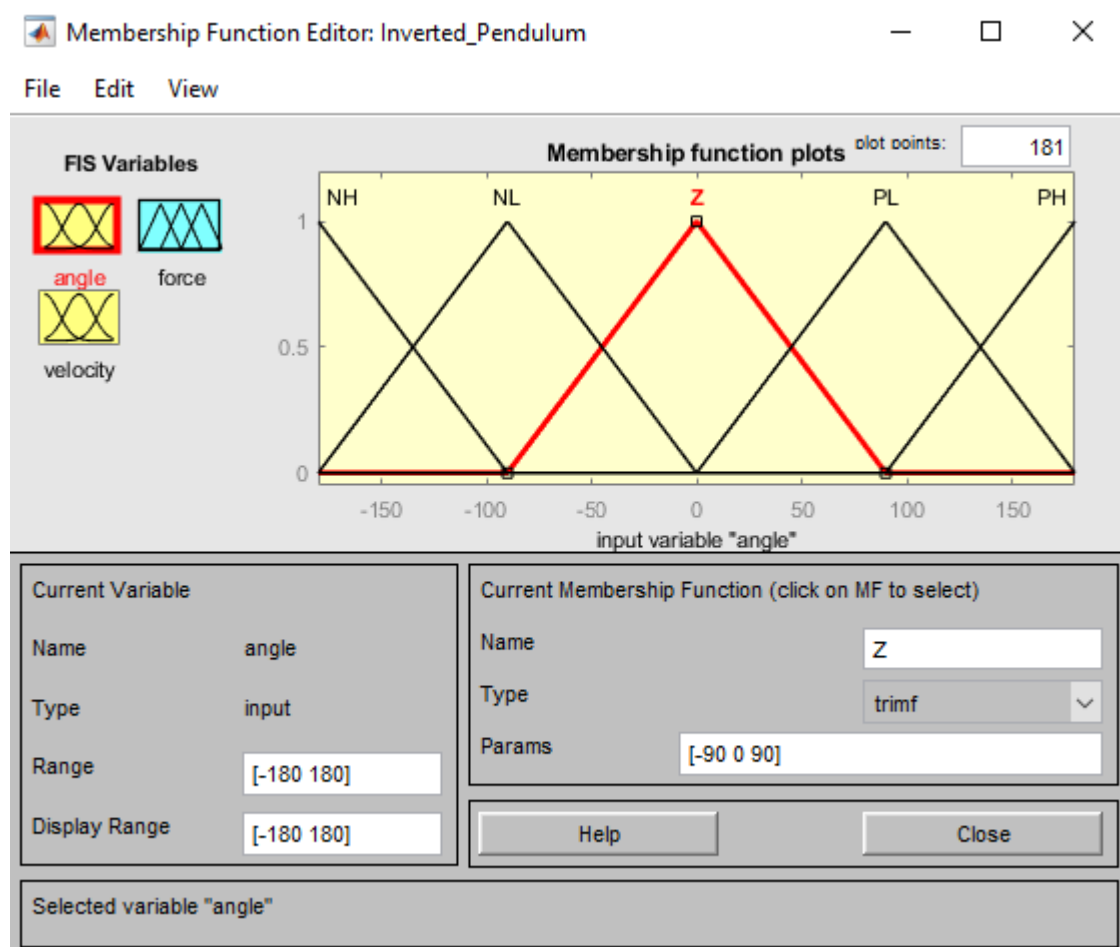


Figure 06 :Input membership function-angle

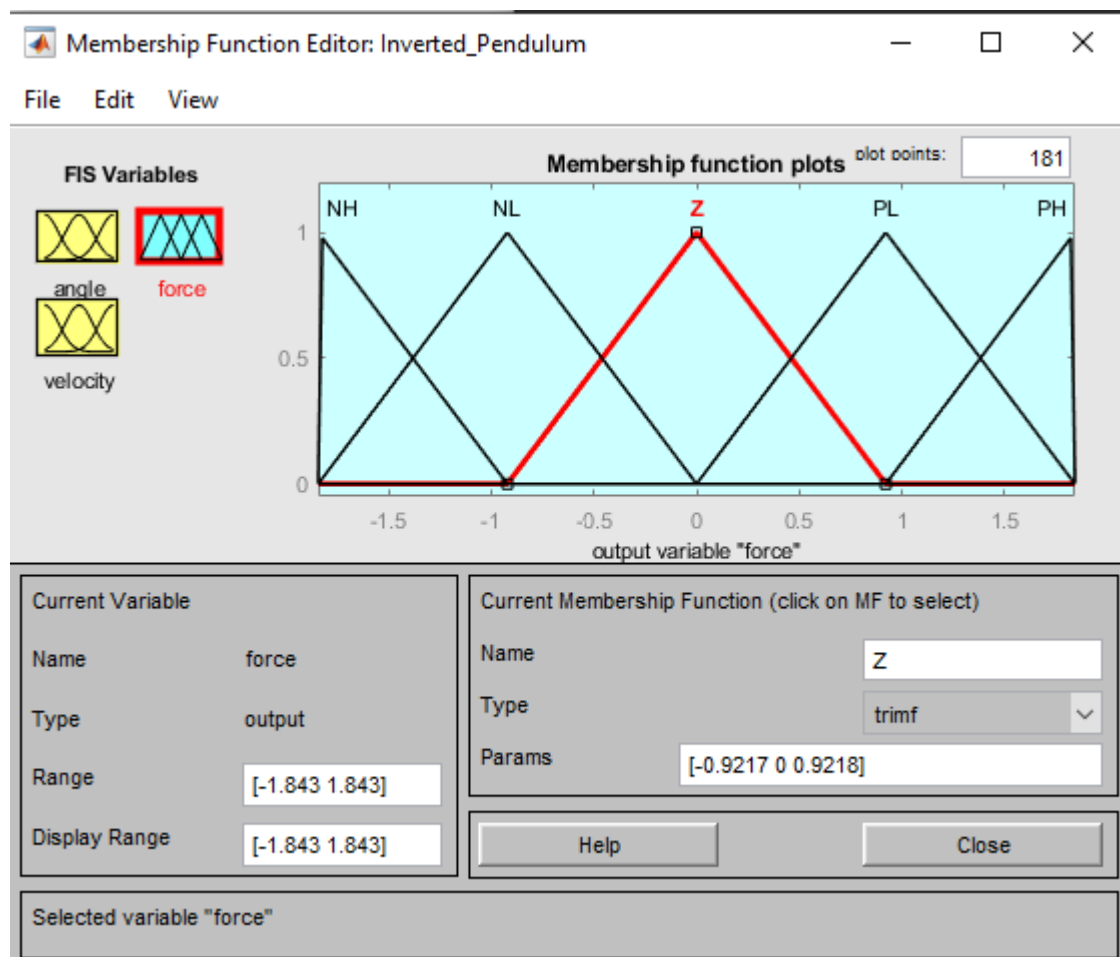


Figure 07 :Output membership function-force

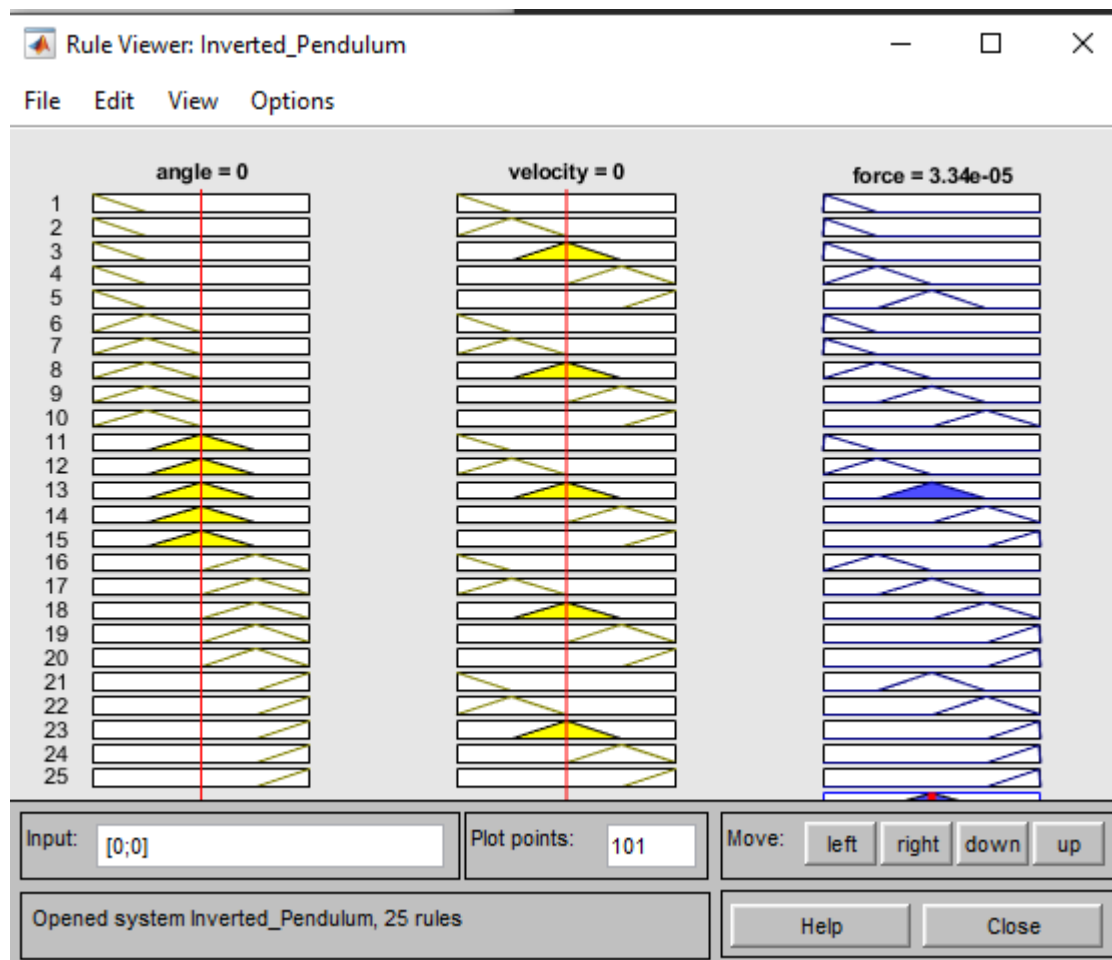


Figure 08: Rule viewer

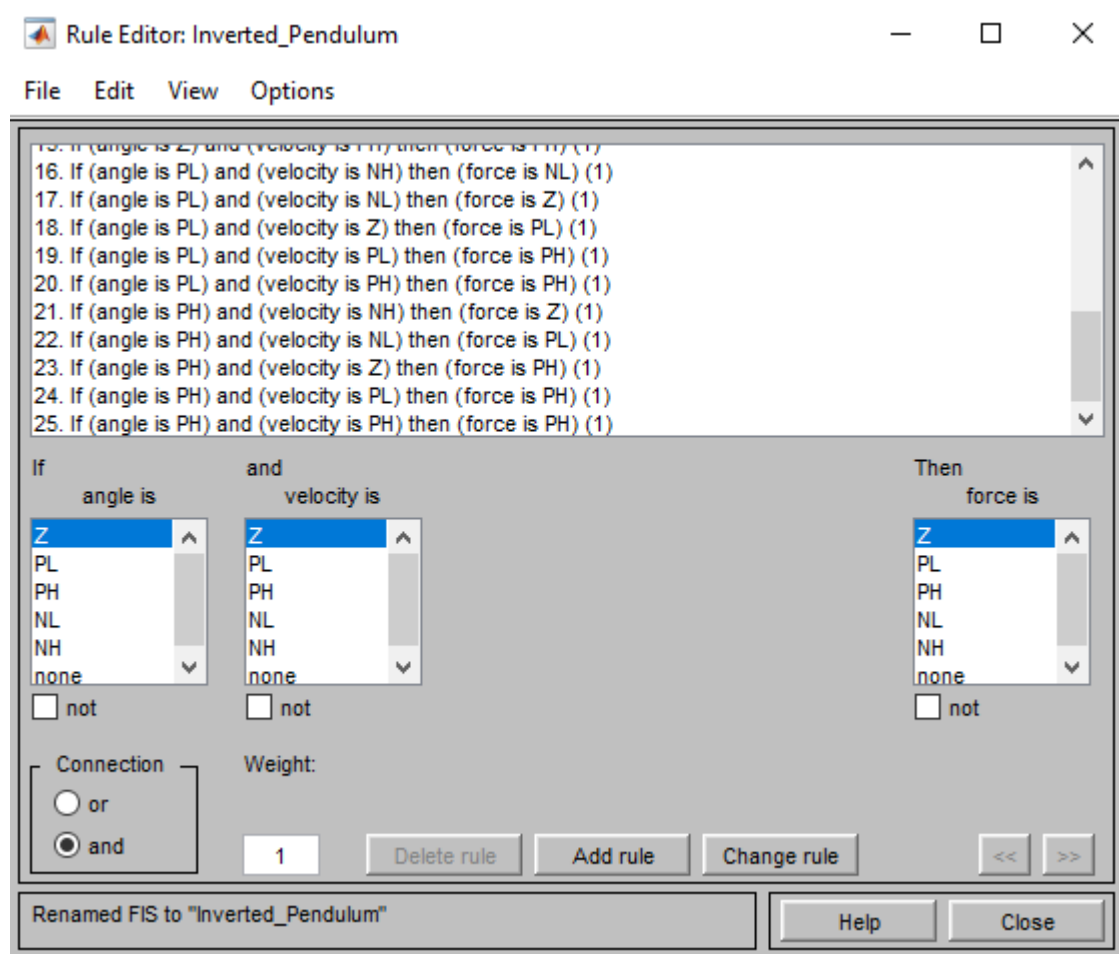


Figure 09 : Rule Base

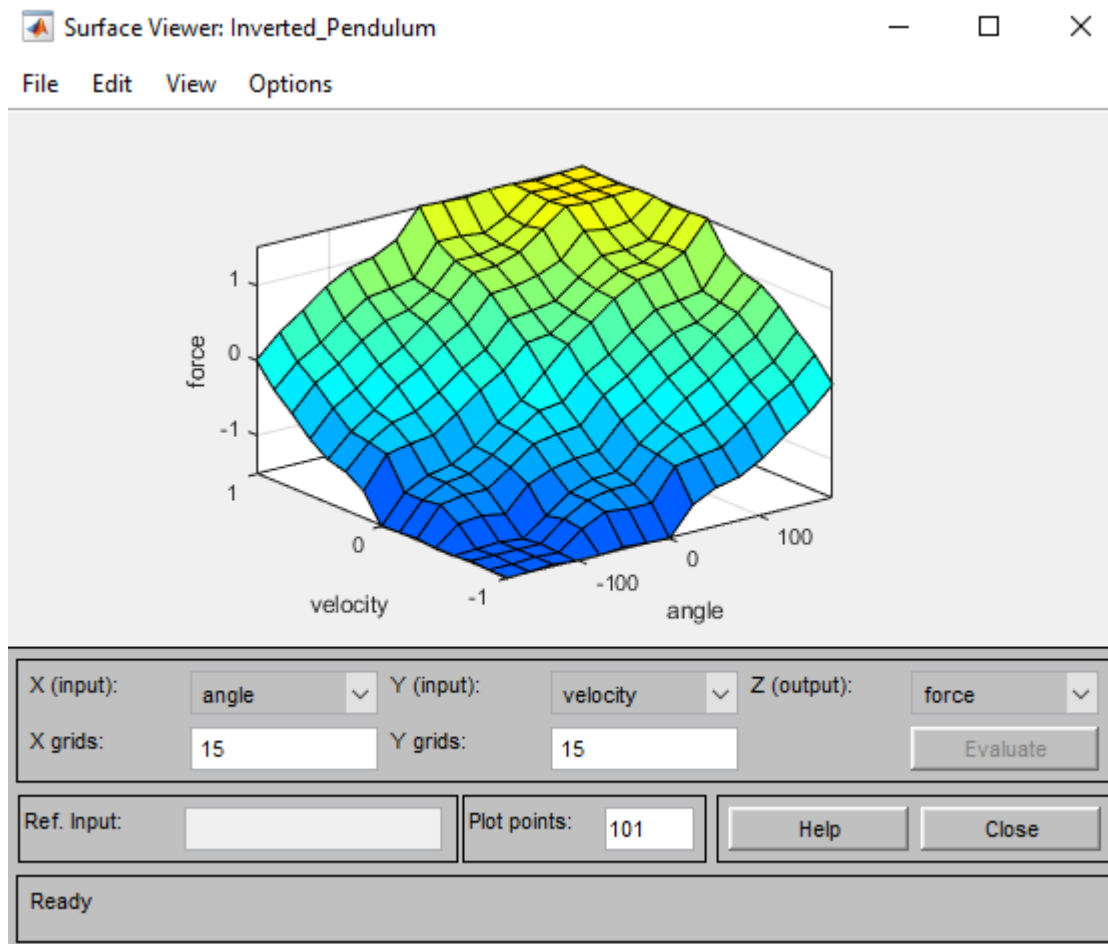


Figure 10 :Fuzzy Logic Surface Viewer

```
>> fis = readfis('Inverted_Pendulum')
```

```
fis =
```

```
struct with fields:
```

```
    name: 'Inverted_Pendulum'
    type: 'mamdani'
    andMethod: 'min'
    orMethod: 'max'
    defuzzMethod: 'centroid'
    impMethod: 'min'
    aggMethod: 'max'
    input: [1x2 struct]
    output: [1x1 struct]
    rule: [1x25 struct]
```

```
>> out = evalfis([65 -0.1],fis)
```

```
out =
```

```
    0.3570
```

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

```
>> |
```

Figure 11 :MATLAB Output

Thus matlab simulation also give same answer as **0.3570 N**