UNIVERSITÉ Concordia UNIVERSITY

Department of Mechanical and Industrial Engineering

Flight Control Systems
Professor Zhang

Design of Fuzzy gain scheduled PID controller for JC2SAT-FF Mission

Oral Presentation of Final Project

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Outlines:

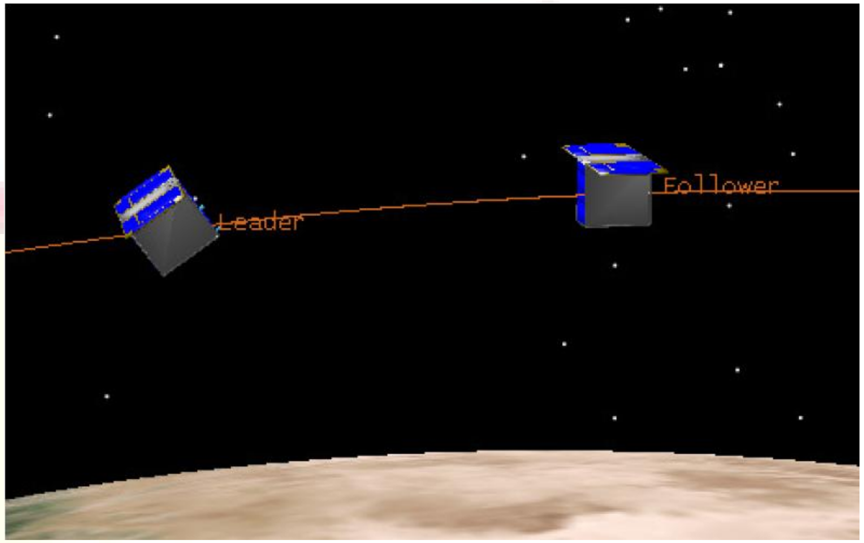
- Brief Introduction to JC2SAT-FF
- Space craft attitude Dynamics
- Actuator Modeling (Momentum Wheel)
- Simple PID design
- Fuzzy Gain Scheduled PID Design
- Results
- Conclusion

JC2Sat-FF (Japan Canada Joint Collaboration Satellites – Formation Flying) Mission

Main objective:
Along track formation keeping

By means of:
Differential atmospheric drag control

How:
By controlling pitch angle of each satellite which results in frontal drag area

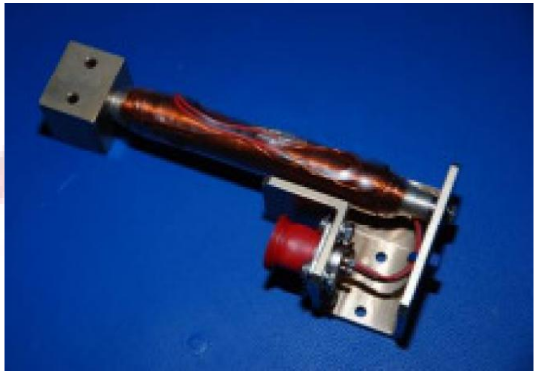


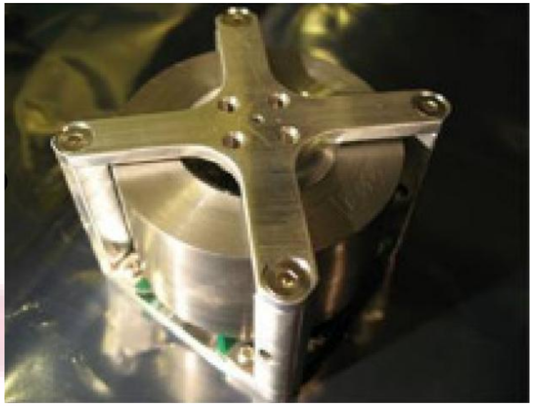
Canadian Space Agency   Agence spatiale canadienne

Japan Aerospace Exploration Agency

Attitude Control hardware:

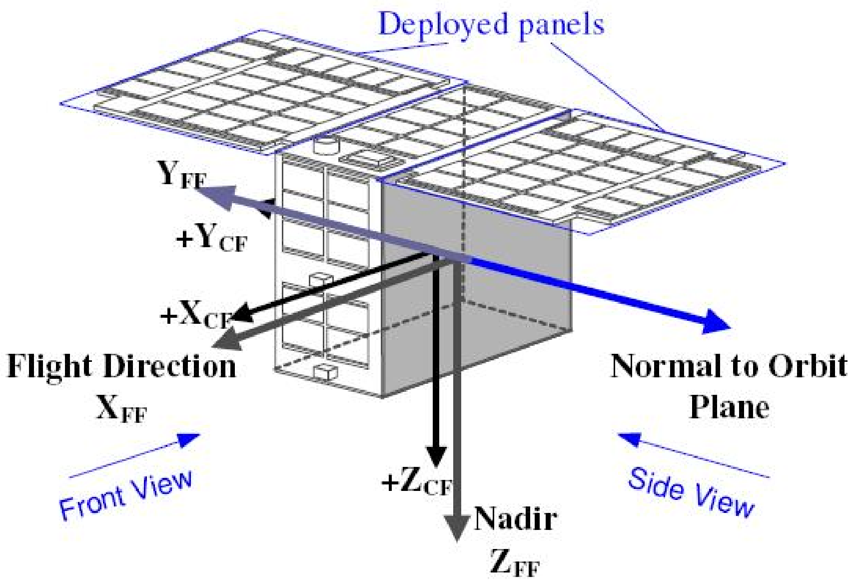
- toque rods
- momentum Wheel (in pitch direction)
- magnetometers
- sun sensors





Reference Frames:

- Spacecraft Body Reference Frame
- Spacecraft Principal Axes reference frame
- Spacecraft Orbital Reference Frame
- Inertial Reference Frame



Space craft attitude Dynamics:

Based on Euler's Moment Equations:

If we assume body frame and Principal Axes reference frame are the same:

$$M_x = I_x \dot{\omega}_x + \omega_y \omega_z (I_z - I_y)$$

$$M_y = I_y \dot{\omega}_y + \omega_x \omega_z (I_x - I_z)$$

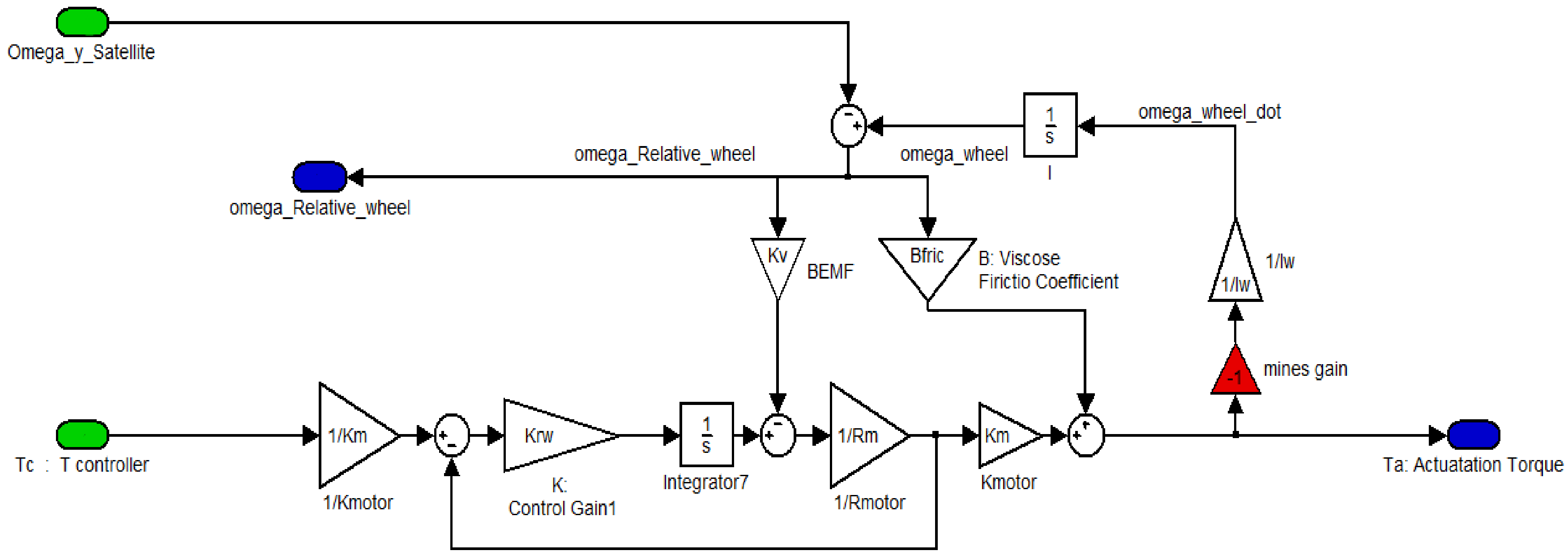
$$M_z = I_z \dot{\omega}_z + \omega_x \omega_y (I_x - I_y)$$

Actuator Dynamics (Reaction Wheel):

- Classified as momentum exchange devices
- Application: moderately fast maneuvers
- no external disturbances and no inertial control torques:

according to Euler's moment equation of angular motion we have:

$$\dot{h}_w + \dot{h}_s = 0$$



Simple PID design:

Zigler and Nicols Method

$$k_u = 1.9$$

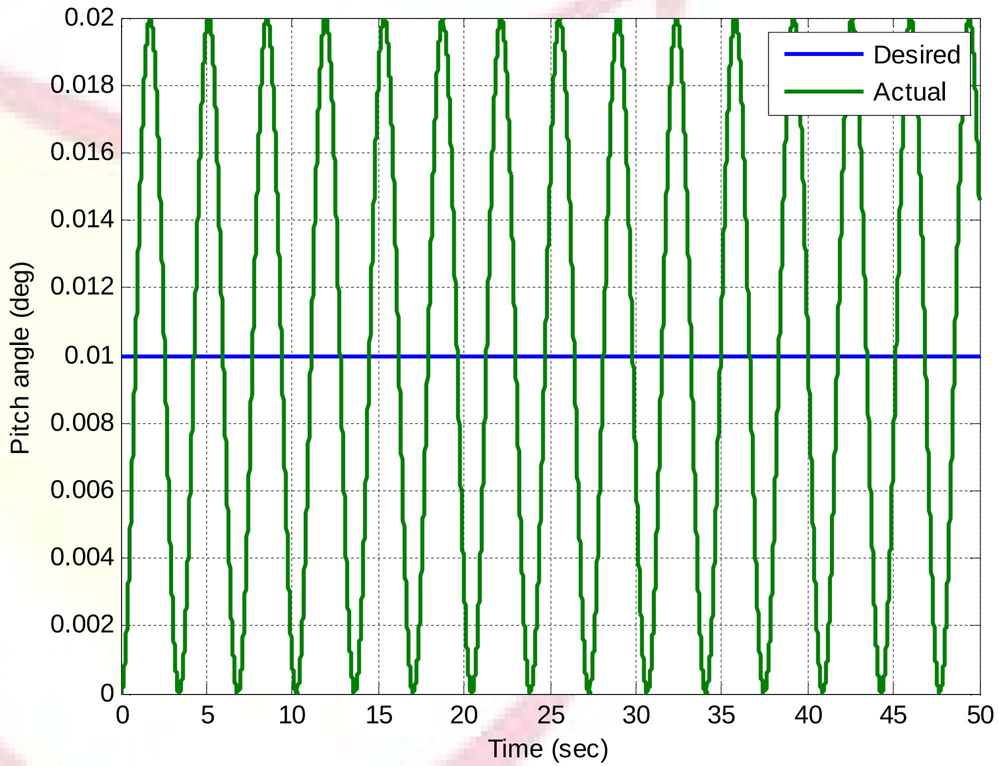
$$P_u = 3.41\ s$$

$$k_c = 0.6k_u ,T_i = 0.5p_u ,T_d = 0.125p_u$$

$$k_p = 0.6 * k_u = 0.855$$

$$T_i = 0.5 * P_u = 2.83$$

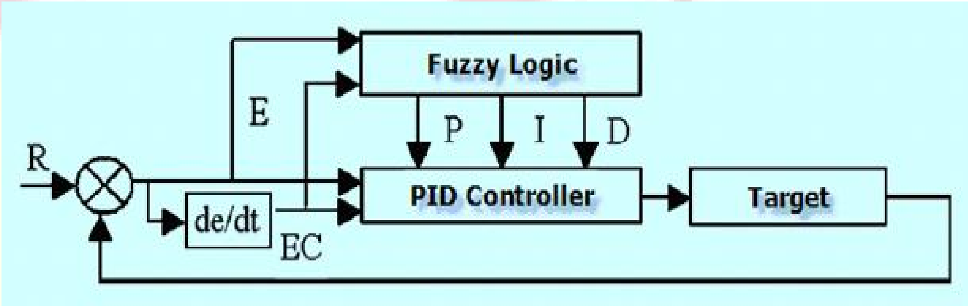
$$T_d = 0.125 * P_u = 2.83$$



Fuzzy Gain Scheduled PID Design:

Based on the paper:

Z. Y. Zhao, M. Tamizuka, and S. Isaka, "Fuzzy Gain Scheduling of PID Controllers," IEEE Trans. Syst. Man, Cybern. ,vol. SMC-15, pp. 116-132, 1985.



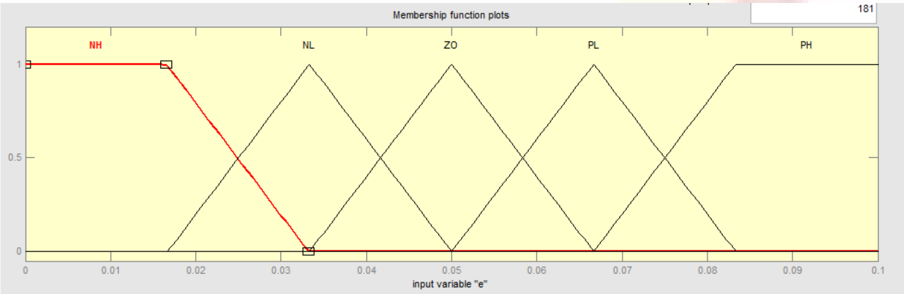
$$if\ \ e\ is\ A_i\ and\ \Delta e\ is\ B_i,\ then\ K_p\ is\ C_i, K_I\ is\ D_i,\ K_d\ is\ E_i.$$

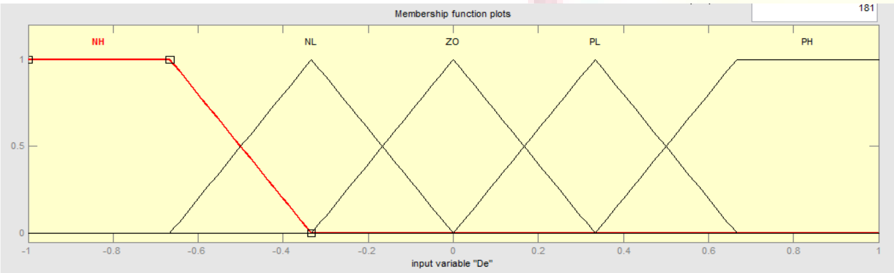
K_P		e				
		PH	PL	ZO	NL	NH
Δe	PH	H	L	L	L	H
	PL	MH	L	H	L	MH
	ZO	MH	H	MH	H	MH
	NL	MH	L	H	L	MH
	NH	H	L	L	L	H

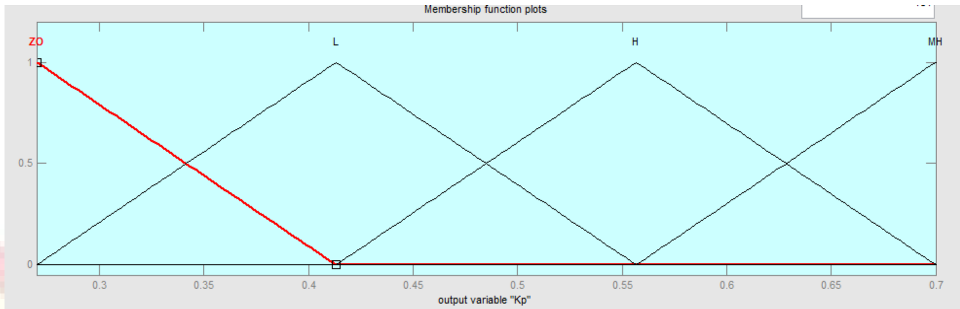
K_I		e				
		PH	PL	ZO	NL	NH
Δe	PH	ZO	L	H	L	ZO
	PL	ZO	H	MH	H	ZO
	ZO	ZO	H	MH	H	ZO
	NL	ZO	H	MH	H	ZO
	NH	ZO	L	H	L	ZO

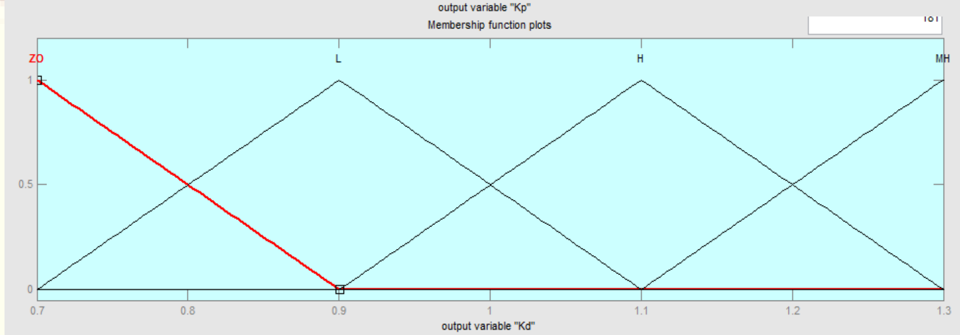
K_D		e				
		PH	PL	ZO	NL	NH
Δe	PH	L	H	L	H	L
	PL	L	H	H	H	L
	ZO	ZO	L	MH	L	ZO
	NL	L	H	H	H	L
	NH	L	H	L	H	L

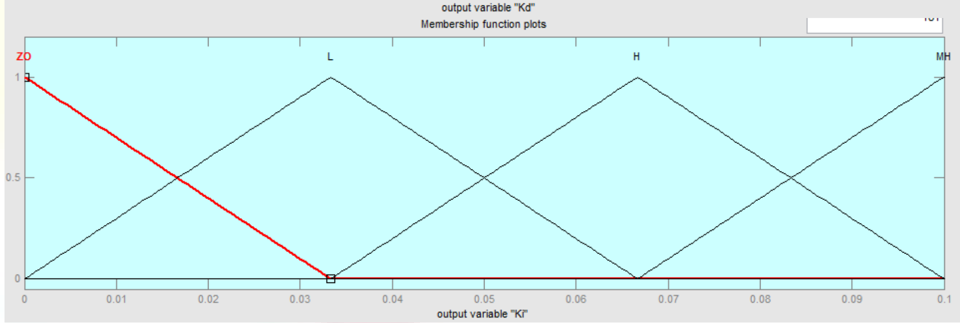
Member ship functions:



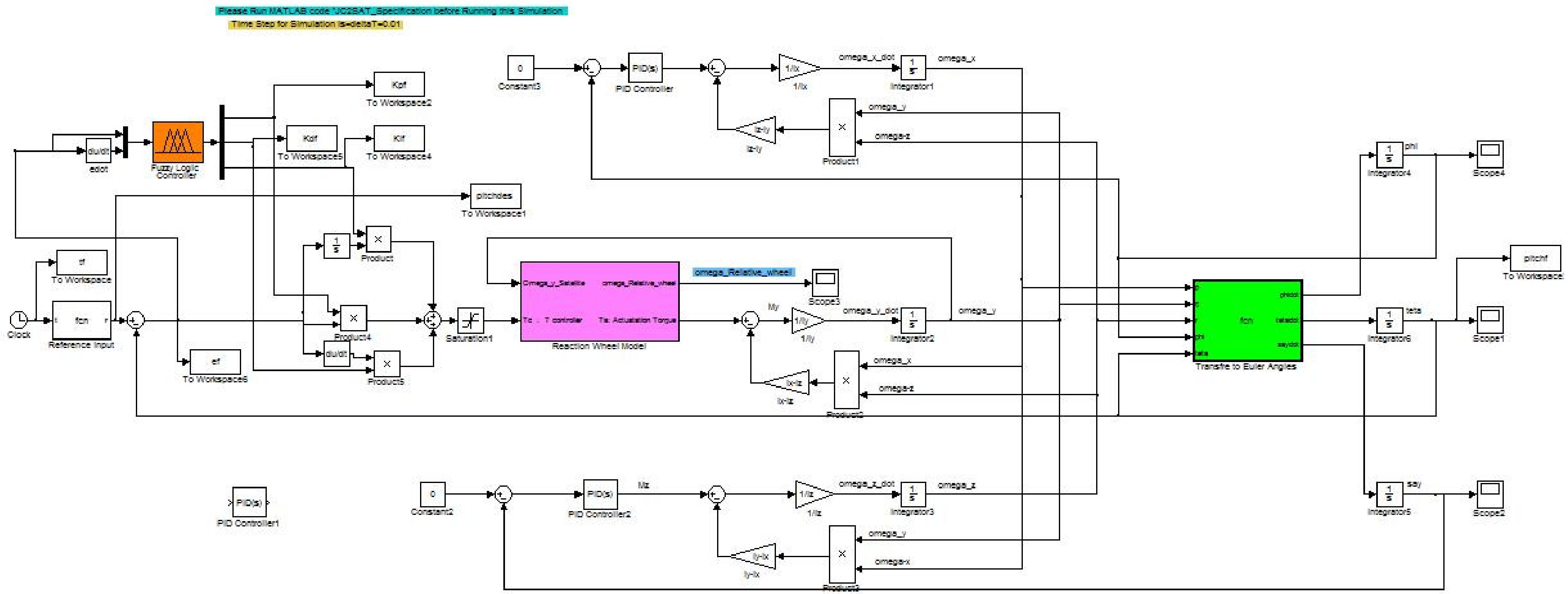




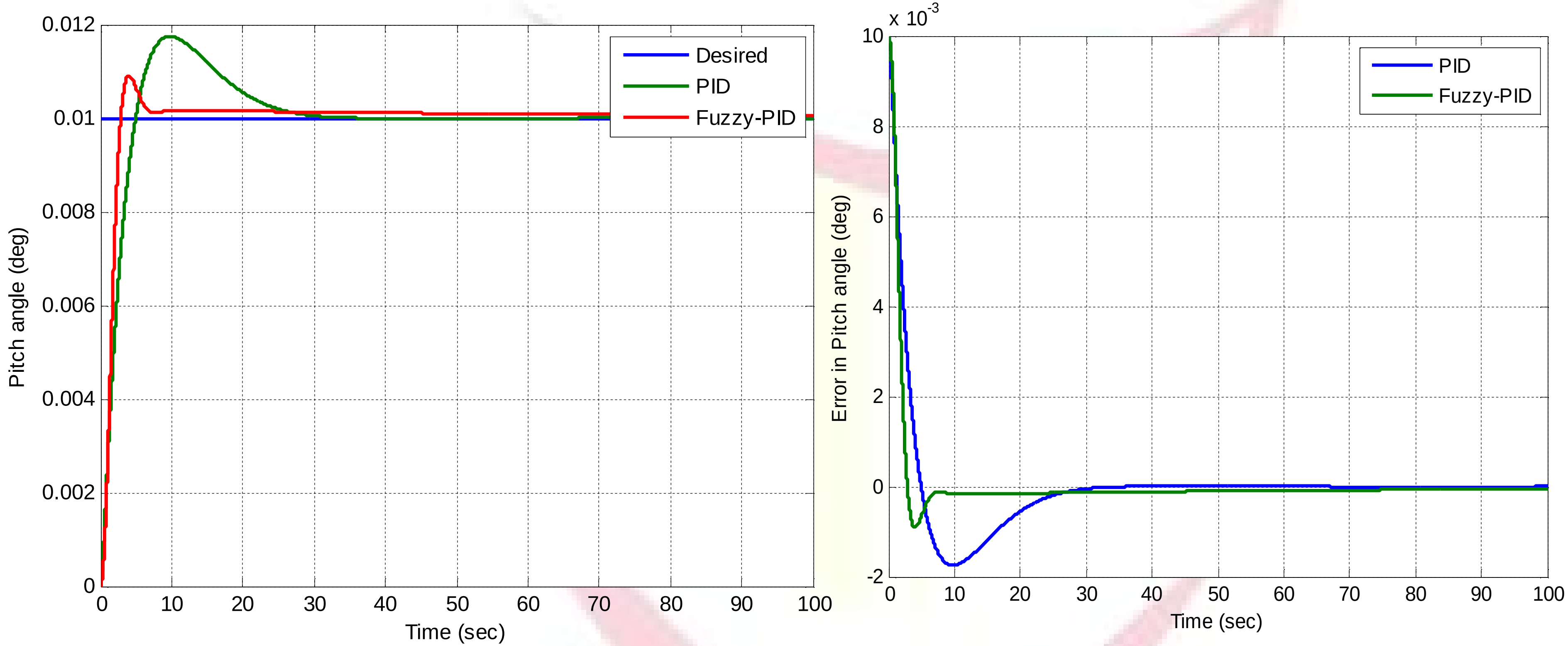




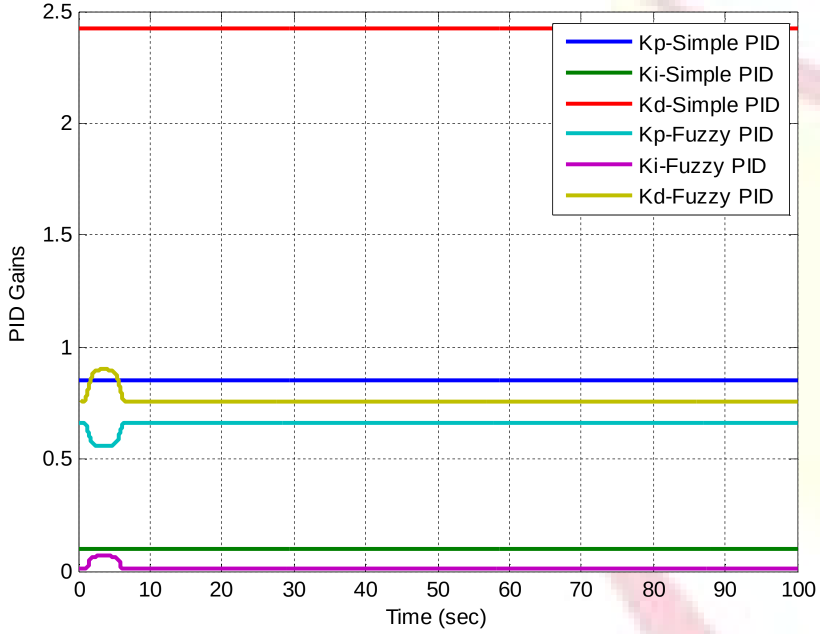
Simulation:

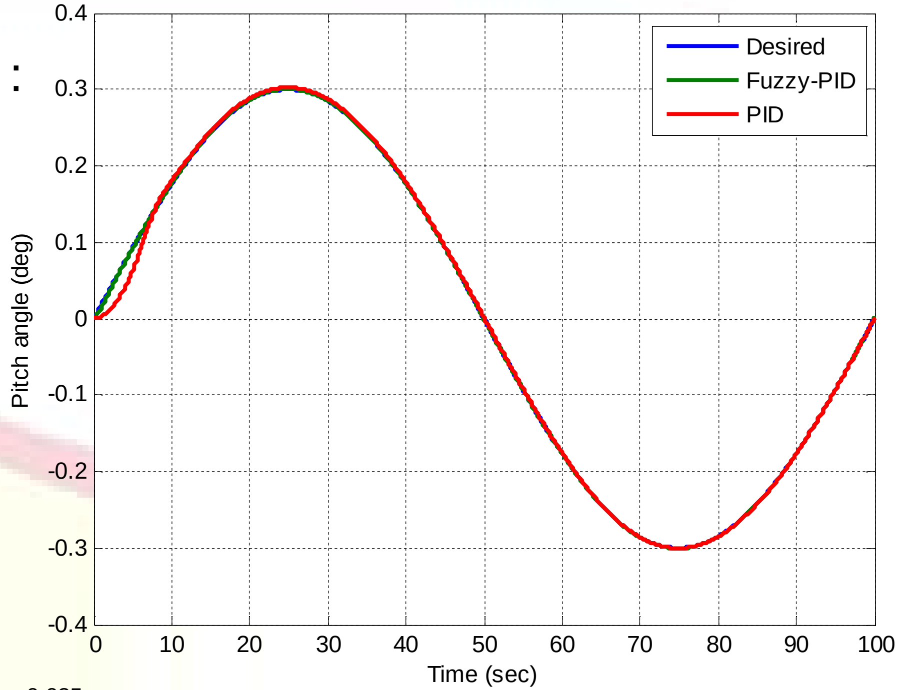


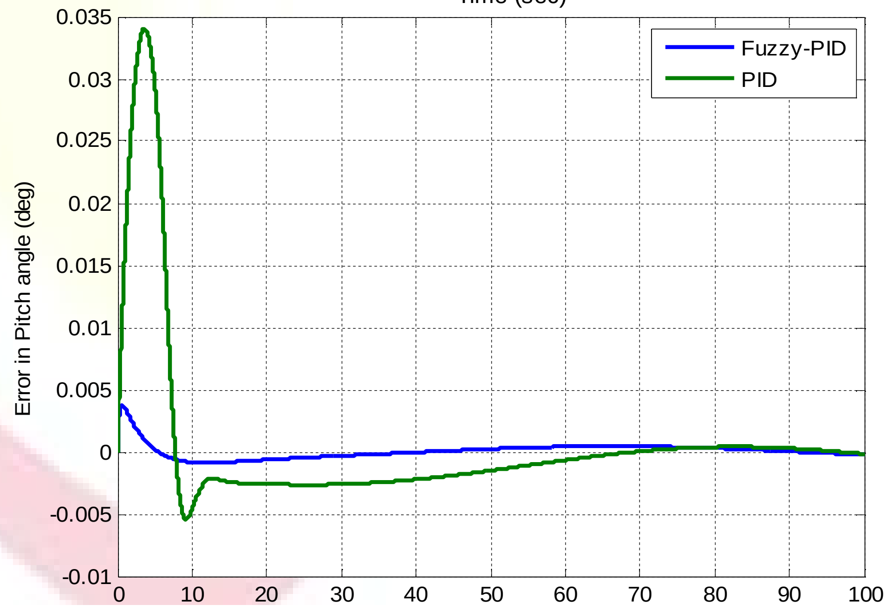
Results for step reference input :



Results for sinusoidal reference input :







Conclusion:

- Fuzzy Gain Scheduled PID is more efficient in terms of settling time, rise time and maximum overshoot

- This type of controllers which is based on soft computing needs heuristic knowledge of the designer

- The performance of controller is based on tuning of controller’s parameters.

Thanks for your attention