



Self-Ruled Fuzzy Logic Based Controller

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Presentation Outline

CONTROLLER STRUCTURE

- 1 – Mapping of Inputs to the Interval $[0 \ 1]$
- 2 – Mapping of Outputs to the Interval $[0 \ 1]$
- 3 – Obtaining the Output from the Controller
- 4 – The Rules Consisted Inherently in the Structure
- 5 – Weighting Filter
- 6 – Tuning of the Controller

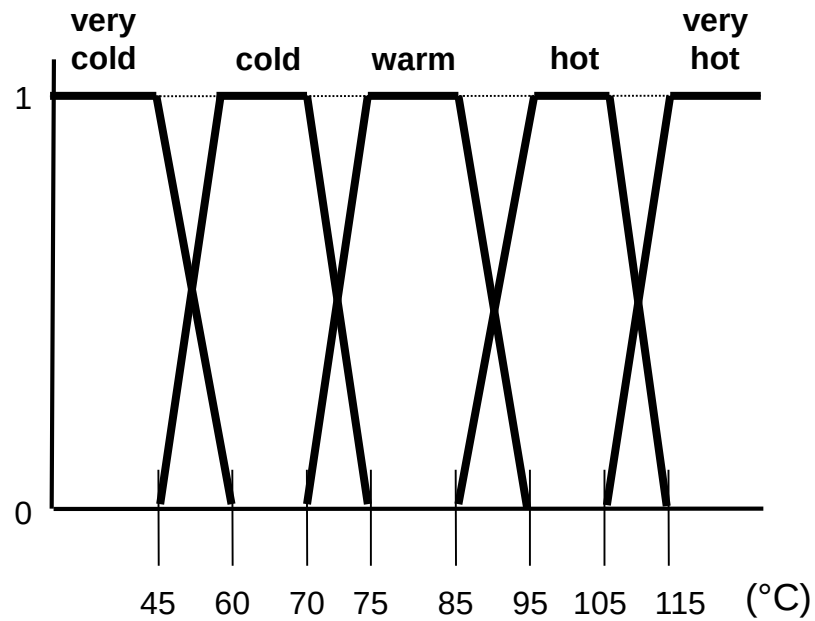
APPLICATION EXAMPLE 1 – QUADROTOR

APPLICATION EXAMPLE 2 – INVERTED PENDULUM

APPLICATION EXAMPLE 3 – BIPEDAL WALKING

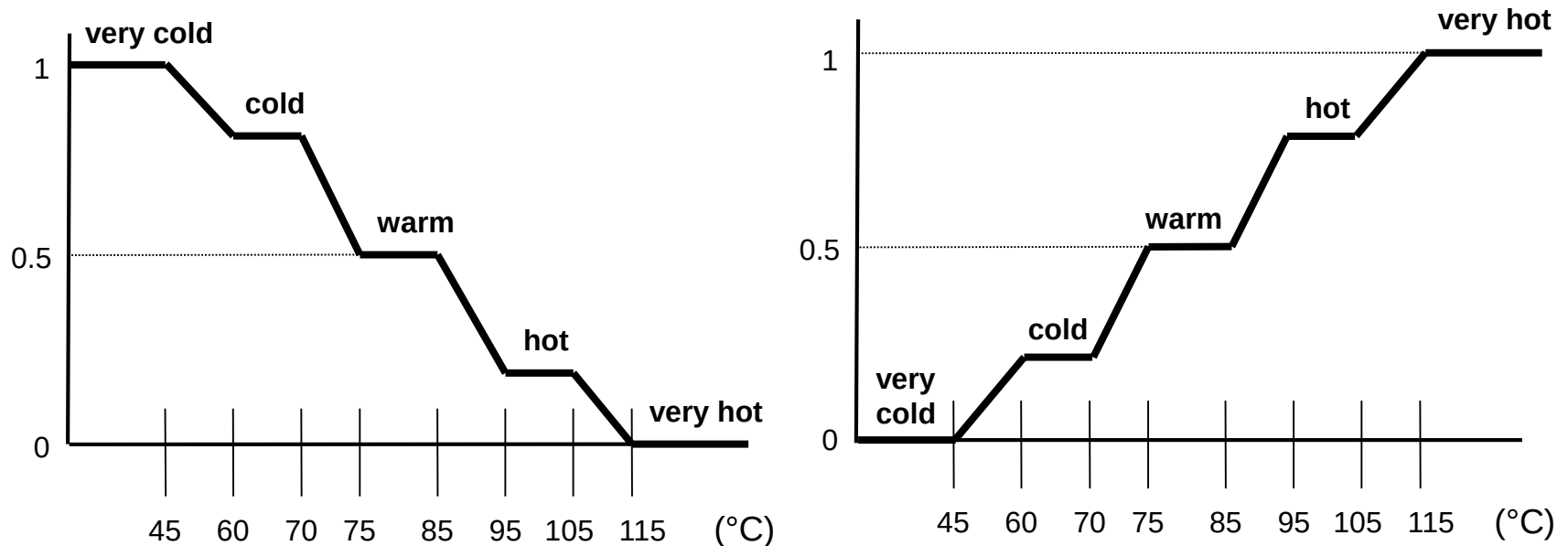
INTRODUCTION

Mapping of concept temperature to the interval [0 1] with membership functions



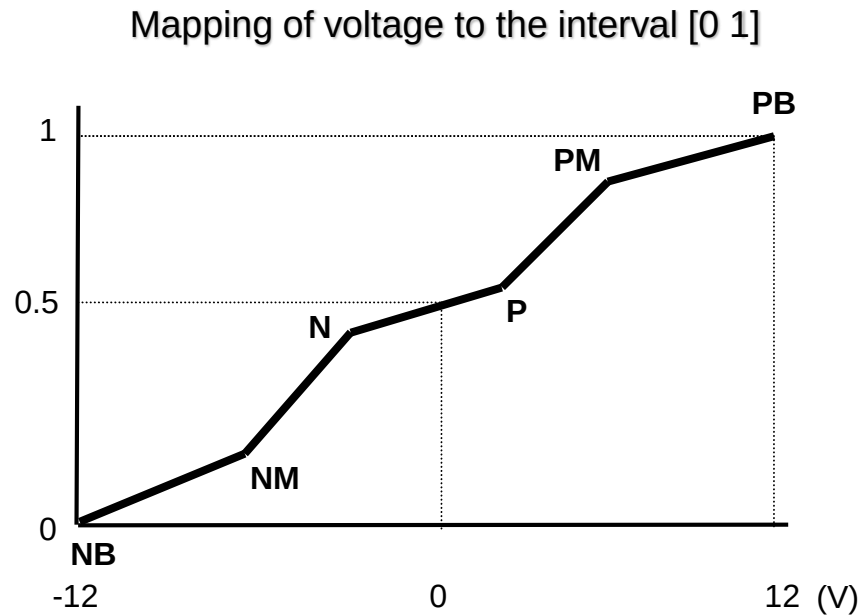
Mapping of Inputs to the Interval [0 1]

Mapping of concept temperature to the interval [0 1]



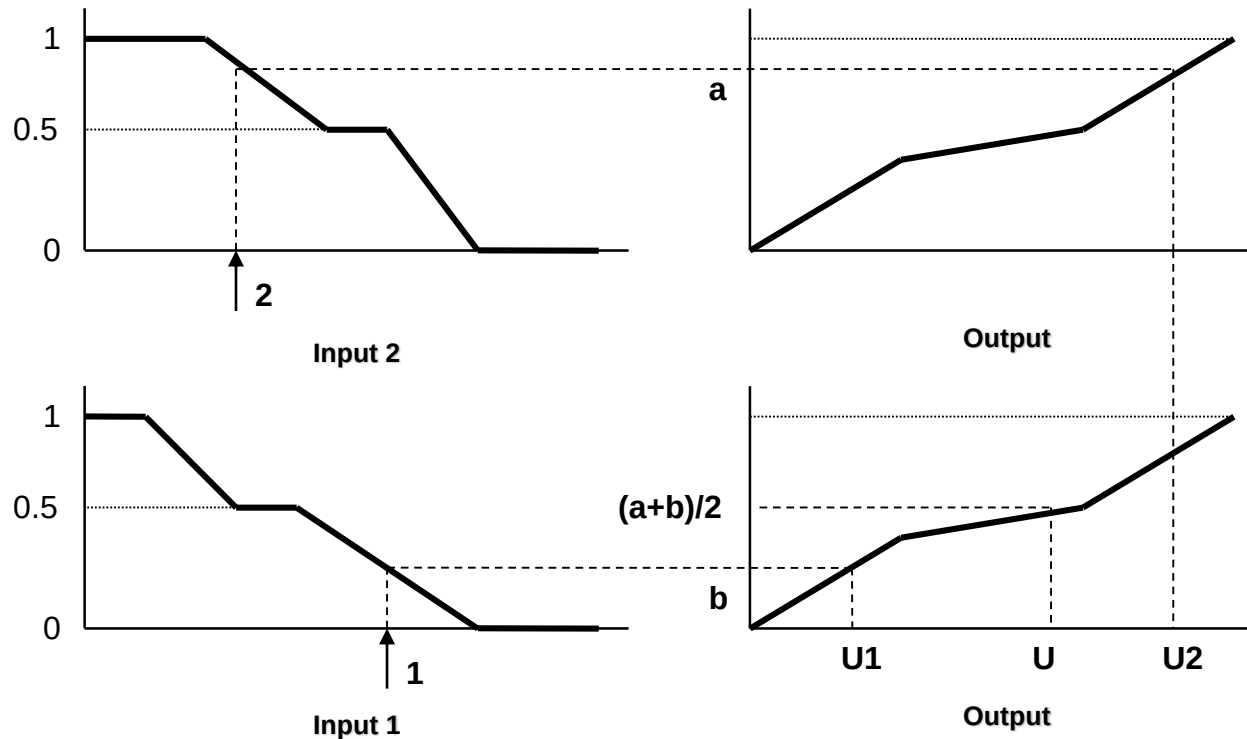
- Concepts are modelled as a whole with one curve.
- Logical 0 and logical 1 are assigned to the poles of the concepts, hence there can be two possible mappings.
- The shape of the curves will be in the form of increasing or decreasing.

Mapping of Outputs to the Interval [0 1]



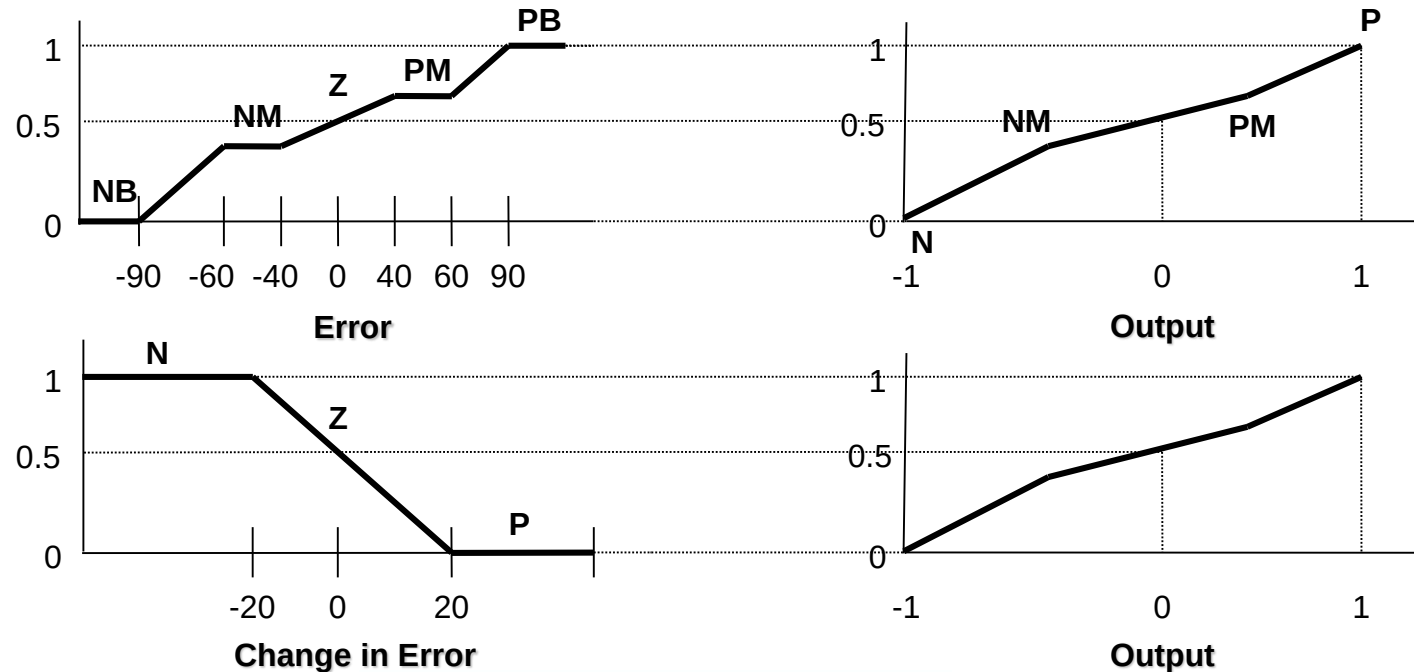
- There are not any horizontal lines at the output curve hence the controller output will be unique.

Obtaining the Output from the Controller



- Every input is intersected with the curve assigned to it and obtained values are conciliated by taking the arithmetic average.
- Obtained single logical value is intersected with the output curve which will yield the corresponding output value assigned to this logical value.
- The procedure is same in case of there are more than two inputs.

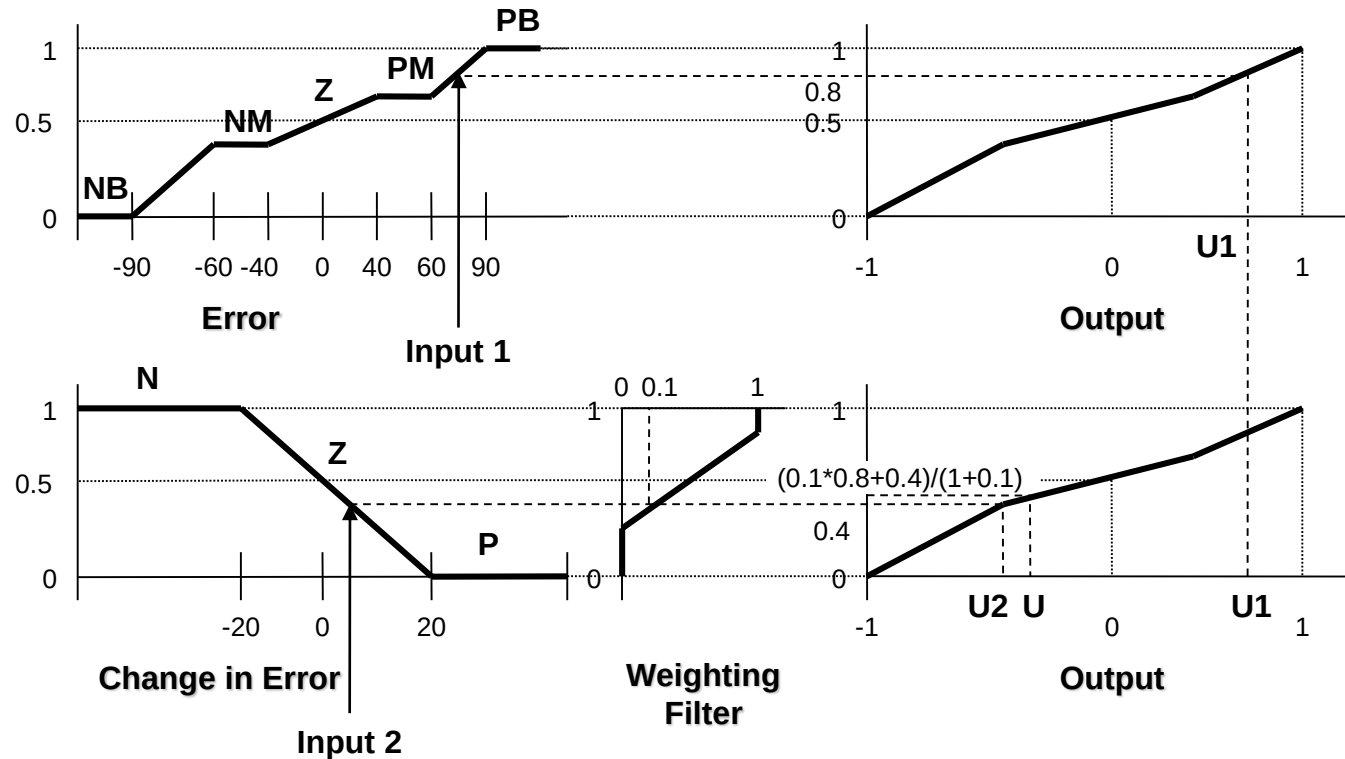
The Rules Consisted Inherently in the Structure



		Error		
		PB	Z	NB
Change in Error	N	P	PM	Z
	Z	PM	Z	NM
	P	Z	NM	N

- If the error is PB [1] and the change in error is N [1] then the output will be P [1]
- If the error is NB [0] and the change in error is N [1] then the output will be Z [0.5]
- If the error is Z [0.5] and the change in error is Z [0.5] then the output will be Z [0.5]
- If the error is Z [0.5] and the change in error is N [1] then the output will be PM [0.75]

Weighting Filter



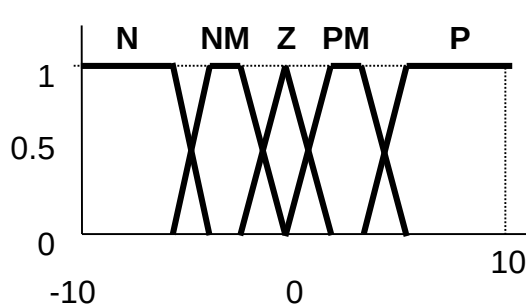
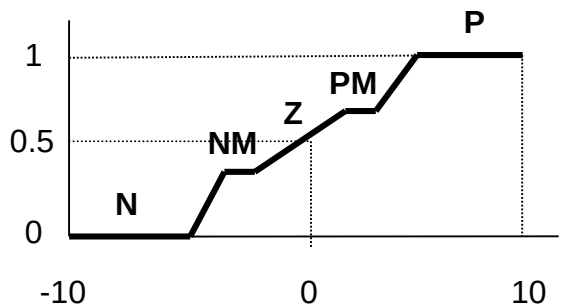
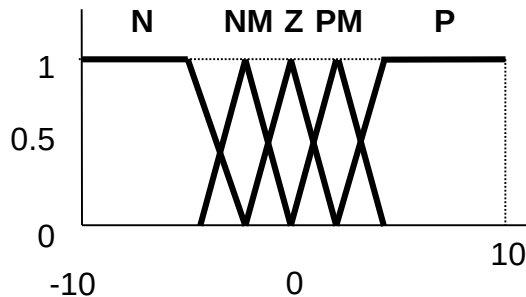
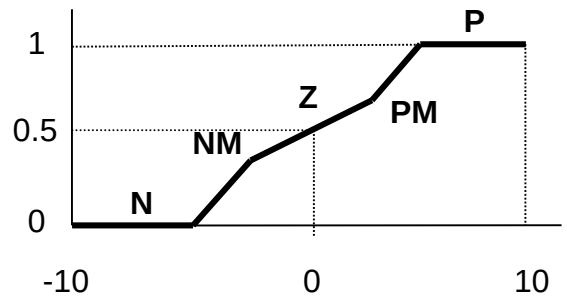
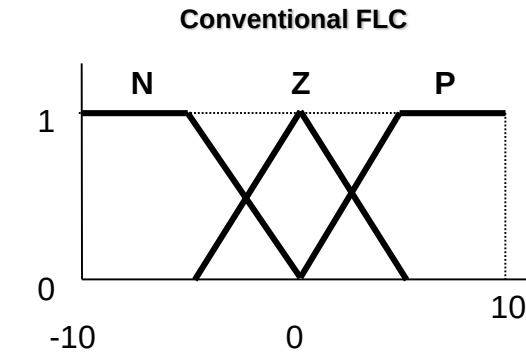
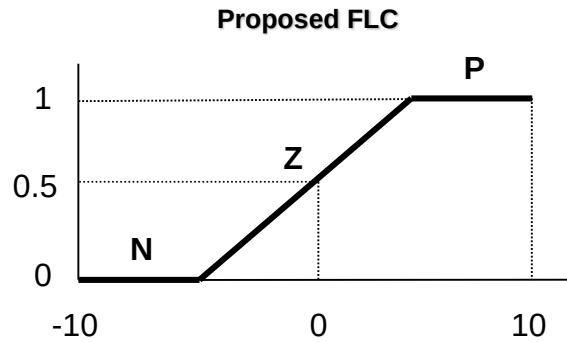
IF the change in error is POSITIVE THEN reduce the importance of the error

	Error		
	PB	Z	NB
Change in Error	P	PM	Z
	PM	Z	NM
	N	N	N

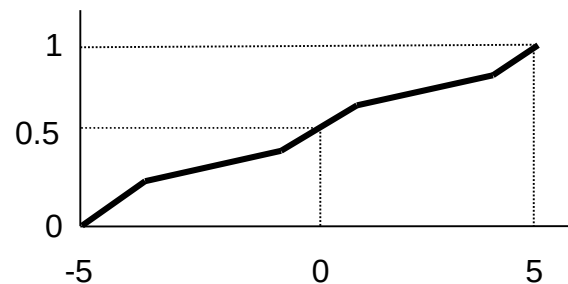
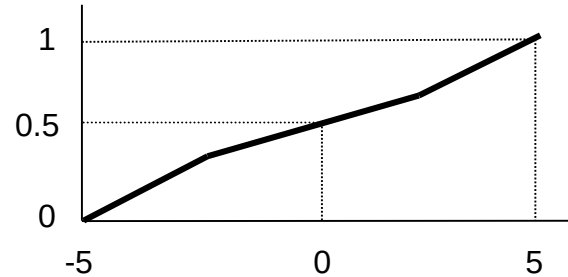
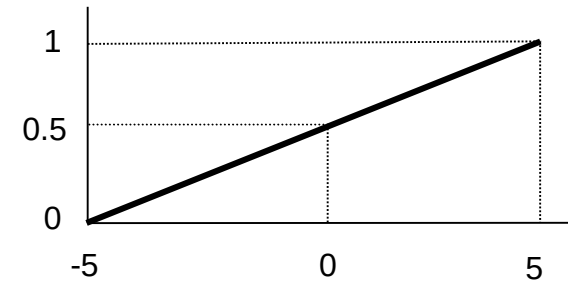
$$\frac{(w_1 \cdot a) + (w_2 \cdot b)}{(w_1 + w_2)}$$

Tuning of the Controller

Tuning of the Inputs



Tuning of the Output



Application Example 1 - Quadrotor



$$m\ddot{X} = u_1 (\cos \phi \sin \theta \cos \psi + \sin \phi \sin \psi)$$

$$m\ddot{Y} = u_1 (\sin \phi \sin \theta \cos \psi - \cos \phi \sin \psi)$$

$$m\ddot{Z} = u_1 (\cos \theta \cos \psi) - mg$$

$$I_{yy} \ddot{\theta} = \dot{\psi} \dot{\phi} (I_{zz} - I_{xx}) + J_R \dot{\psi} \Omega + u_2 l$$

$$I_{xx} \ddot{\psi} = \dot{\theta} \dot{\phi} (I_{yy} - I_{zz}) - J_R \dot{\theta} \Omega + u_3 l$$

$$I_{zz} \ddot{\phi} = u_4$$

$$u_1 = F_1 + F_2 + F_3 + F_4$$

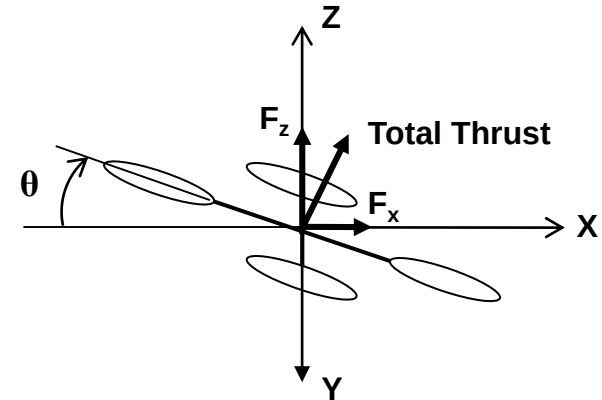
$$u_2 = F_3 - F_1$$

$$u_3 = F_4 - F_2$$

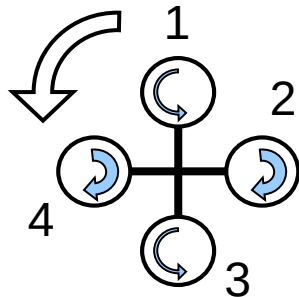
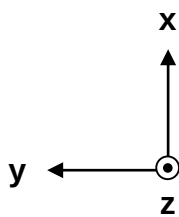
$$u_4 = C(F_1 - F_2 + F_3 - F_4)$$

Force to moment scaling factor

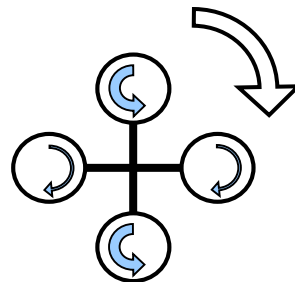
F_i : Propeller Forces



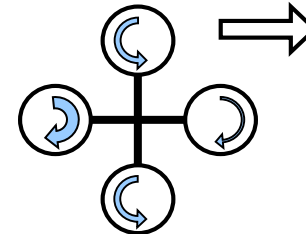
- Angular motions will be controlled with 3 SRFLCs, X and Y motion will be controlled through the angles θ and ψ with 2 SRFLCs, Z motion will be controlled with 1 SRFLC.



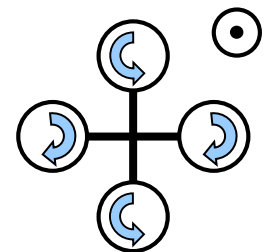
Rotate Left



Rotate Right

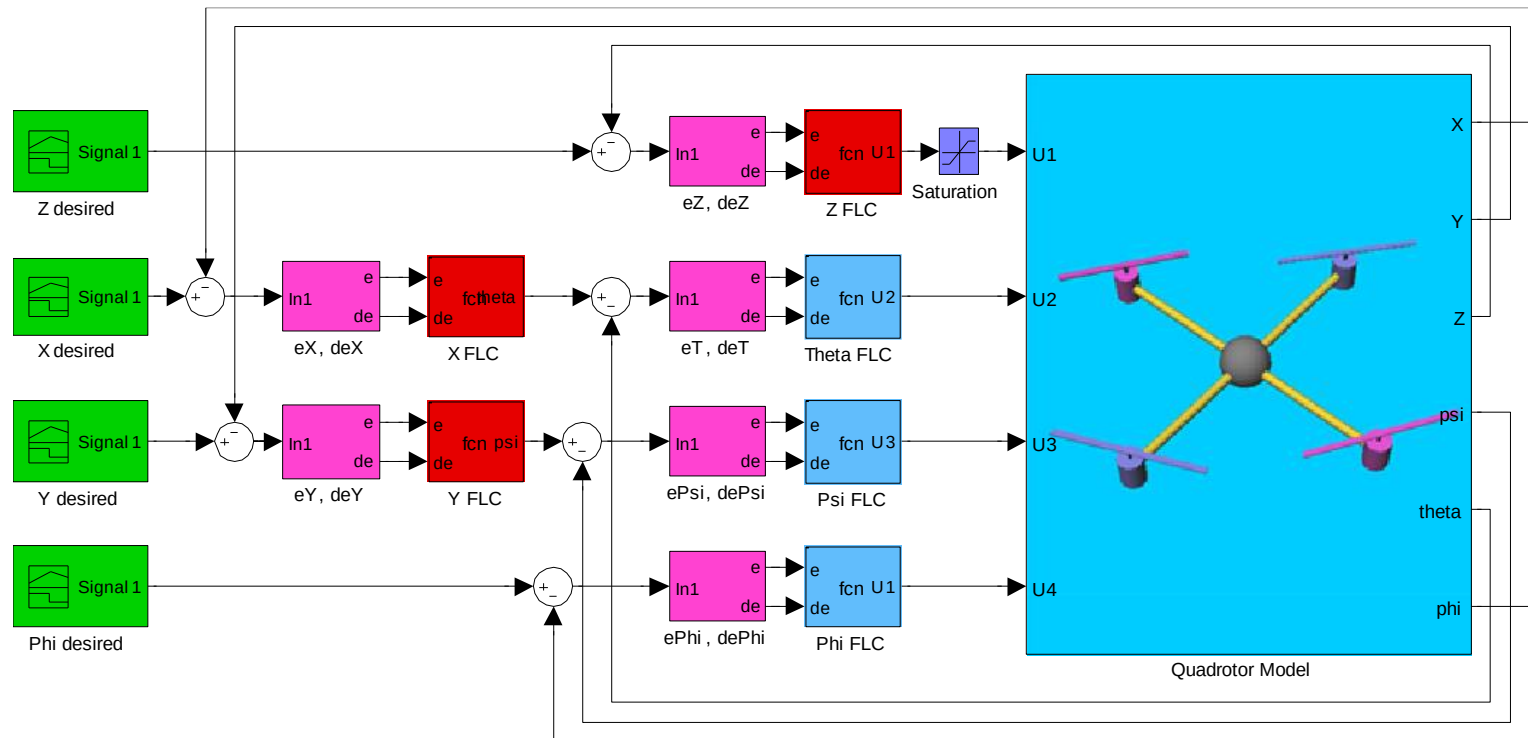


Move Right



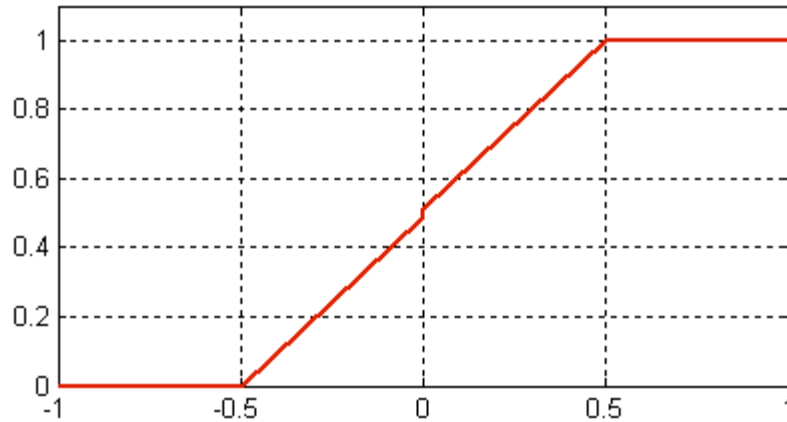
Going Up

Application Example 1 - Quadrotor



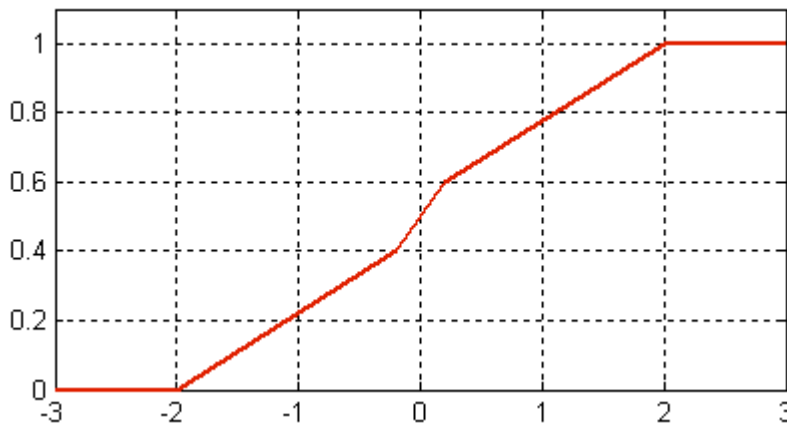
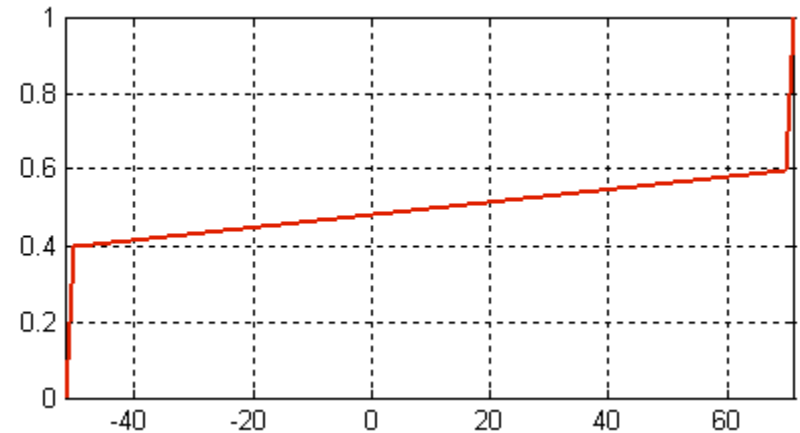
Z Controller Structure

INPUTS



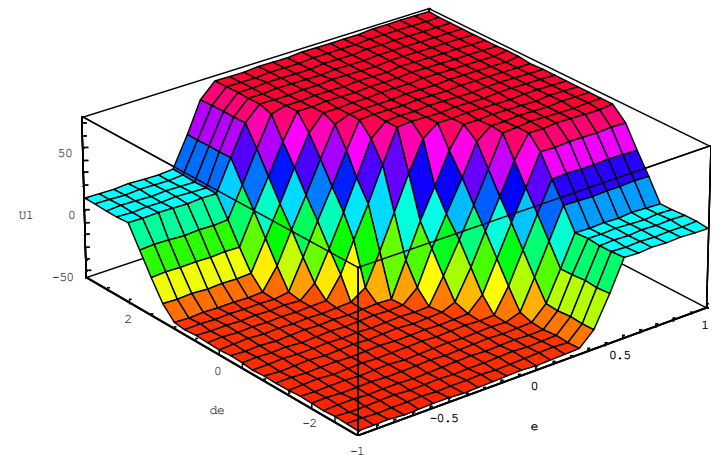
Error

OUTPUT



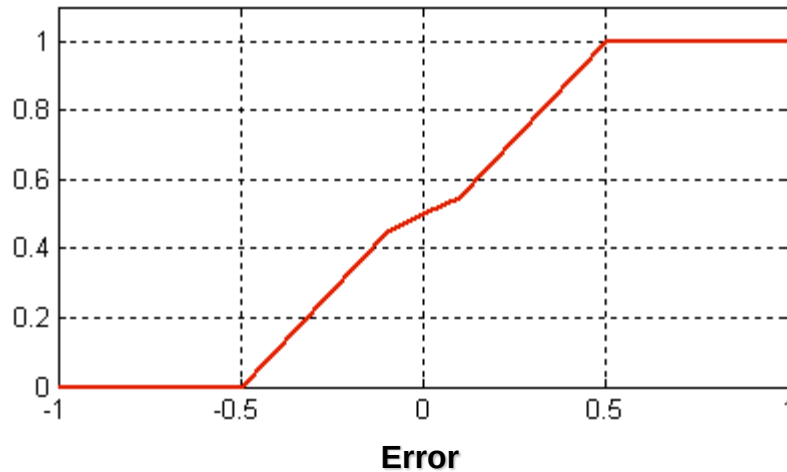
Change in Error

CONTROL SURFACE

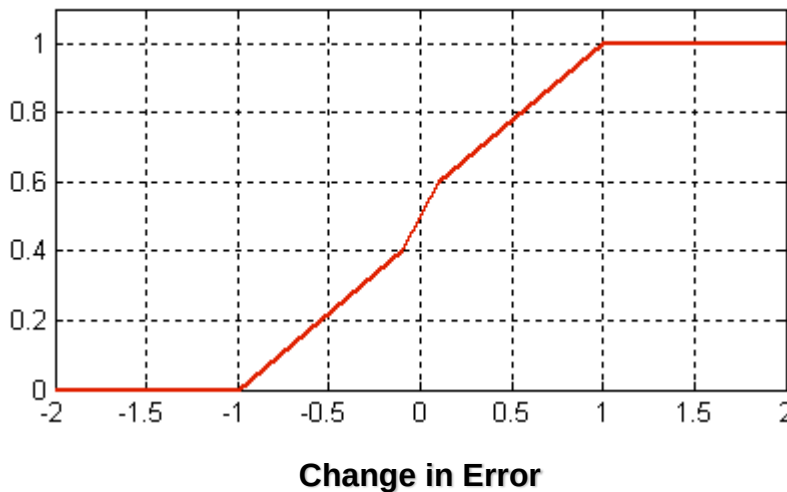
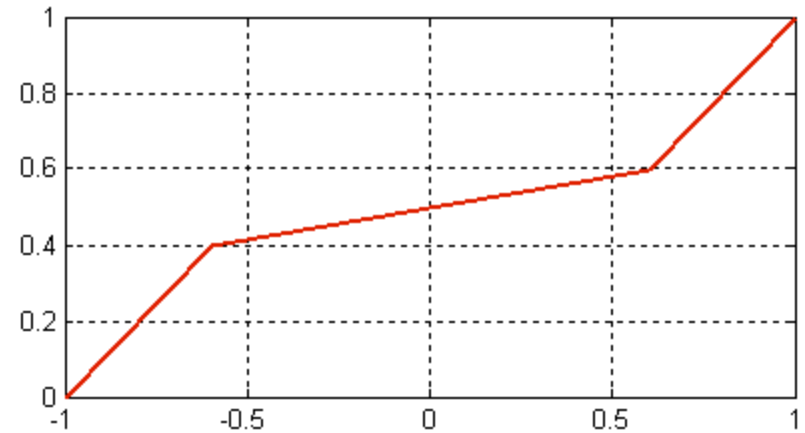


X and Y Controller Structure

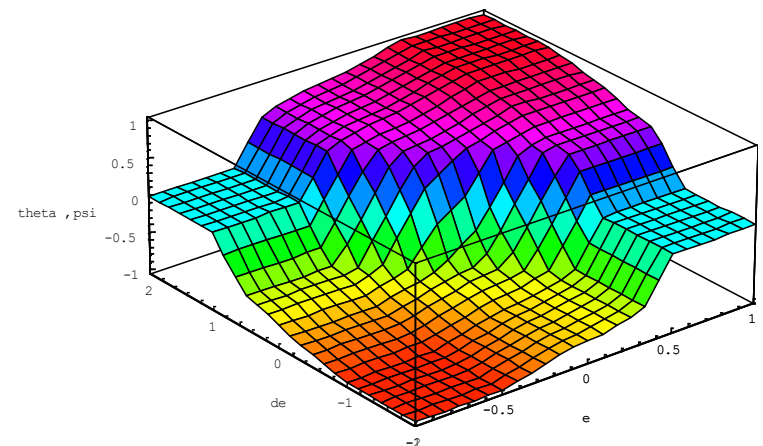
INPUTS



OUTPUT

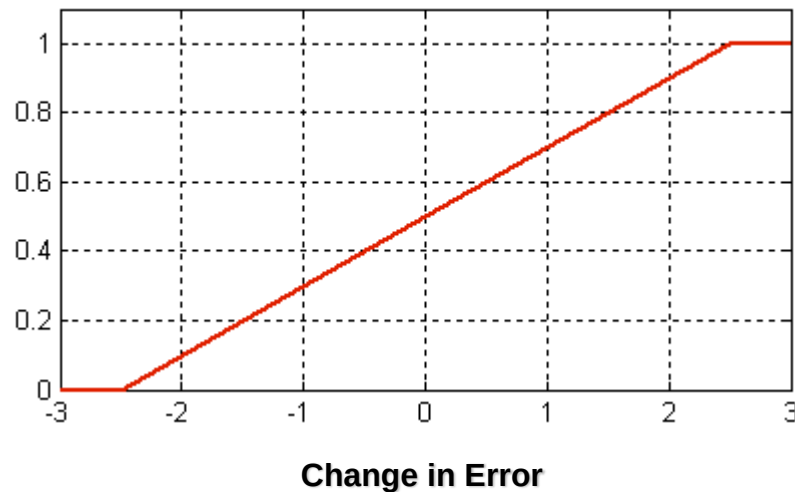
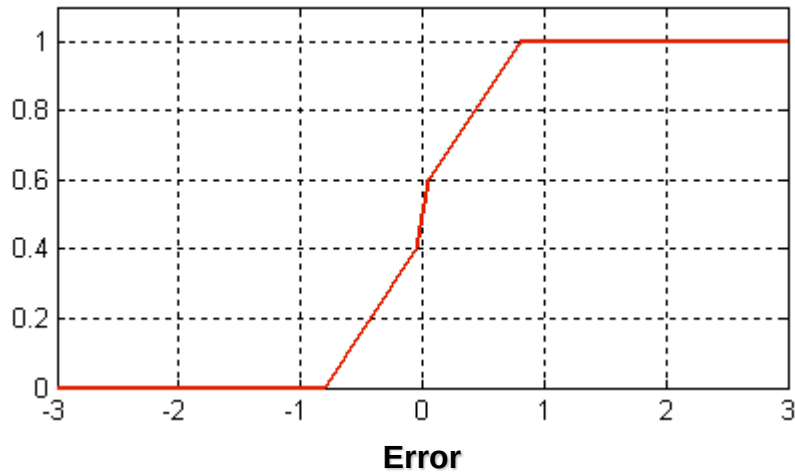


CONTROL SURFACE

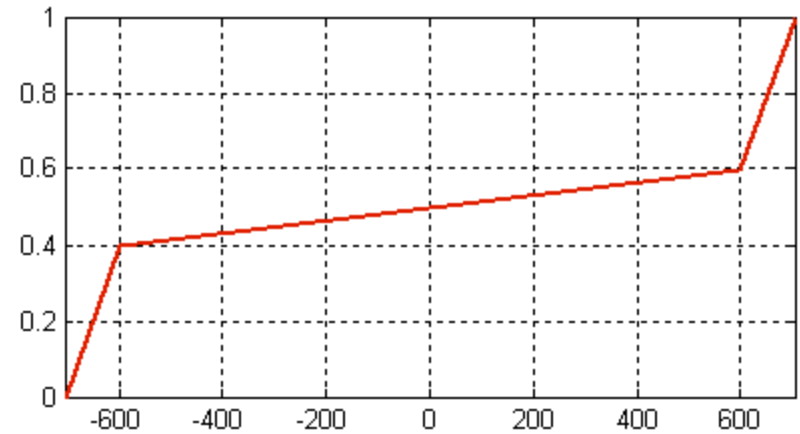


θ and ψ Controller Structure

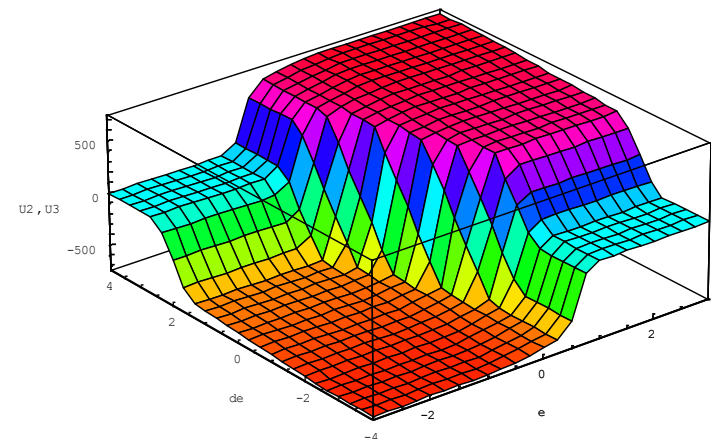
INPUTS



OUTPUT

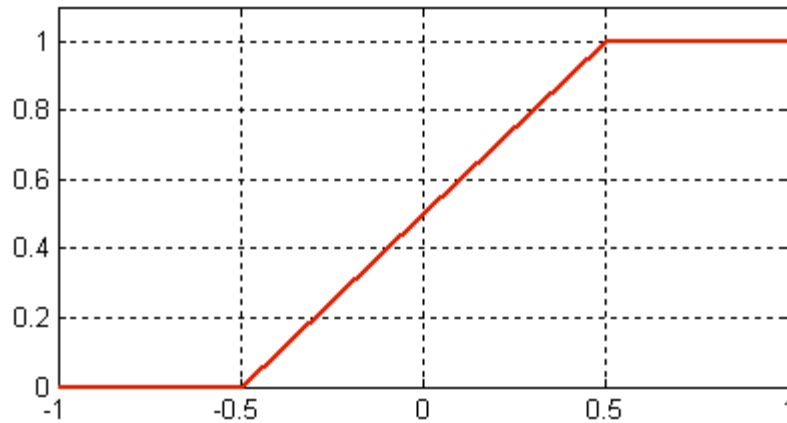


CONTROL SURFACE

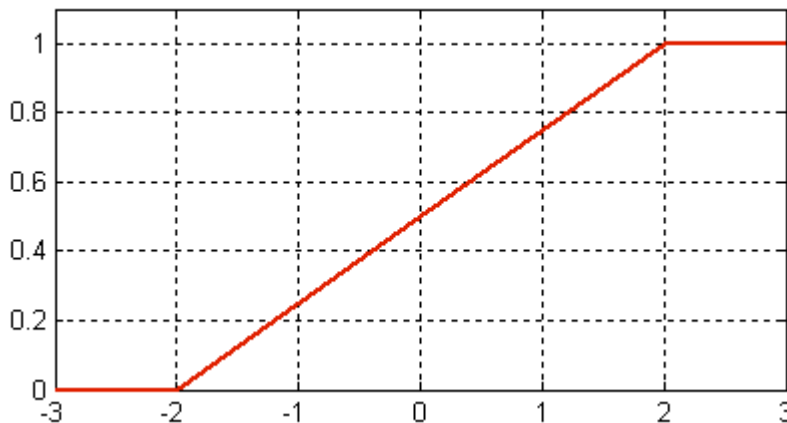


Φ Controller Structure

INPUTS

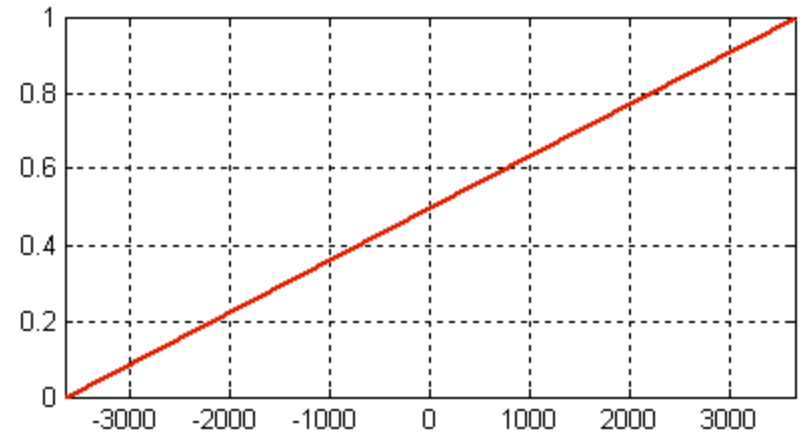


Error

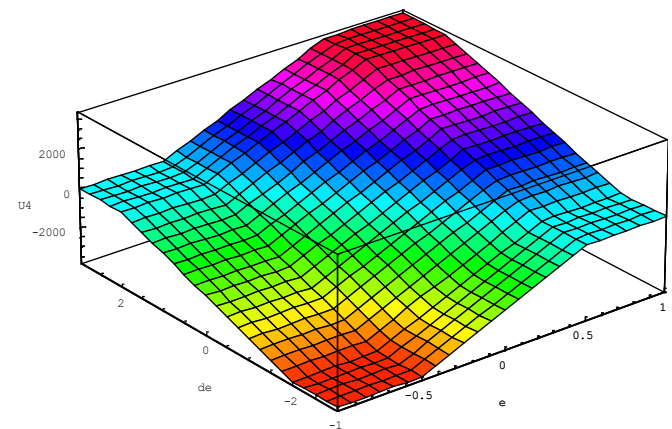


Change in Error

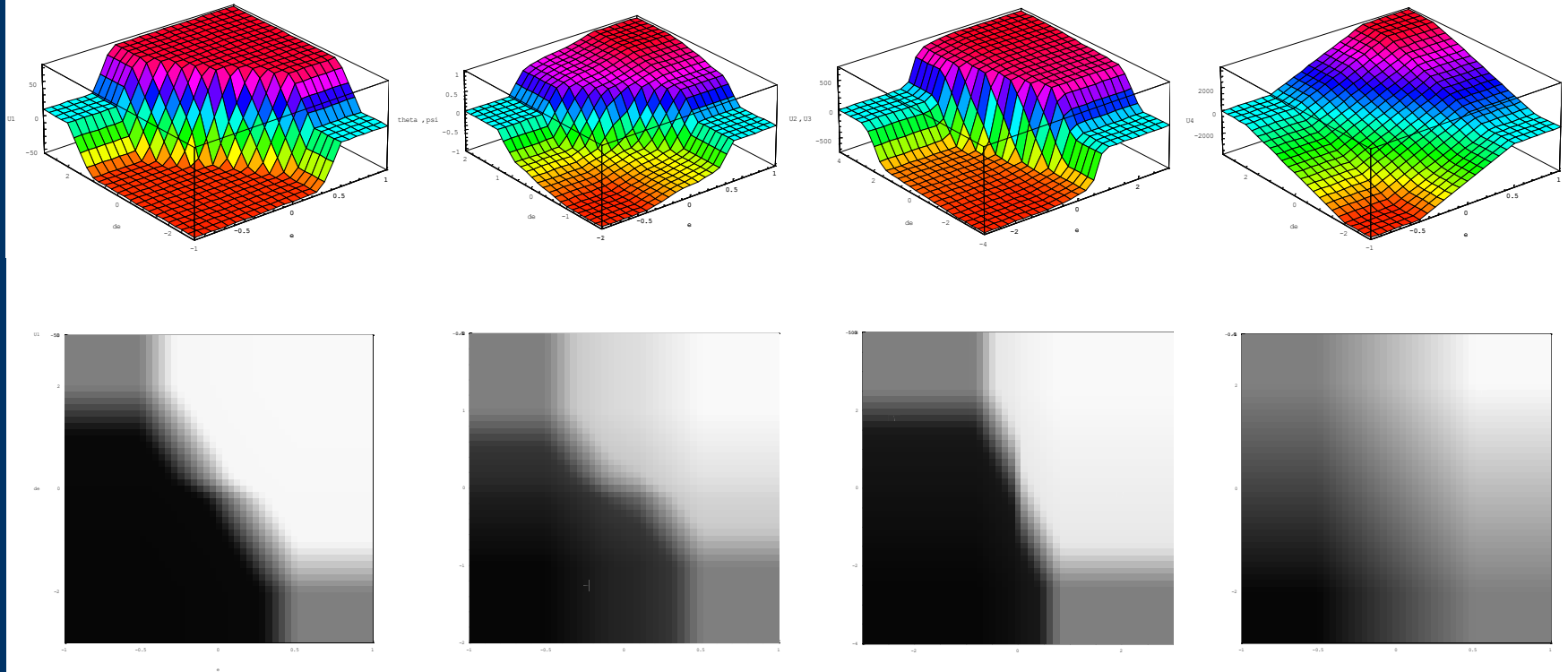
OUTPUT



CONTROL SURFACE



Rule Bases

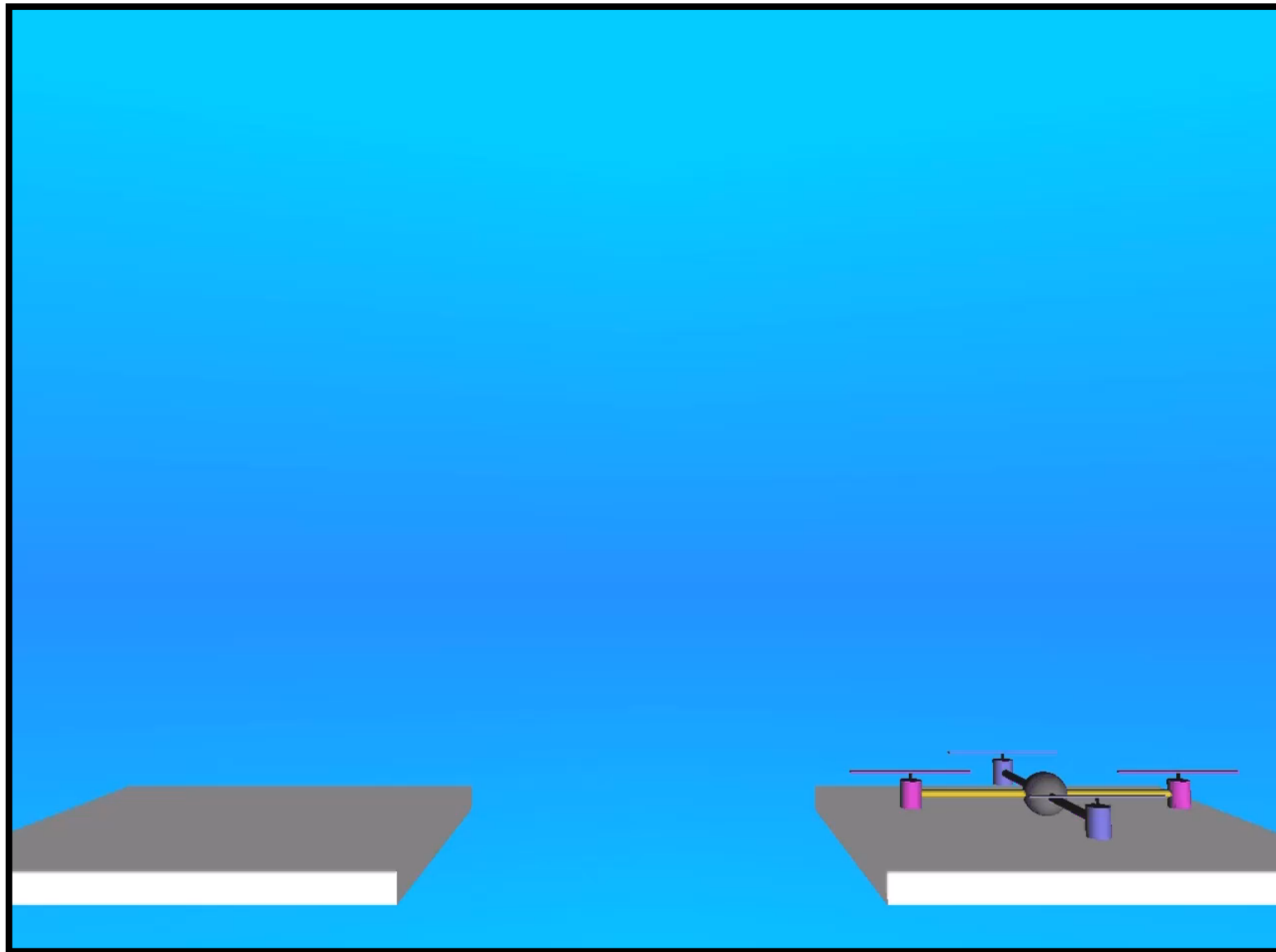
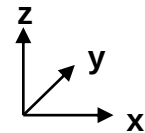


White – Strictly PB output

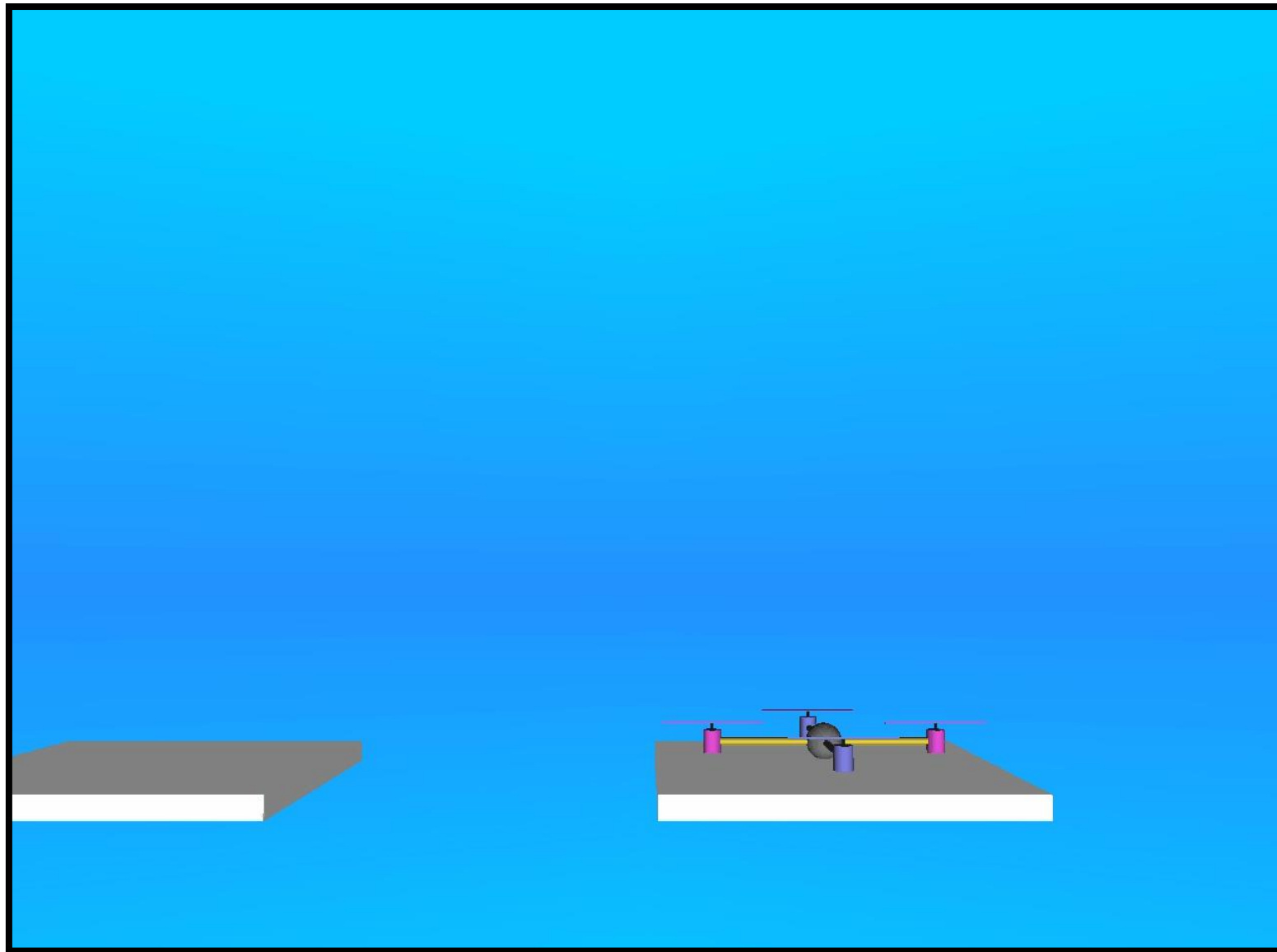
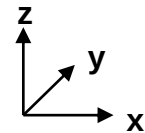
Black – Strictly NB output

Gray – Strictly Z output

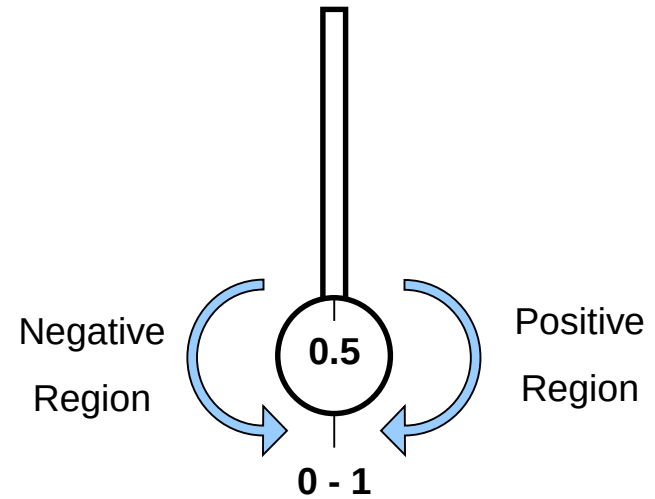
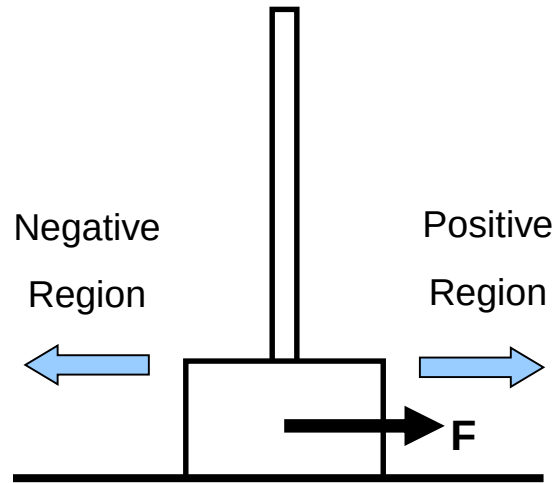
Quadrotor Simulation 1



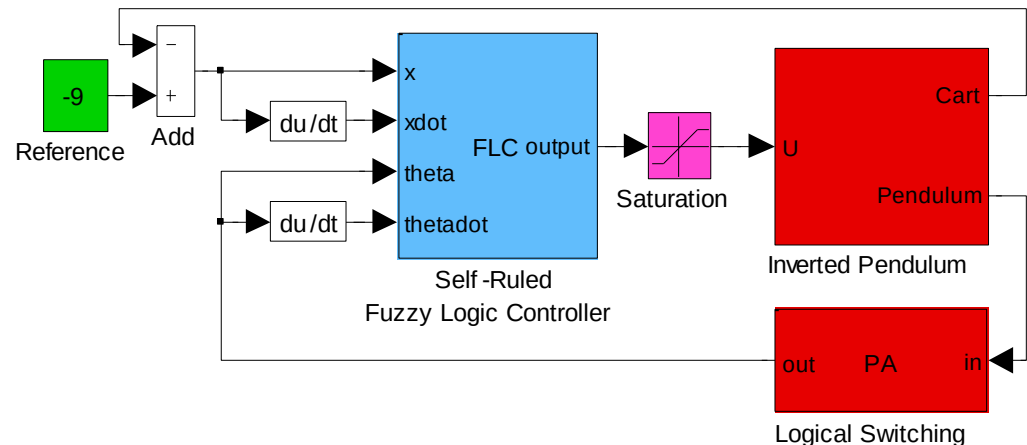
Quadrotor Simulation 2



Application Example 2 – Inverted Pendulum

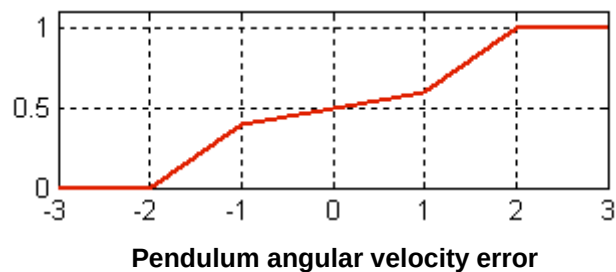
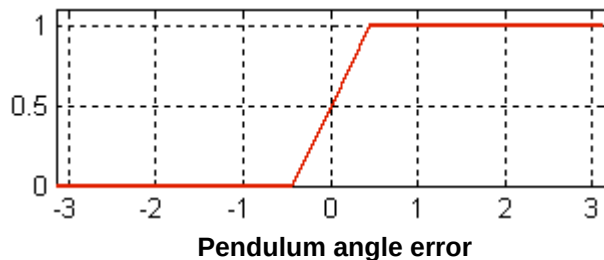
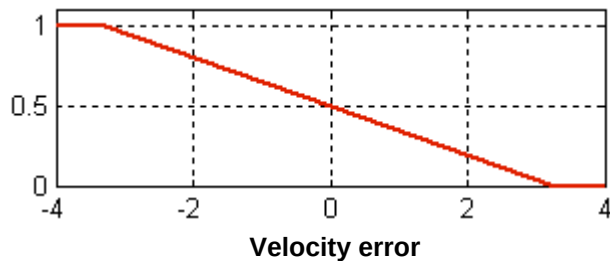
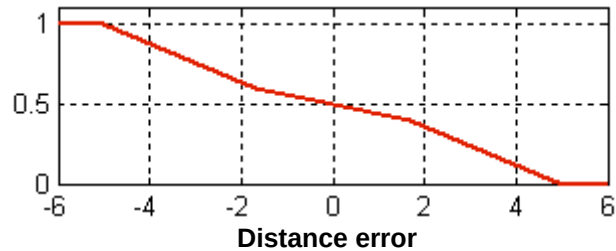


- There is a logical switch point at angle $\pm\pi$ which must be considered.
- Logical 1 and Logical 0 are assigned to the same angle of the pendulum. Hence the controller will lock up at the angle $\pm\pi$.

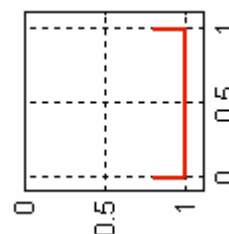
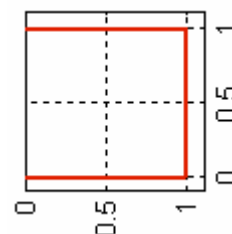
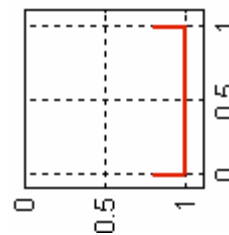
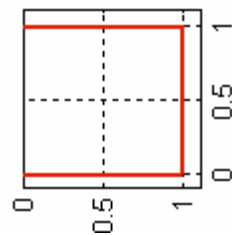


Application Example 2 – Inverted Pendulum

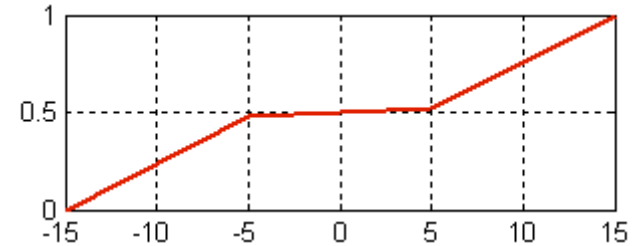
INPUTS



WEIGHTING FILTERS



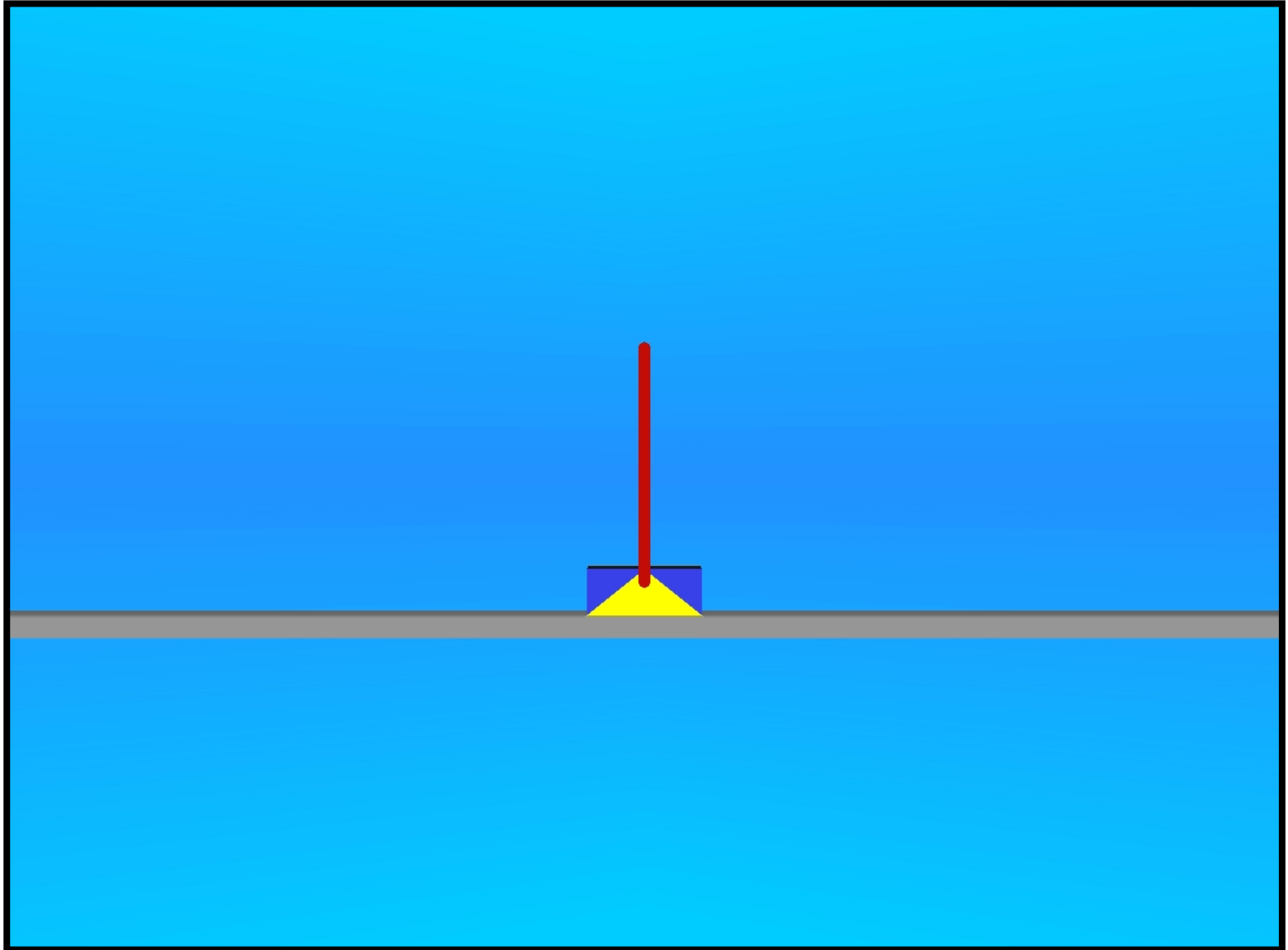
OUTPUT



IF the pendulum angle or
angular velocity is PB-NB
THEN reduce the
importance of the distance
error and velocity error

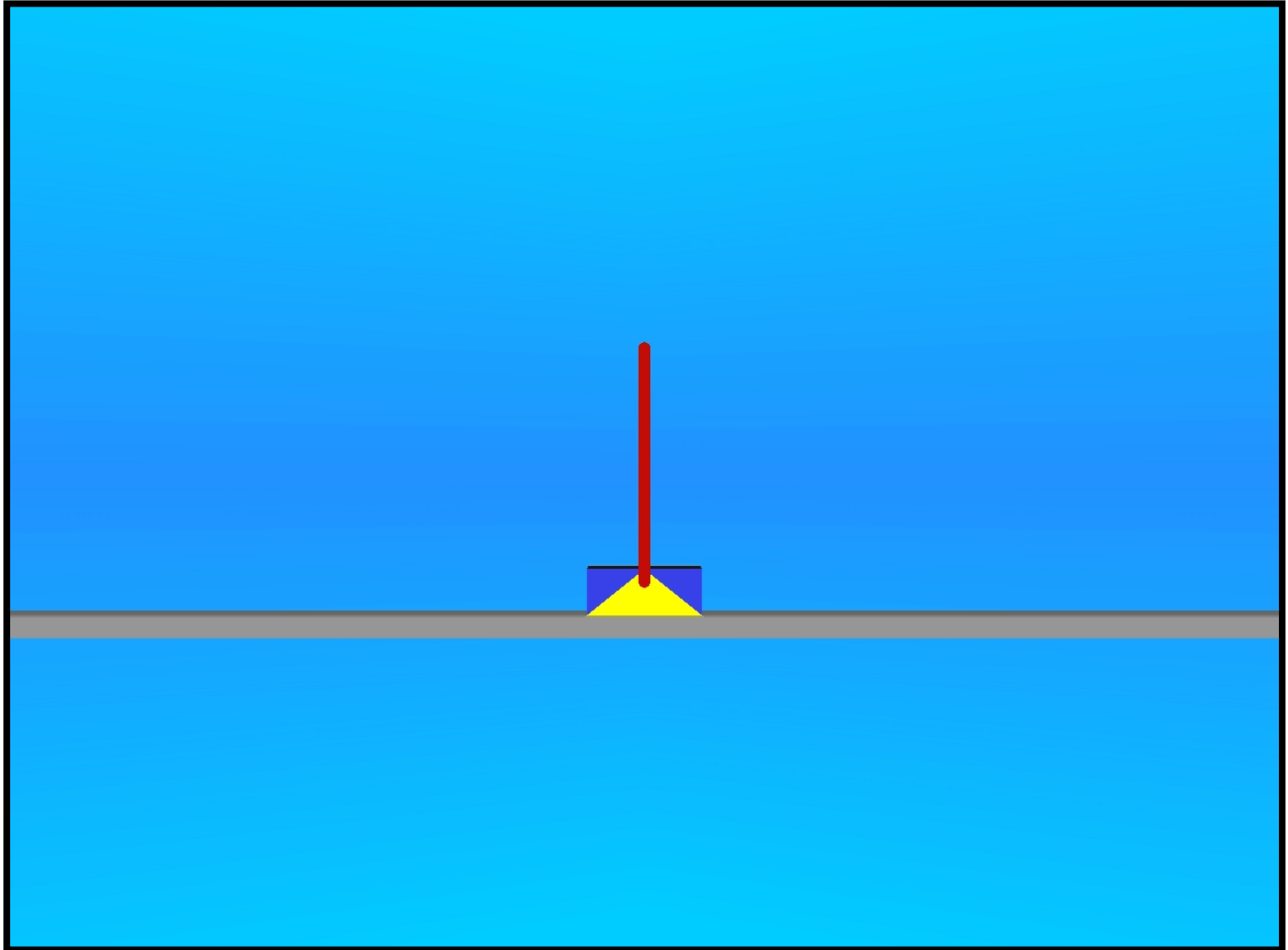
Inverted Pendulum Simulation 1

$\theta_0 = 0.9\text{rad}$, $X_d = -9\text{m}$, $F_{\max} = 10\text{N}$



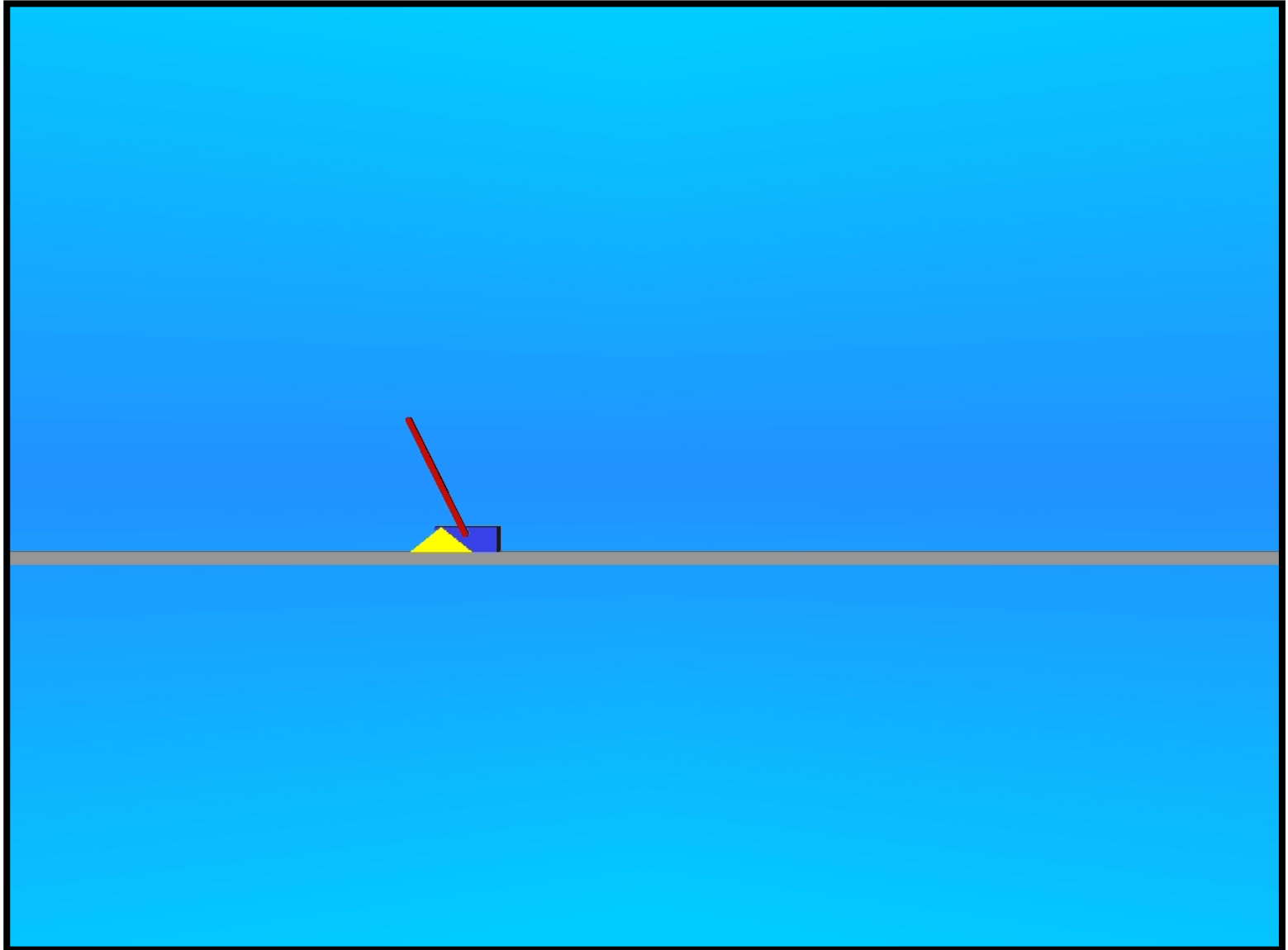
Inverted Pendulum Simulation 2

$\theta_0 = 3\text{rad}$, $X_d = -9\text{m}$, $F_{\max} = 10\text{N}$

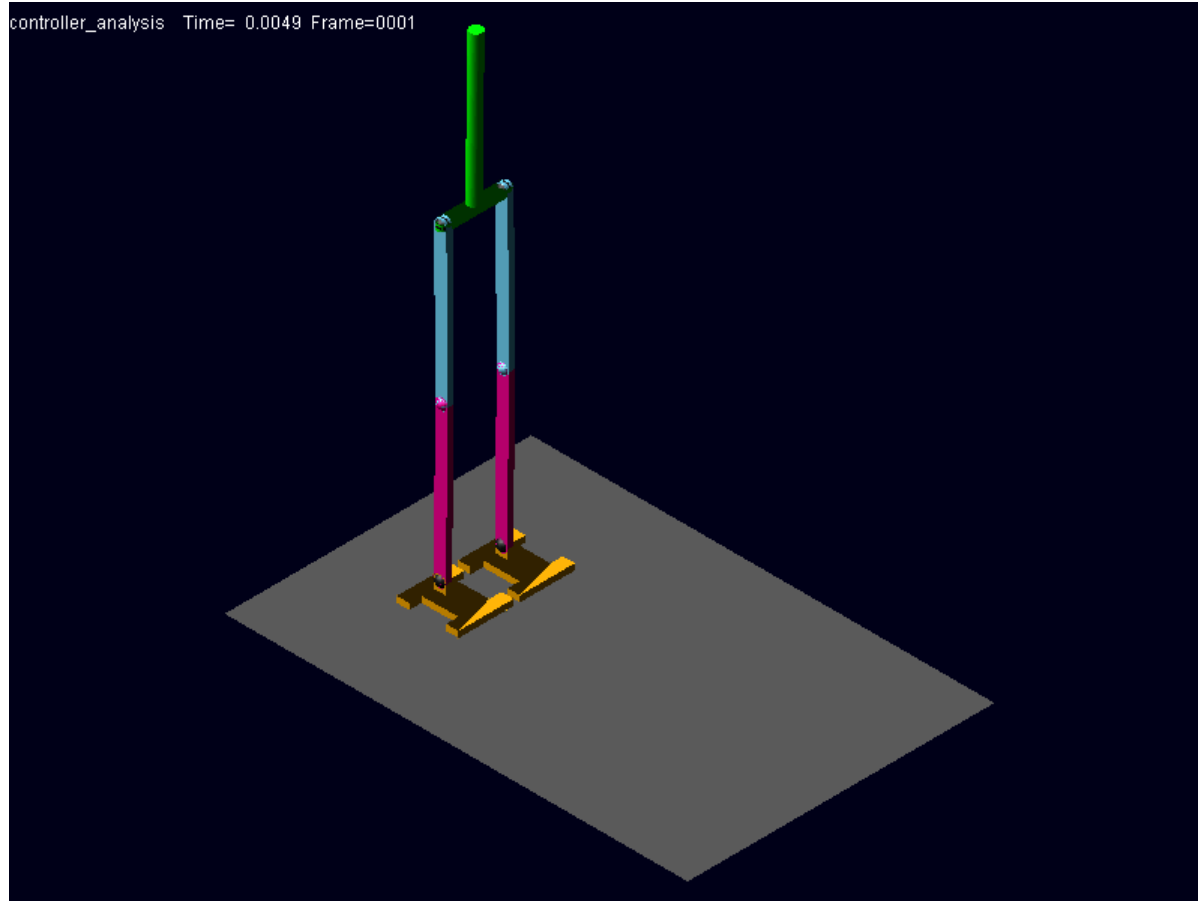


Inverted Pendulum Simulation 3

$X_d = \text{Sinusoidal Amp} = 9\text{m}$, $F_{\max} = 10\text{N}$, Disturbance($\pm 1\text{N}$) , Noise($\pm 0.1\text{rad}$)



Application Example 3 – Bipedal Walking



CONCLUSION

- Obtaining the output from the controller is computationally efficient.
- The controller has guaranteed continuity at the output.
- Due to the simple and systematic nature of the structure applications with multi-input controllers will be easier.
- The structure may not be as flexible as conventional FLCs.
- The controller can be tuned with a trial and error method however there is a need to make the controller adaptive.

THANKS FOR YOUR ATTENTION