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.

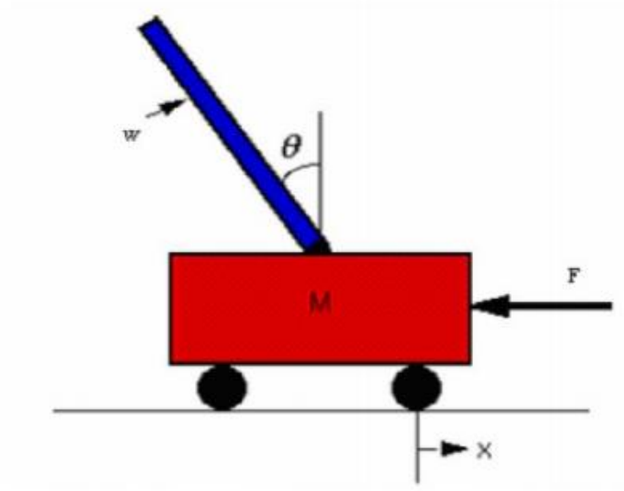

Figure 1: Inverted Pendulum in a cart

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)

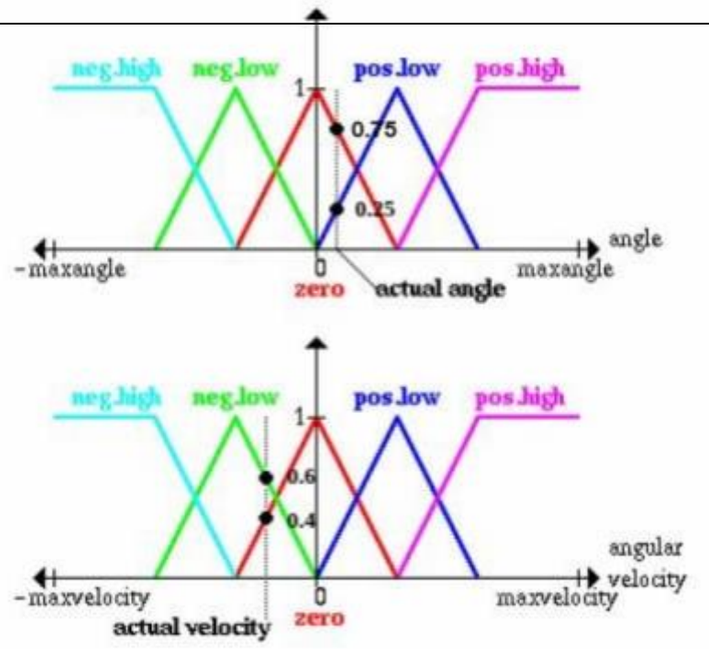

Figure 2: Membership for angle and angular velocity

Lab Tasks

1. Define all the fuzzy rules for the scenario.

	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

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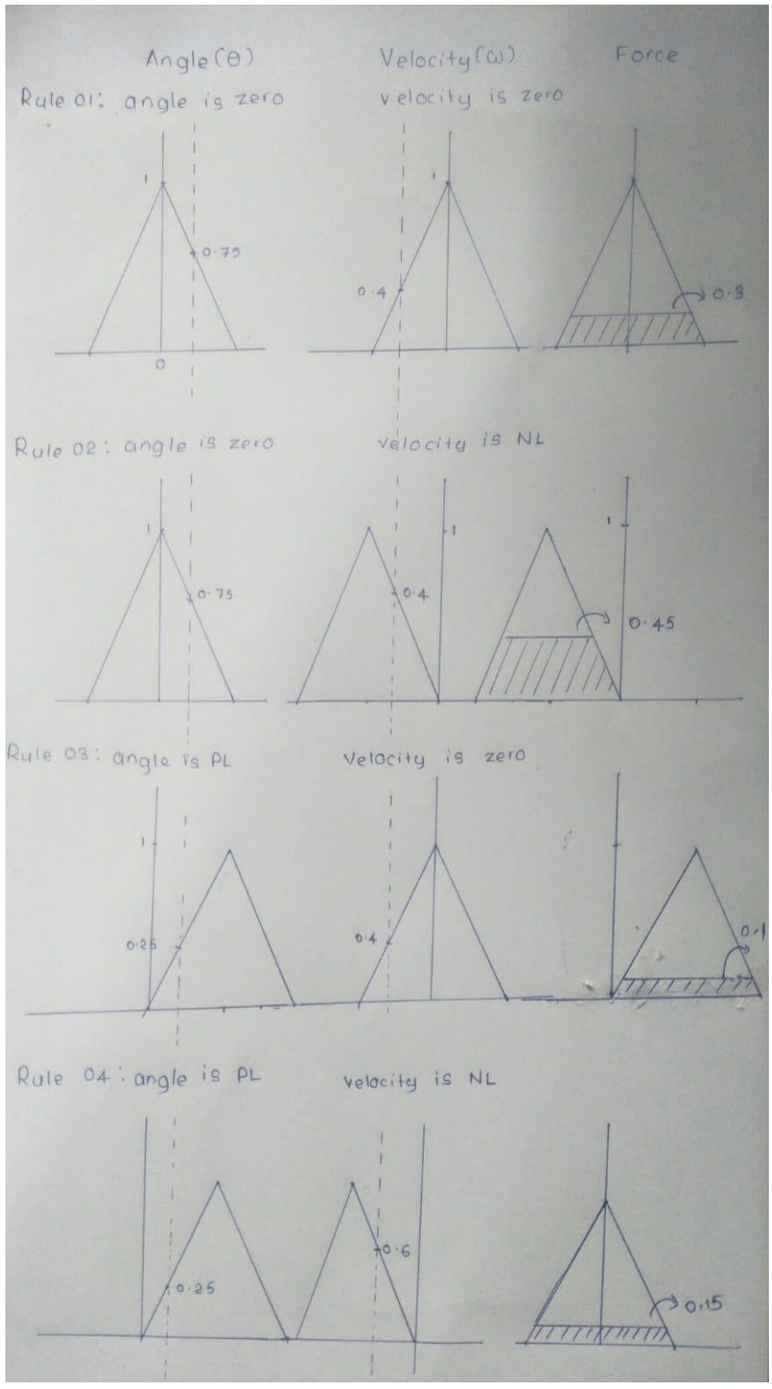

Figure 03: Graphical calculations

μ_{33} = 0.75x0.4 = 0.3
μ_{23} = 0.75x0.6 = 0.45
μ_{34} = 0.4x0.25 = 0.1
μ_{24} = 0.6x0.25 = 0.15

- Using centroid defuzzification method

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

Force = (Z x μ_{33} + NL x μ_{23} + PL x μ_{34} + Z x μ_{24} / (μ_{33} + μ_{23} + μ_{34} + μ_{24})
= 0.35 N

3. Solving the same using Fuzzy Logic toolbox in MATLAB

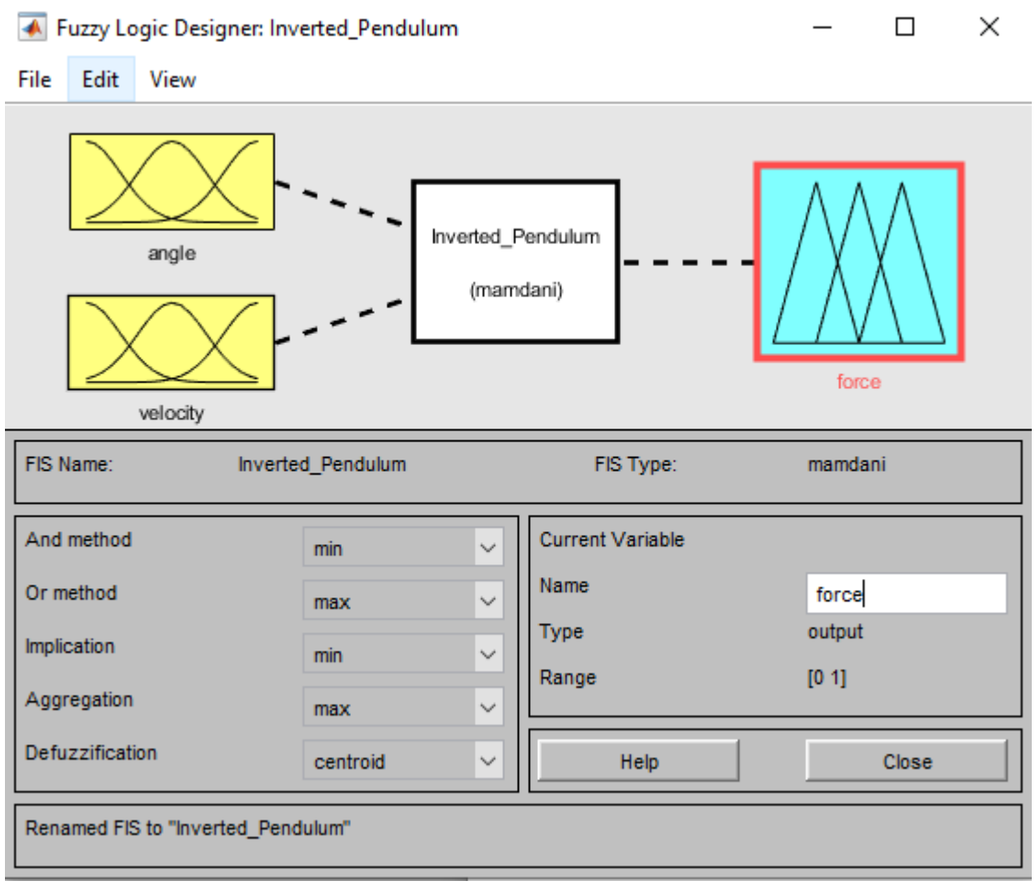

Figure 04 :Fuzzy Logic Editor

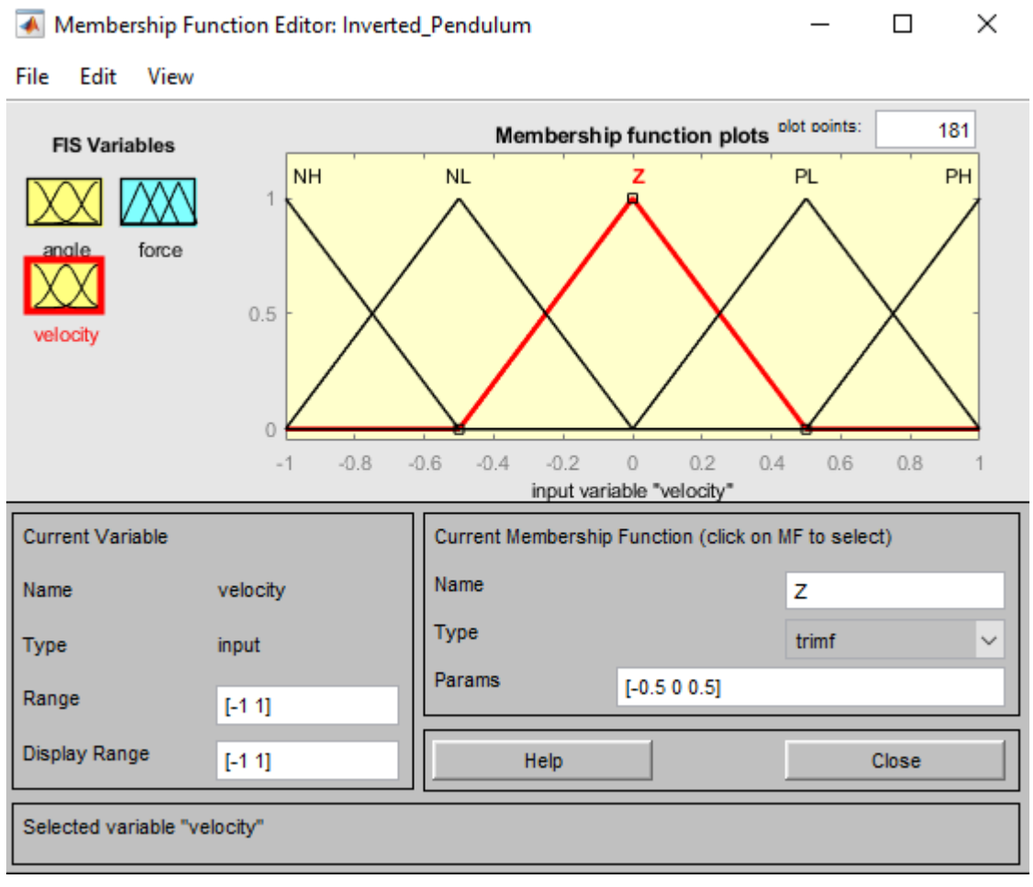

Figure 05 :input membership function-velocity

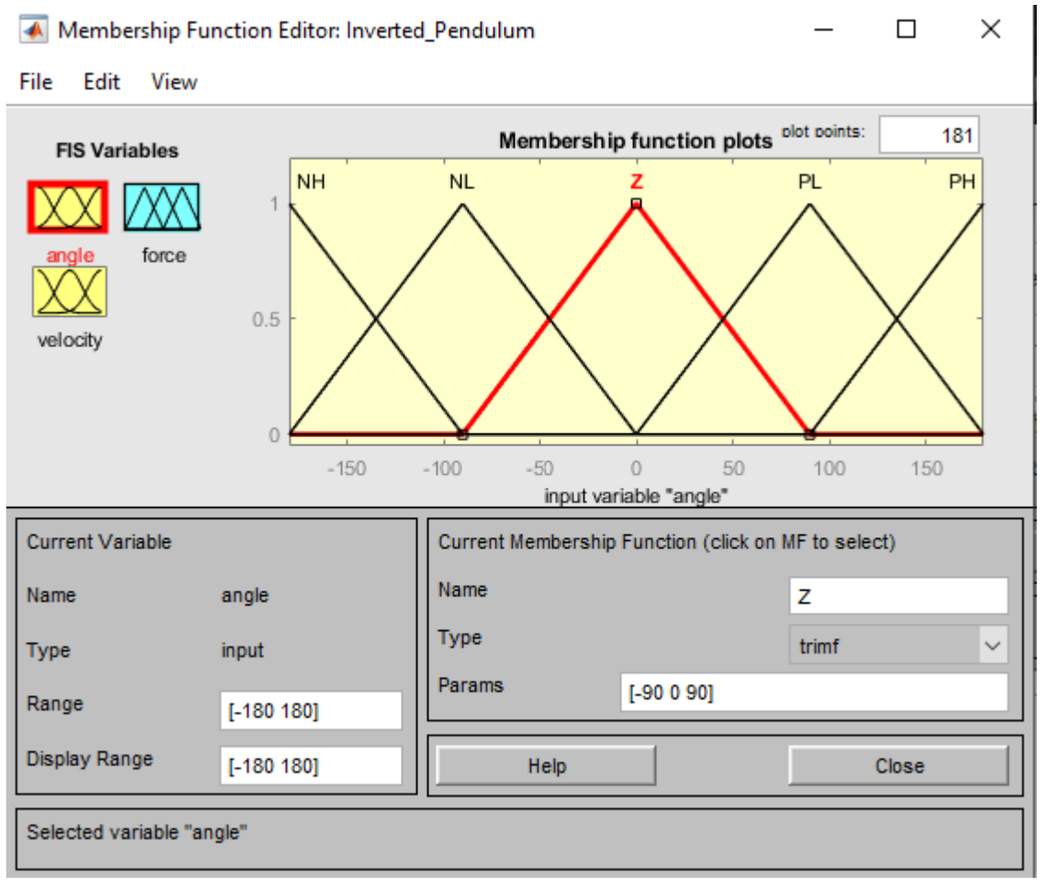

Figure 06 :Input membership function-angle

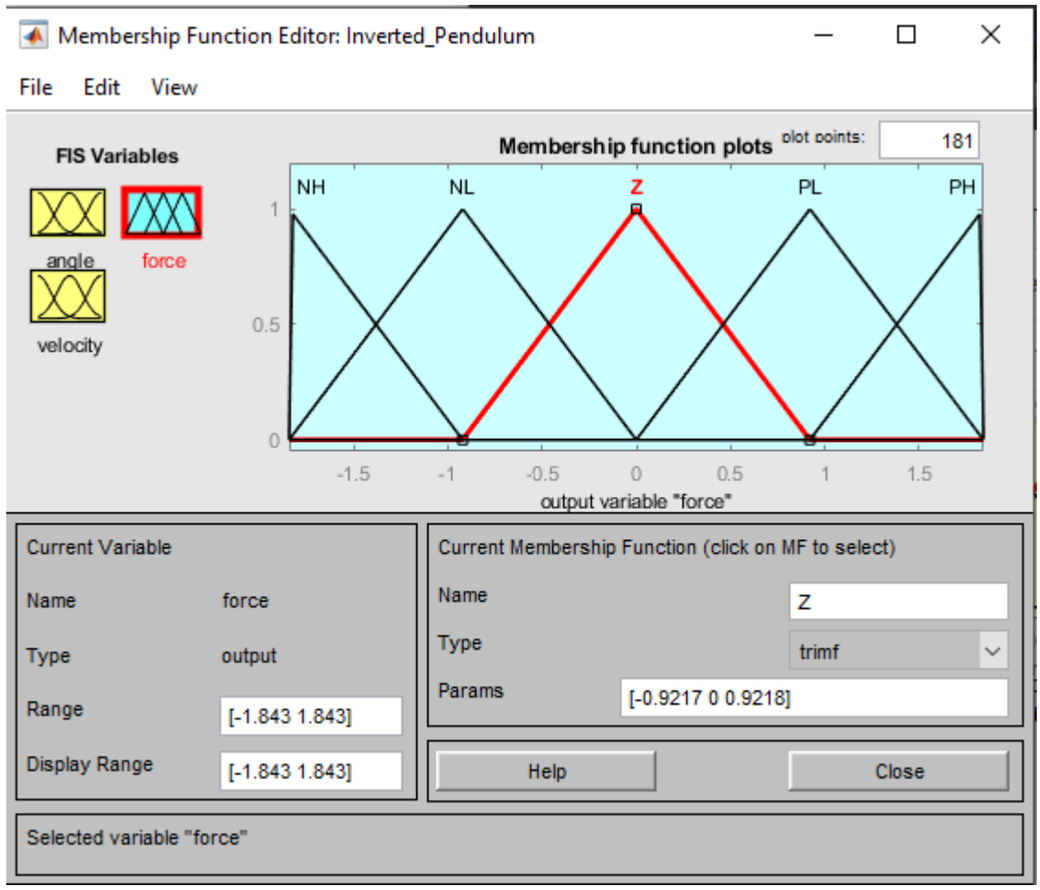

Figure 07 :Output membership function-force

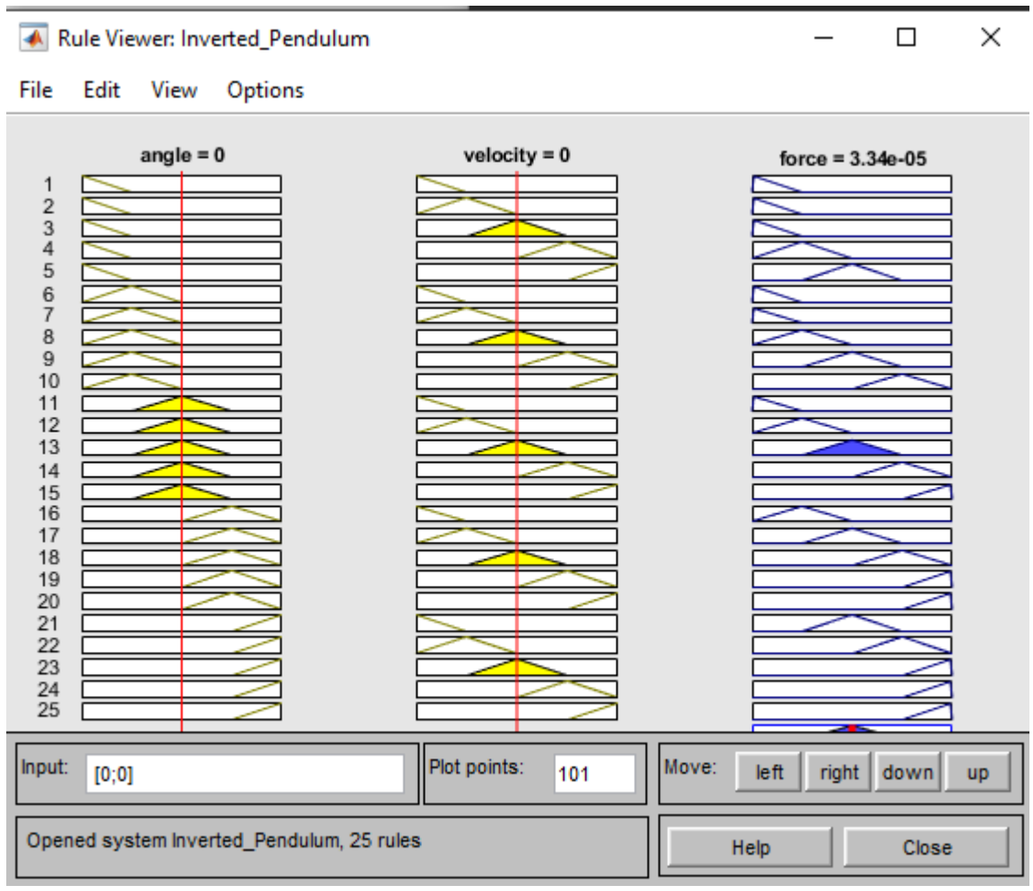

Figure 08: Rule viewer

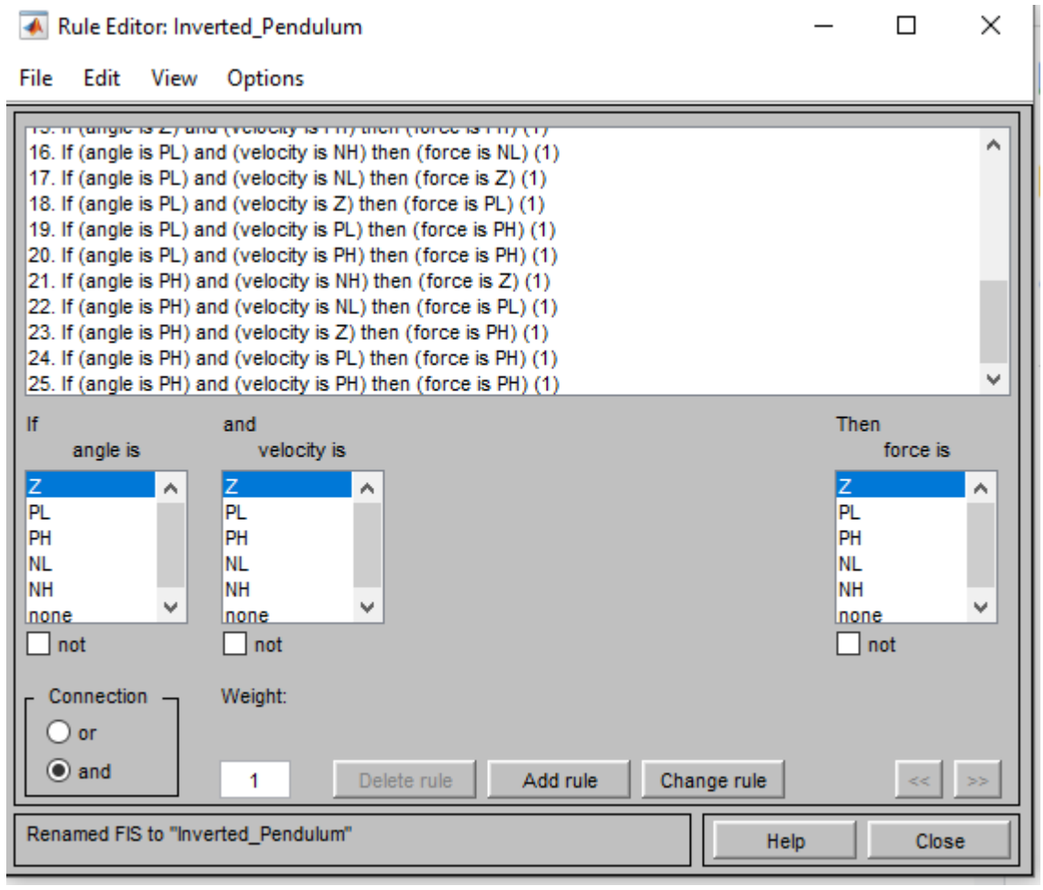

Figure 09 : Rule Base

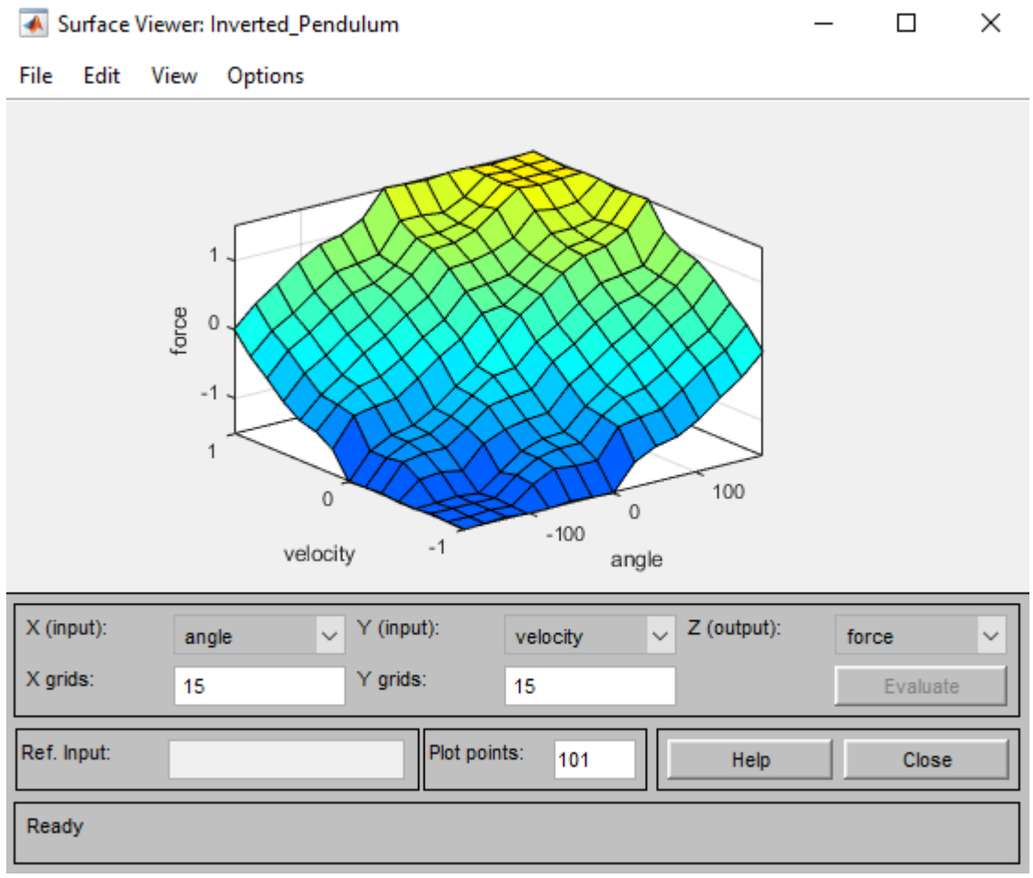

Figure 10 :Fuzzy Logic Surface Viewer

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

fis =

  struct with fields:

           name: 'Inverted_Pendulum'
           type: 'mamdani'
      andMethod: 'min'
       orMethod: 'max'
   defuzzMethod: 'centroid'
      impMethod: 'min'
      aggMethod: 'max'
          input: [1×2 struct]
         output: [1×1 struct]
           rule: [1×25 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**