

CO 542 – Neural Networks and Fuzzy Systems
Lab 02 – Fuzzy Logic

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E/16/232

① Input 1 : Angle (θ)

State of Input 1: (NH, WL, Z, PL, PH)

Input 2 : Angular Velocity (ω)

State of input 2: (NH, NL, Z, PL, PH)

Output : Force to be exerted to cart (F)

State of output: (NH, NL, Z, PL, PH)

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

NH - Negative Height (-2)

NL - Negative Low (-1)

Z - Zero (0)

PH - Positive High (+2)

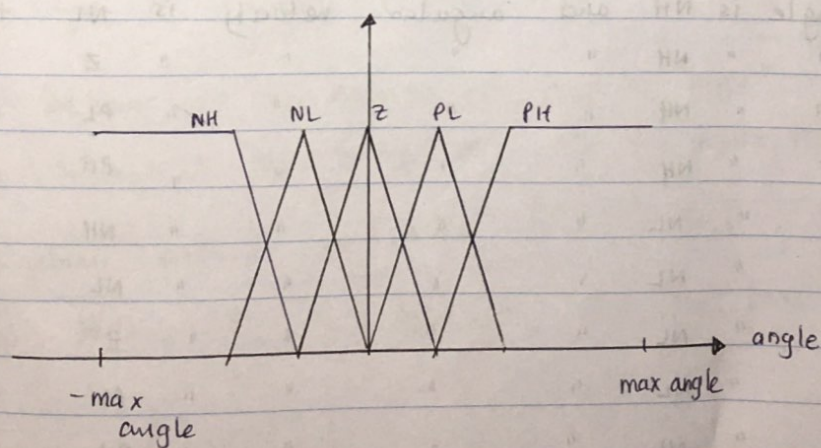
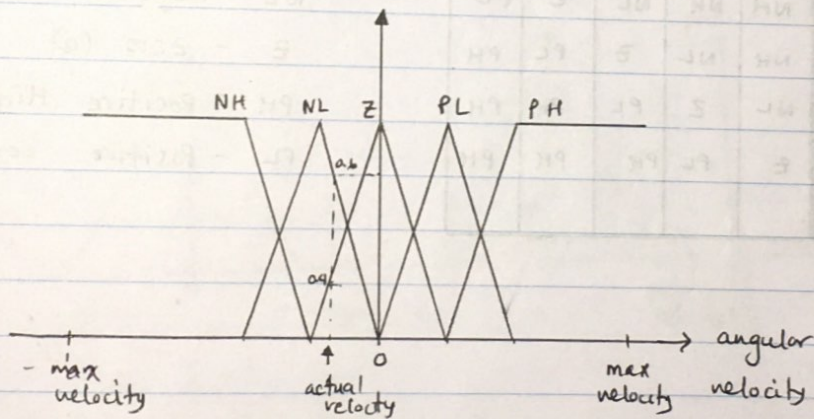
PL - Positive Low (+1)

Rules:

- (1) If angle is NH and angular velocity is NH then force is NH
- (2) If angle is NH and angular velocity is NL then force is NH.
- (3) " " " NH " " " " Z " " " NH
- (4) " " " NH " " " " PL " " " NL
- (5) " " " NH " " " " PH " " " Z
- (6) " " " NL " " " " NH " " " NH
- (7) " " " NL " " " " NL " " " NH
- (8) " " " NL " " " " Z " " " NL
- (9) " " " NL " " " " PL " " " Z
- (10) " " " NL " " " " PH " " " PL
- (11) " " " Z " " " " NH " " " NH
- (12) " " " Z " " " " NL " " " NL
- (13) " " " Z " " " " Z " " " Z

(14)	If	angle	is	Z	angl	angular	velocity	is	PL	then	force	is	PL
(15)	"	"	"	Z	"	"	"	"	PH	"	"	"	PH
(16)	"	"	"	PL	"	"	"	"	NH	"	"	"	NL
(17)	"	"	"	PL	"	"	"	"	NL	"	"	"	Z
(18)	"	"	"	PL	"	"	"	"	Z	"	"	"	PL
(19)	"	"	"	PL	"	"	"	"	PL	"	"	"	PH
(20)	"	"	"	PH	"	"	"	"	PH	"	"	"	PH
(21)	"	"	"	PH	"	"	"	"	NH	"	"	"	Z
(22)	"	"	"	PH	"	"	"	"	NL	"	"	"	PL
(23)	"	"	"	PH	"	"	"	"	Z	"	"	"	PH
(24)	"	"	"	PH	"	"	"	"	PL	"	"	"	PH
(25)	"	"	"	PH	"	"	"	"	PH	"	"	"	PH

(2)



Step 1: Relevant rules for this case

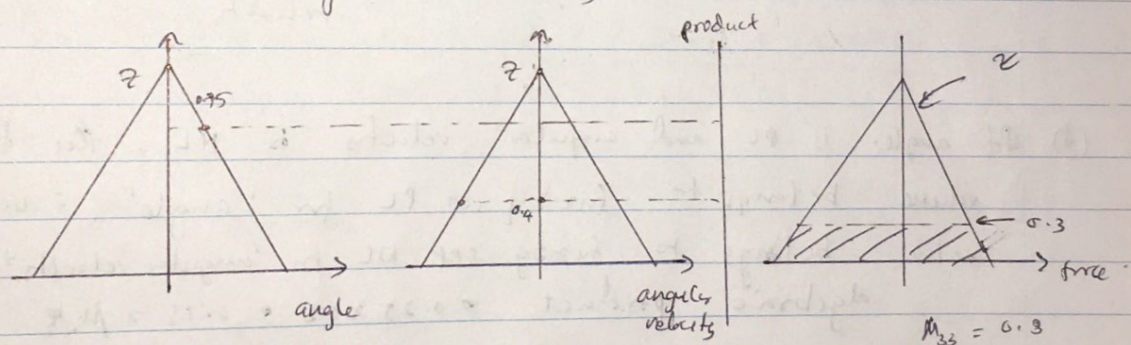
- (a) If angle is Z and angular velocity is Z then force is Z.
- (b) If angle is Z and angular velocity is NL then force is NL.
- (c) If angle is PL and angular velocity is Z then force is PL.
- (d) If angle is PL and angular velocity is NL then force is Z.

Step 2: Membership function value to each fuzzy output.

- (a) Member If angle is Z and angular velocity is Z, then force is Z.
 The value belongs to the fuzzy set zero for "angle" = 0.75
 The value belongs to the fuzzy set zero for "angular velocity" = 0.4

$$\therefore \text{Algebraic product} = 0.75 \times 0.4 = 0.3 = \mu_{33}$$

\therefore the value belongs to the "fuzzy set zero for "force" = 0.3

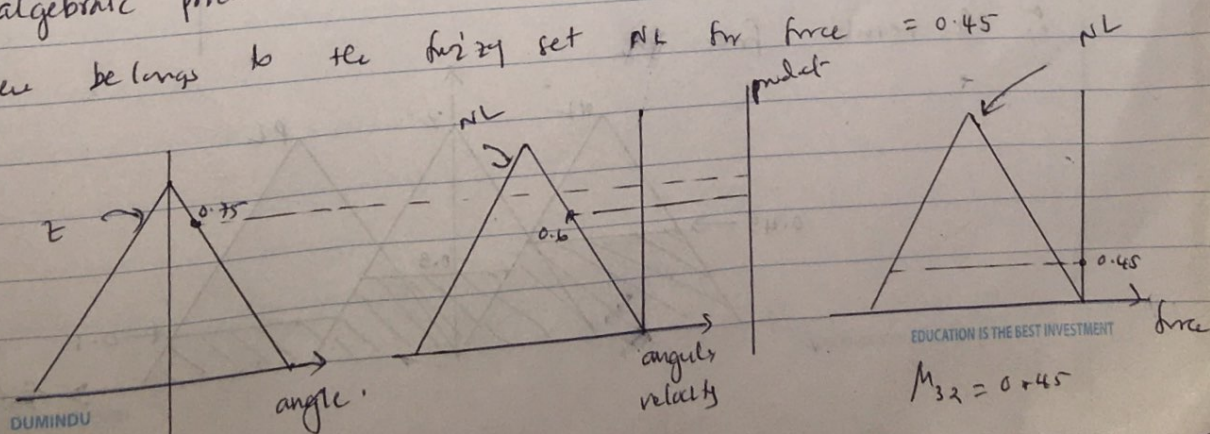


- (b) If angle is Z and angular velocity is NL, then force is NL

Value belongs to the fuzzy set zero for "angle" = 0.75
 Value belongs to the fuzzy set NL for angular velocity = 0.6

$$\text{algebraic product } 0.75 \times 0.6 = 0.45 = \mu_{32}$$

Value belongs to the fuzzy set NL for force = 0.45



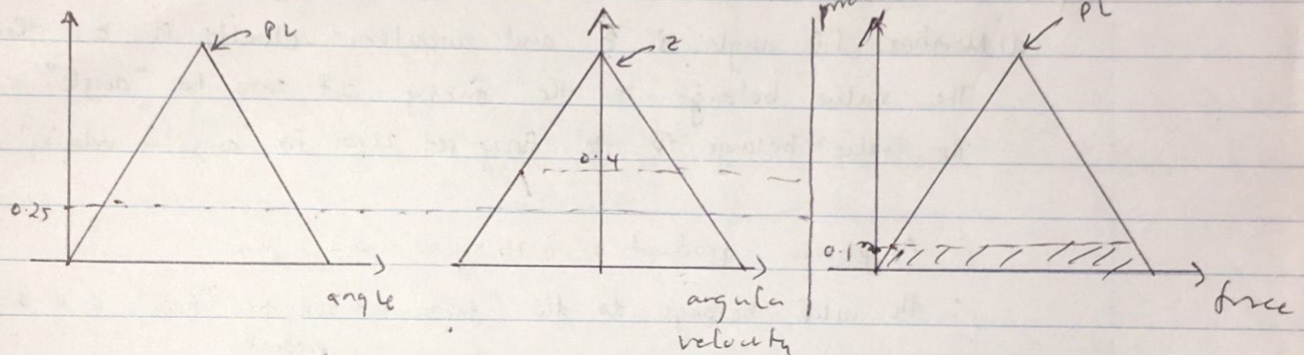
(c) If angle is PL and angular velocity is E then force is PL

value for fuzzy set PL for "angle" = 0.25

value for fuzzy set E for "angular velocity" = 0.4

algebraic product = $0.25 \times 0.4 = 0.1 = \mu_{43}$

\therefore value for fuzzy set PL for "force" = 0.1



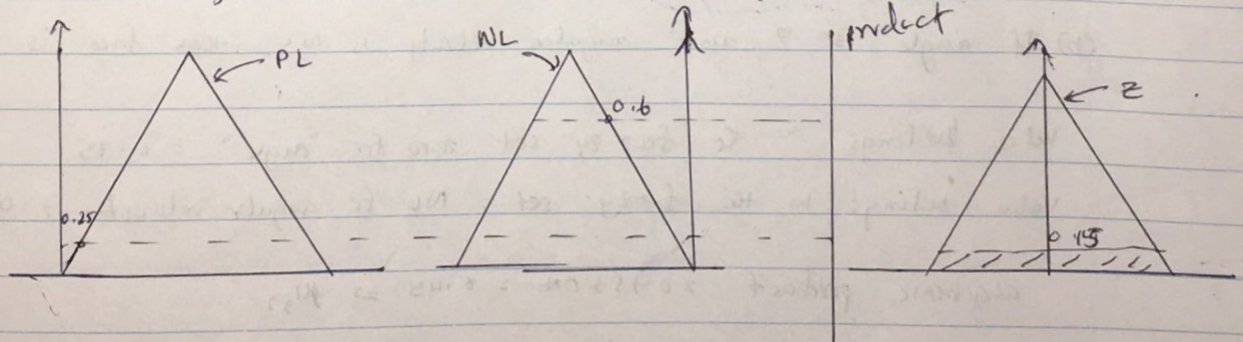
(d) If angle is PL and angular velocity is HL, then force is Z.

value belongs to fuzzy set PL for 'angle' = 0.25

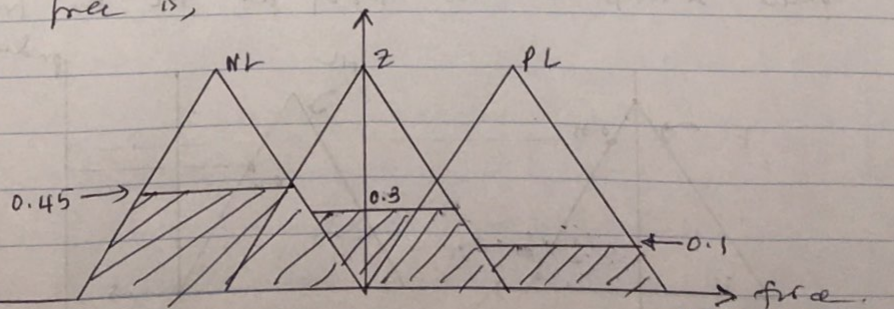
value belongs to fuzzy set HL for 'angular velocity' = 0.6

algebraic product = $0.25 \times 0.6 = 0.15 = \mu_{42}$

value belongs to the fuzzy set E for "force" = 0.15



\therefore The result force is,



Step 3: Defuzzification.

Centroid Defuzzification.

$$f(n) = \frac{\sum_{i=1}^n z_i \prod_{j=1}^n \mu_{ij}(n_j)}{\sum_{i=1}^n \prod_{j=1}^n \mu_{ij}(n_j)}$$

$$\therefore \text{force} = \frac{("Z" \times \mu_{33}) + ("NL" \times \mu_{32}) + ("PL" \times \mu_{43}) + ("Z" \times \mu_{44})}{(\mu_{33} + \mu_{32} + \mu_{43} + \mu_{44})}$$

$$= \frac{(0 \times 0.3) + (0.1 \times 0.45) + (1 \times 0.1) + (0 \times 0.15)}{(0.3 + 0.45 + 0.1 + 0.15)}$$

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

3. Solving the same using Fuzzy Logic tool box in MATLAB

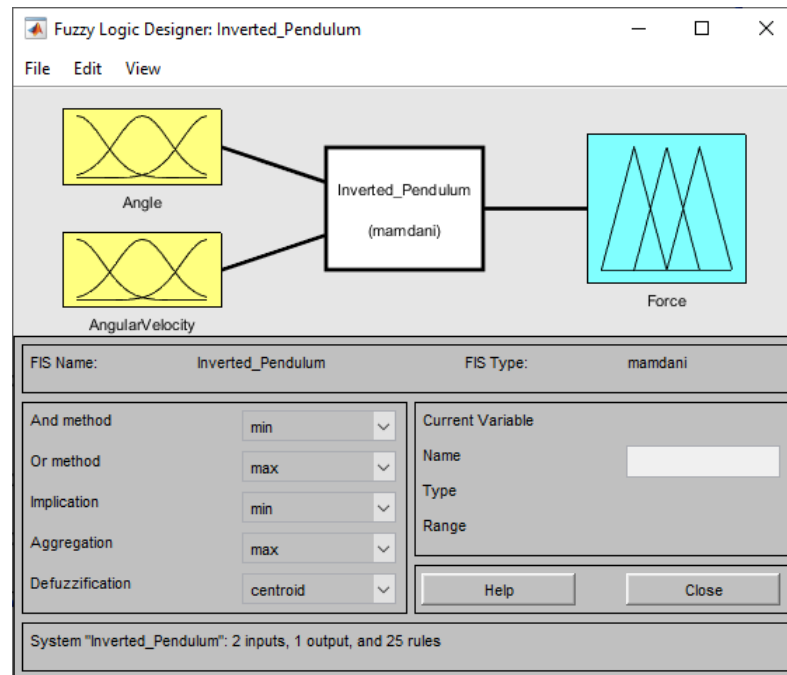


Figure 1: Fuzzy Interference System (FIS) Editor Window

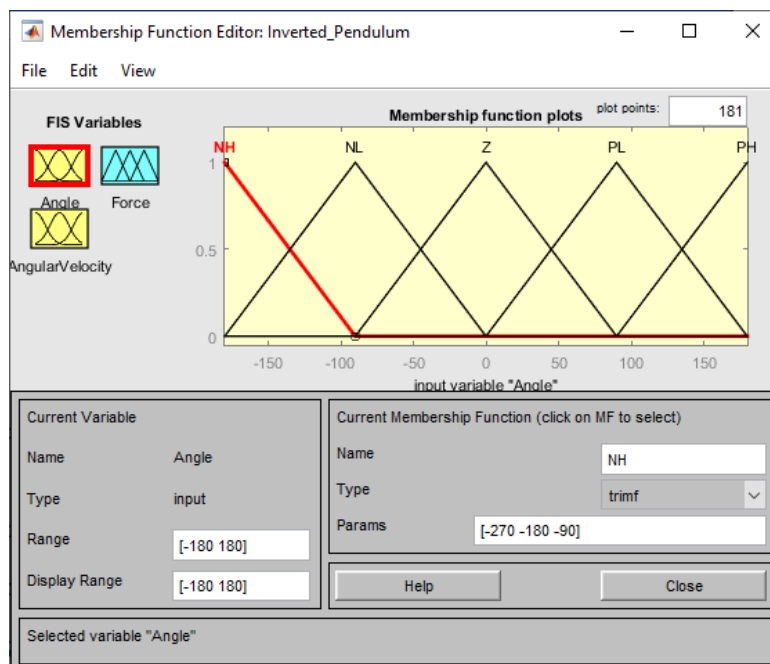


Figure 2: Input Membership Function Editor Window – Angle

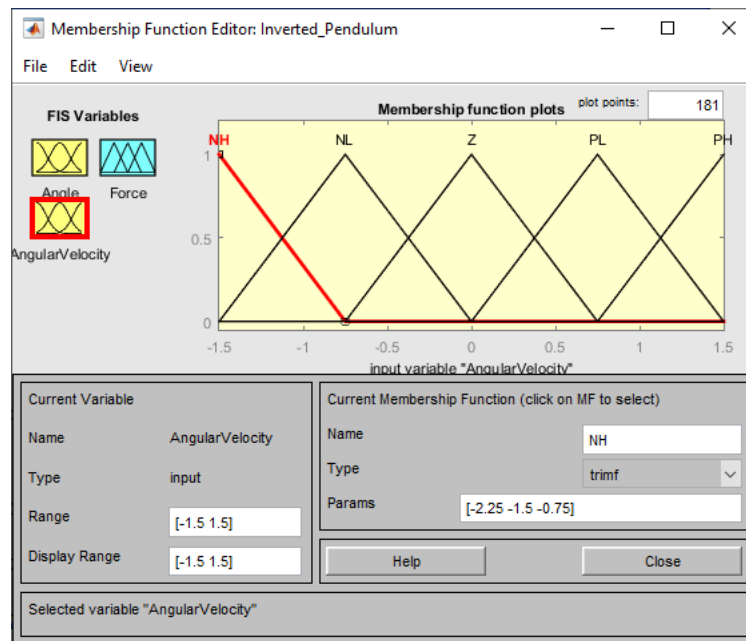


Figure 3: Input Membership Function Editor Window – Angular Velocity

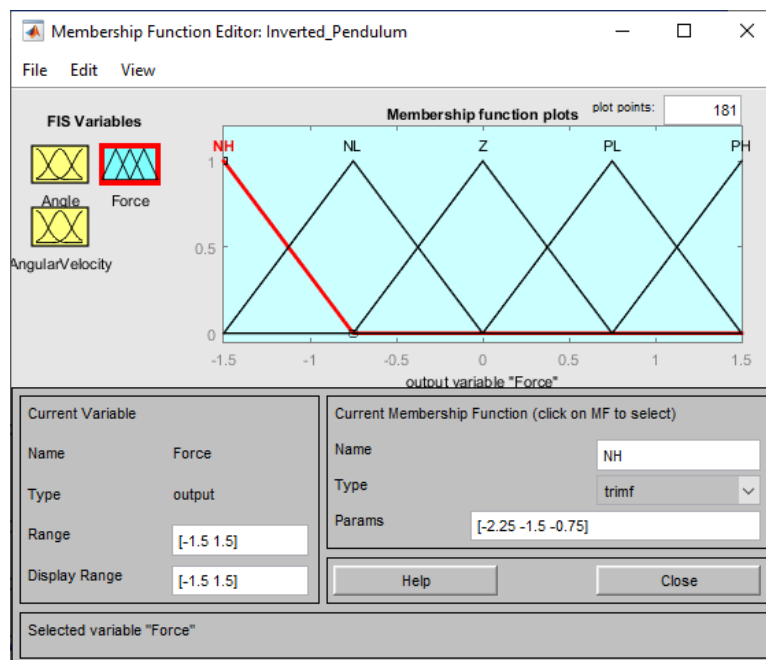


Figure 4: Output Membership Function Editor Window – Force

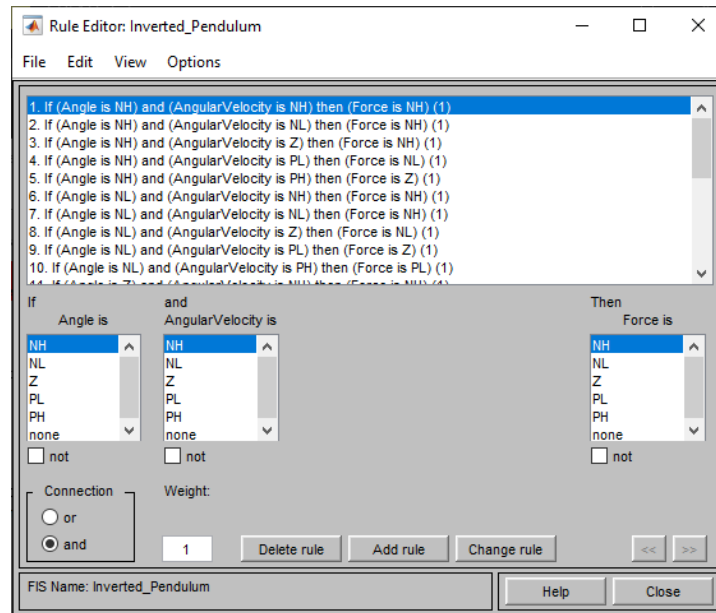


Figure 5: Rule Editor Window

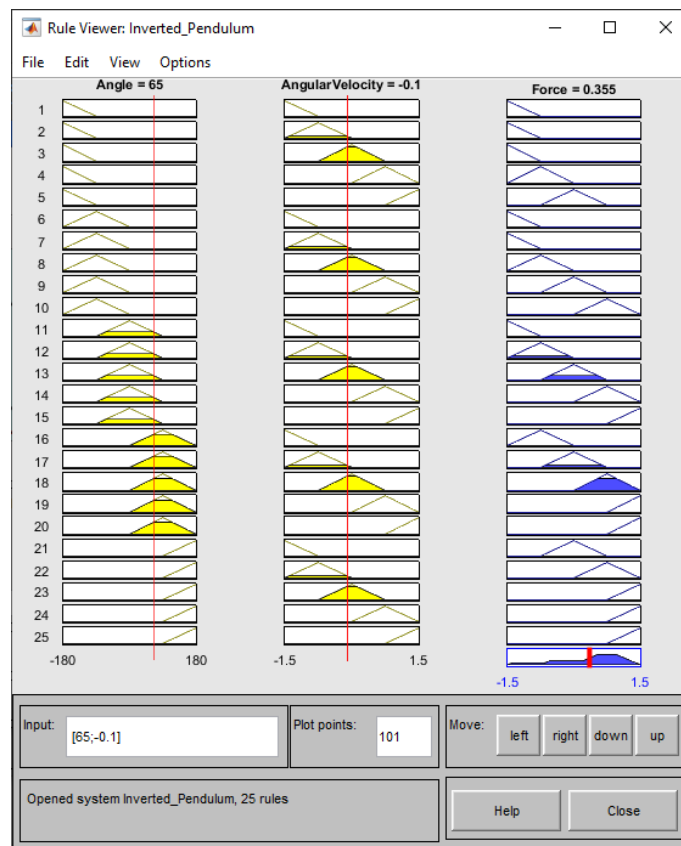


Figure 6: Rule Viewer Window

```
Command Window

>> fuzzy
>> fis = readfis('Inverted_Pendulum.fis')

fis =

    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 =

    0.3551

>> surfview(fis)
```

Figure 7: Output

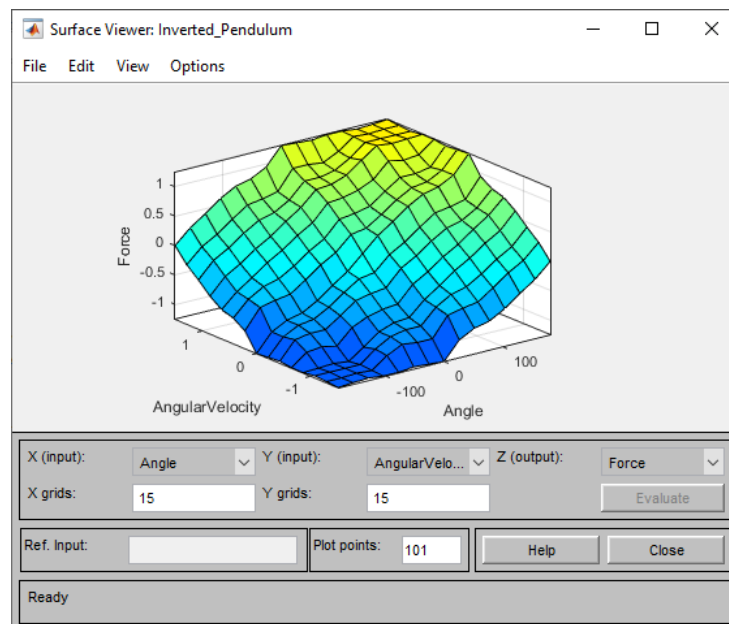


Figure 8: Surface Viewer Window