Fuzzy Logic Control of Quadrotor

Intelligent Systems

&

Soft Computing

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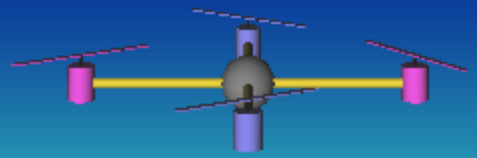
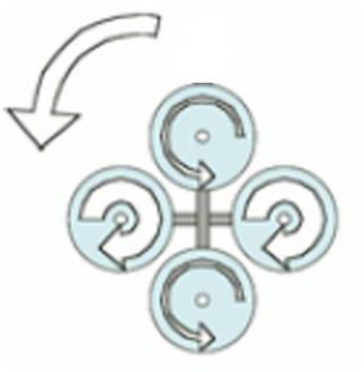
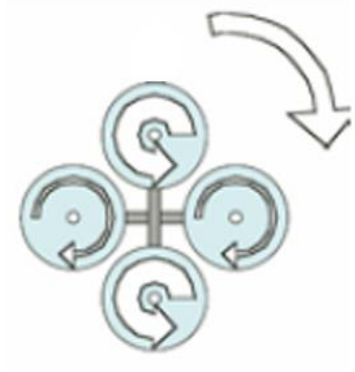


QUADROTOR CONCEPT

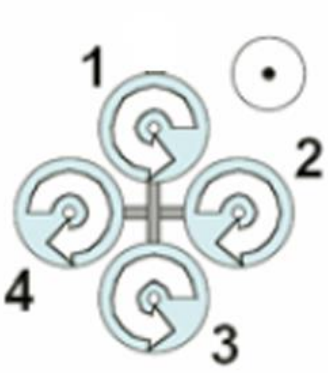
A quadrotor has four motors located at the front, rear, left, and right ends of a cross frame. The quadrotor is controlled by changing the speed of rotation of each motor. The front and rear rotors rotate in a counter-clockwise direction while the left and right rotors rotate in a clockwise direction to balance the torque created by the spinning rotors.



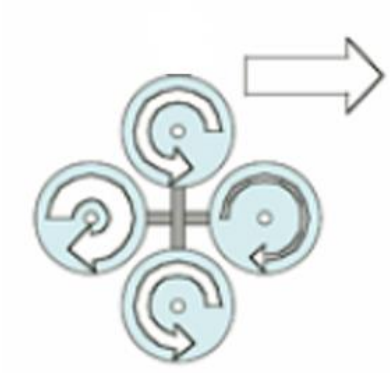
Rotate Left



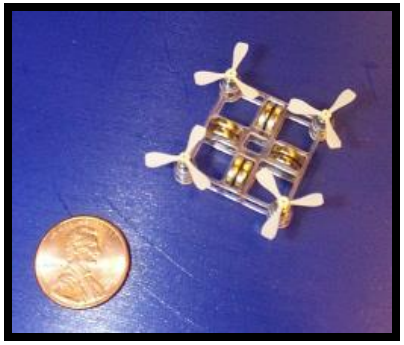
Rotate Right



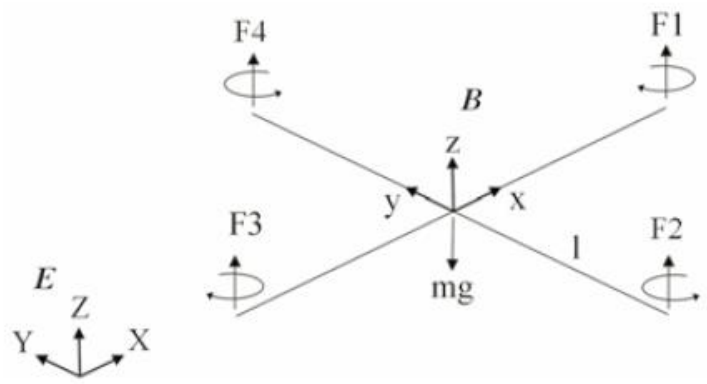
Going Up



Move Right



DYNAMIC MODEL



$$m\ddot{X} = \sum_{i=1}^{n} F_i(\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi)$$

$$m\ddot{Y} = \sum_{i=1}^{n} F_i(\sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi)$$

$$m\ddot{Z} = \sum_{i=1}^{n} F_i(\cos\theta\cos\psi) - mg$$

$$I_{xx}\ddot{\psi} = (F_3 - F_1)l$$

$$I_{yy}\ddot{\theta} = (F_4 - F_2)l$$

$$I_{zz}\ddot{\phi} = C(F_1 - F_2 + F_3 - F_4)$$

$$u_1 = (F_1 + F_2 + F_3 + F_4)/m$$

$$u_2 = (F_4 - F_2)/I_{yy}$$

$$u_3 = (F_3 - F_1)/I_{xx}$$

$$u_4 = C(F_1 - F_2 + F_4 - F_4)/I_{zz}$$

C: Force to Moment Scaling Factor

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

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

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

$$\ddot{\theta} = u_2 l$$

$$\ddot{\psi} = u_3 l$$

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

PROPERTIES OF DYNAMIC MODEL, PHYSICAL VALUES & CONSTRAINTS

- Rotations are not affected by translations.
- Angular subsystem is linear.
- System is underactuated.
- System has coupling effects.
- System is unstable.

$$\ddot{X} = u_1(\cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi)$$
$$\ddot{Y} = u_1(\sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi)$$
$$\ddot{Z} = u_1(\cos\theta\cos\psi) - g$$
$$\ddot{\theta} = u_2 l$$
$$\ddot{\psi} = u_3 l$$
$$\ddot{\phi} = u_4$$

Physical Values:

$$l = 0.21m$$
$$I_{xx} = 0.0142\,kg.m^2$$
$$I_{yy} = 0.0142\,kg.m^2$$
$$I_{zz} = 0.0071\,kg.m^2$$
$$m = 0.56\,kg$$
$$g = 9.81\,m/s^2$$
$$C = 1.3$$

Constraints:

$$F_{\max} = 10N$$

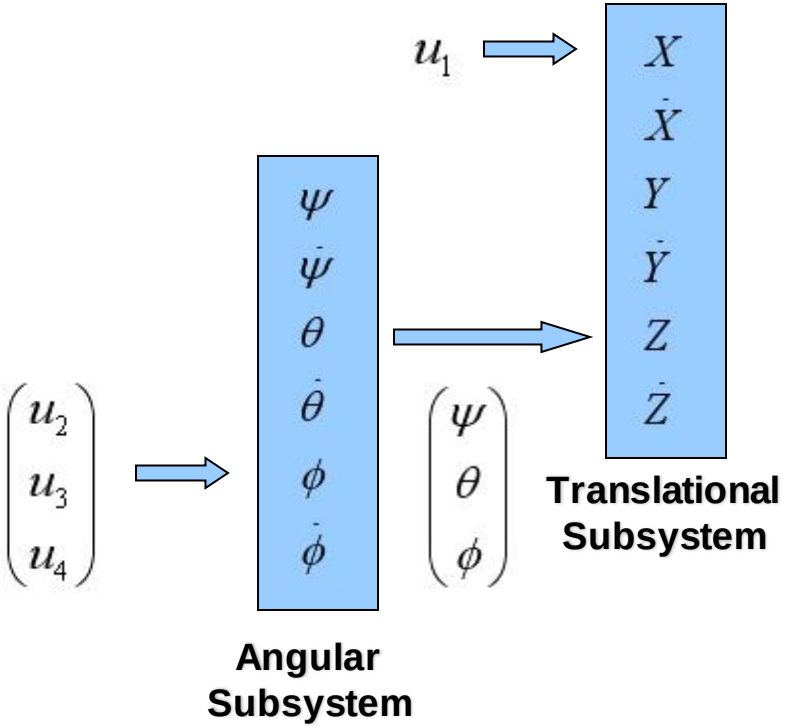
$$0 \le u_1 \le 71.429$$
$$-704.23 \le u_2 \le 704.23$$
$$-704.23 \le u_3 \le 704.23$$
$$-3662 \le u_4 \le 3662$$

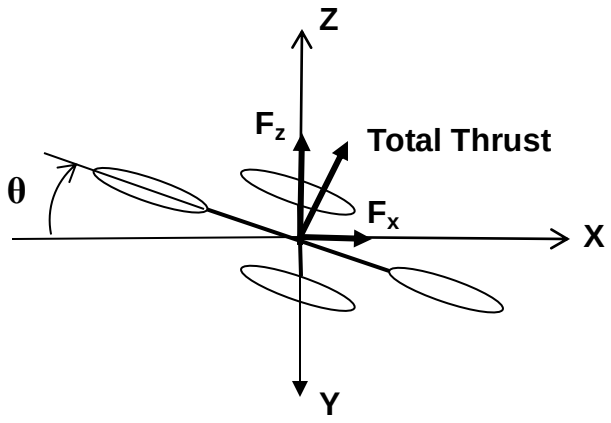
To avoid crash

$$4F_{\max}\cos\theta\cos\psi \ge mg$$

is required. This is restricted with the outputs of the fuzzy logic controllers.

CONTROL STRATEGY

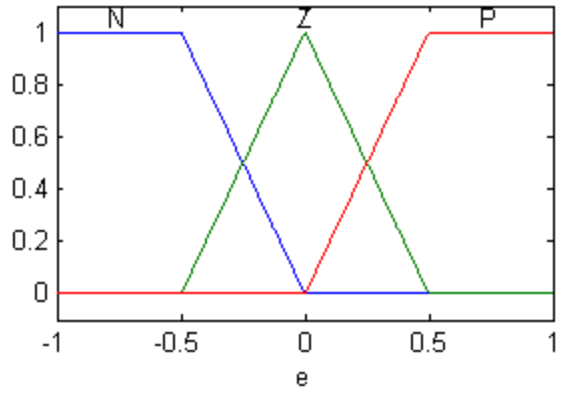




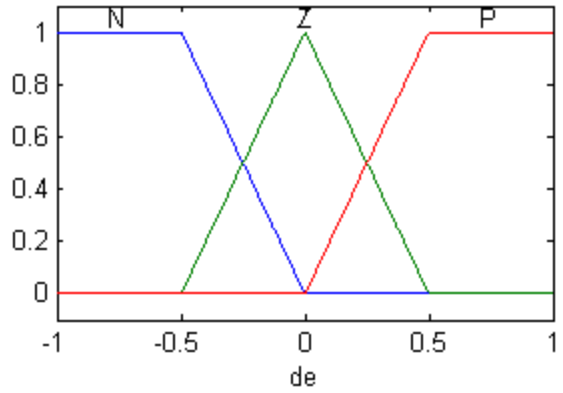
- Angular subsystem will be controlled independent from translational subsystem with 3 fuzzy logic controllers.
- X and Y motion will be controlled through the angles θ and ψ with 2 fuzzy logic controllers.
- Z motion will be controlled with one fuzzy logic controller.

X AND Y CONTROLLER

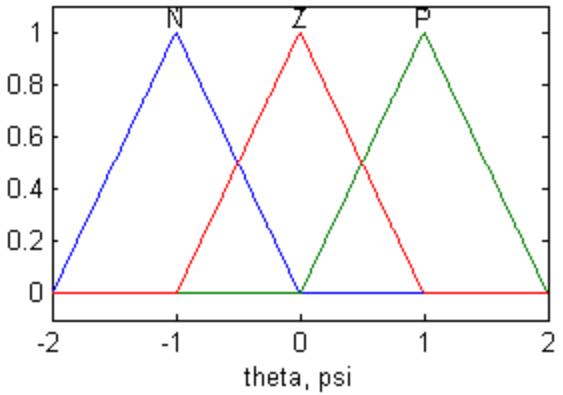
Error



Change of Error



θ , Ψ

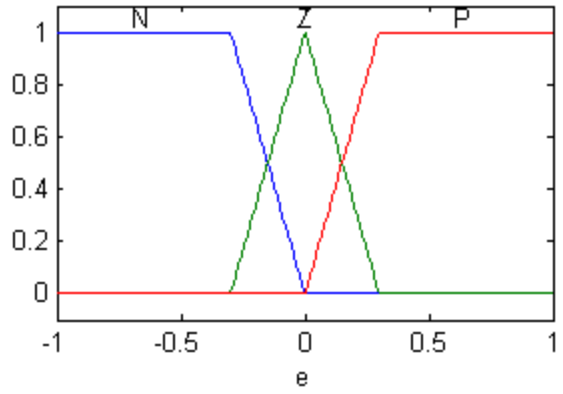


General Properties of FLCs

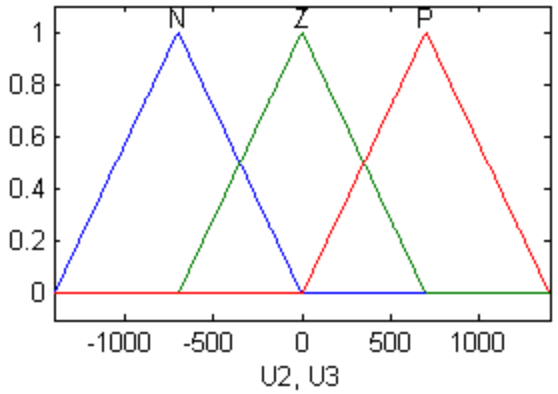
- Mamdani type inference
- Max-min composition
- Center of gravity defuzzification
- Two inputs, one output
- 9 rules
- Triangular MFs

θ AND Ψ CONTROLLER

Error



U2 , U3



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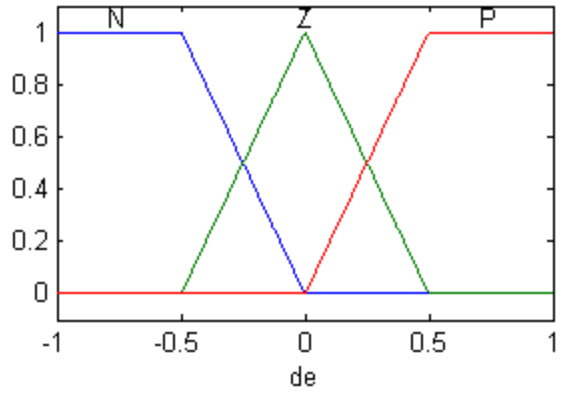
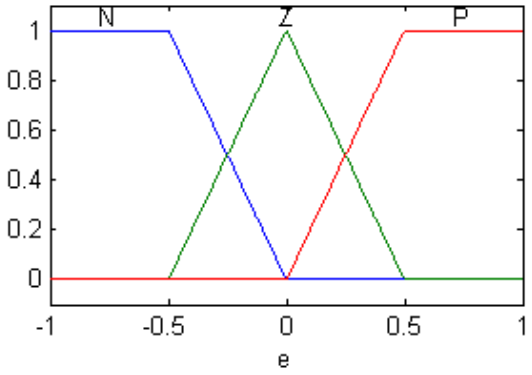


Rule Base

de \ e	**P**	**Z**	**N**
P	P	P	Z
Z	P	Z	N
N	Z	N	N

Φ AND Z CONTROLLER

Error



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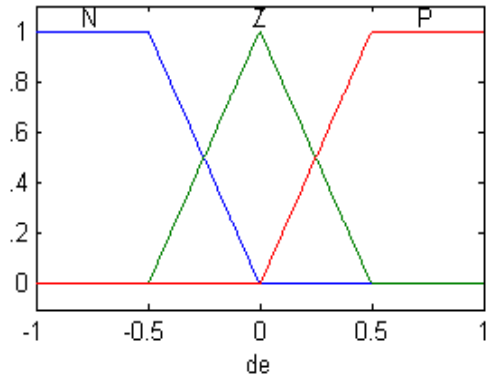
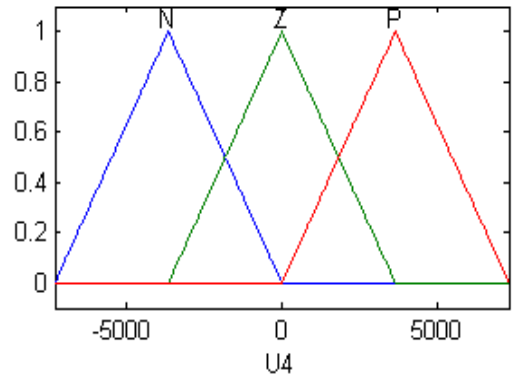


U4



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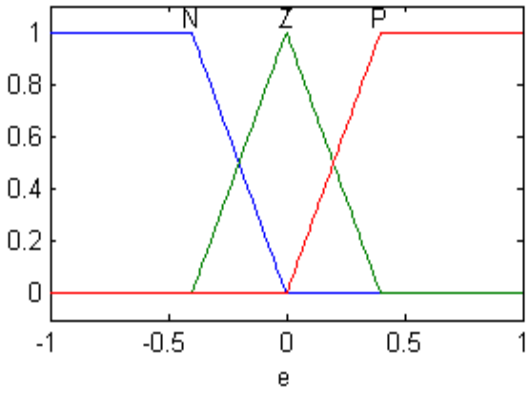

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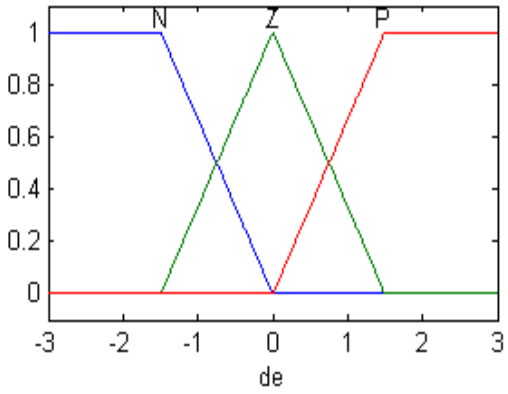
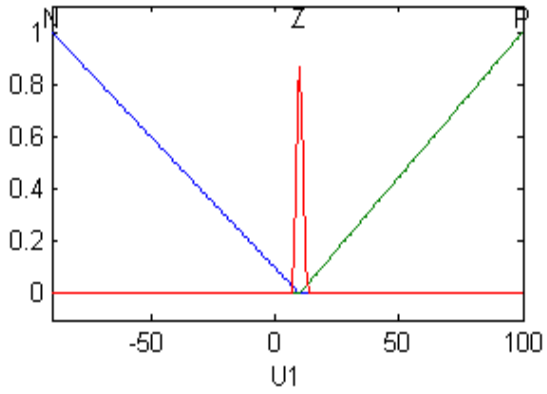
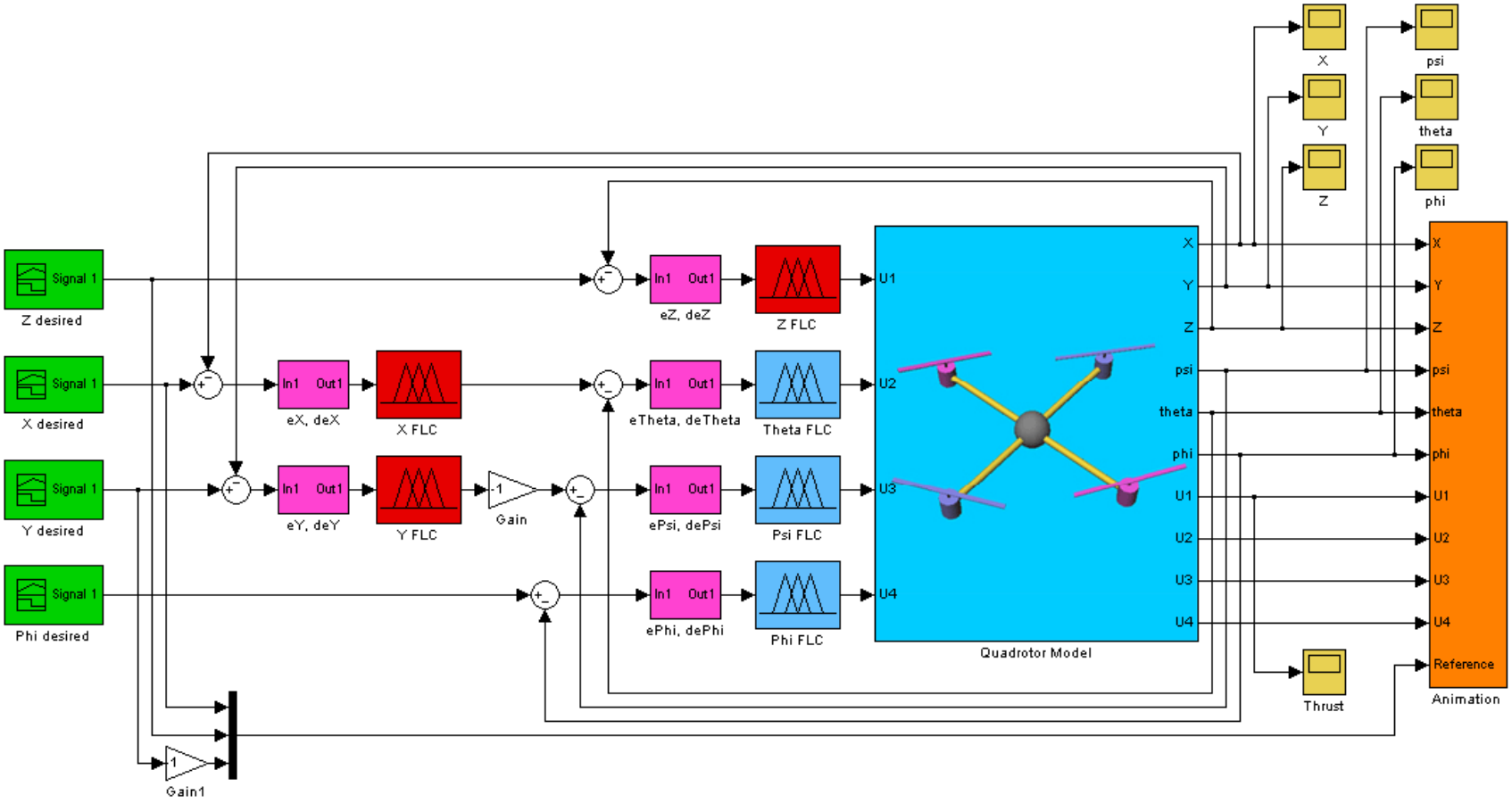
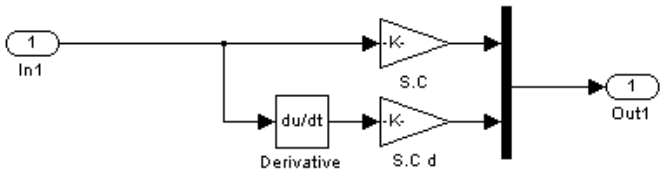


U1

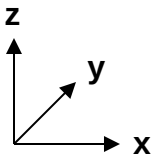


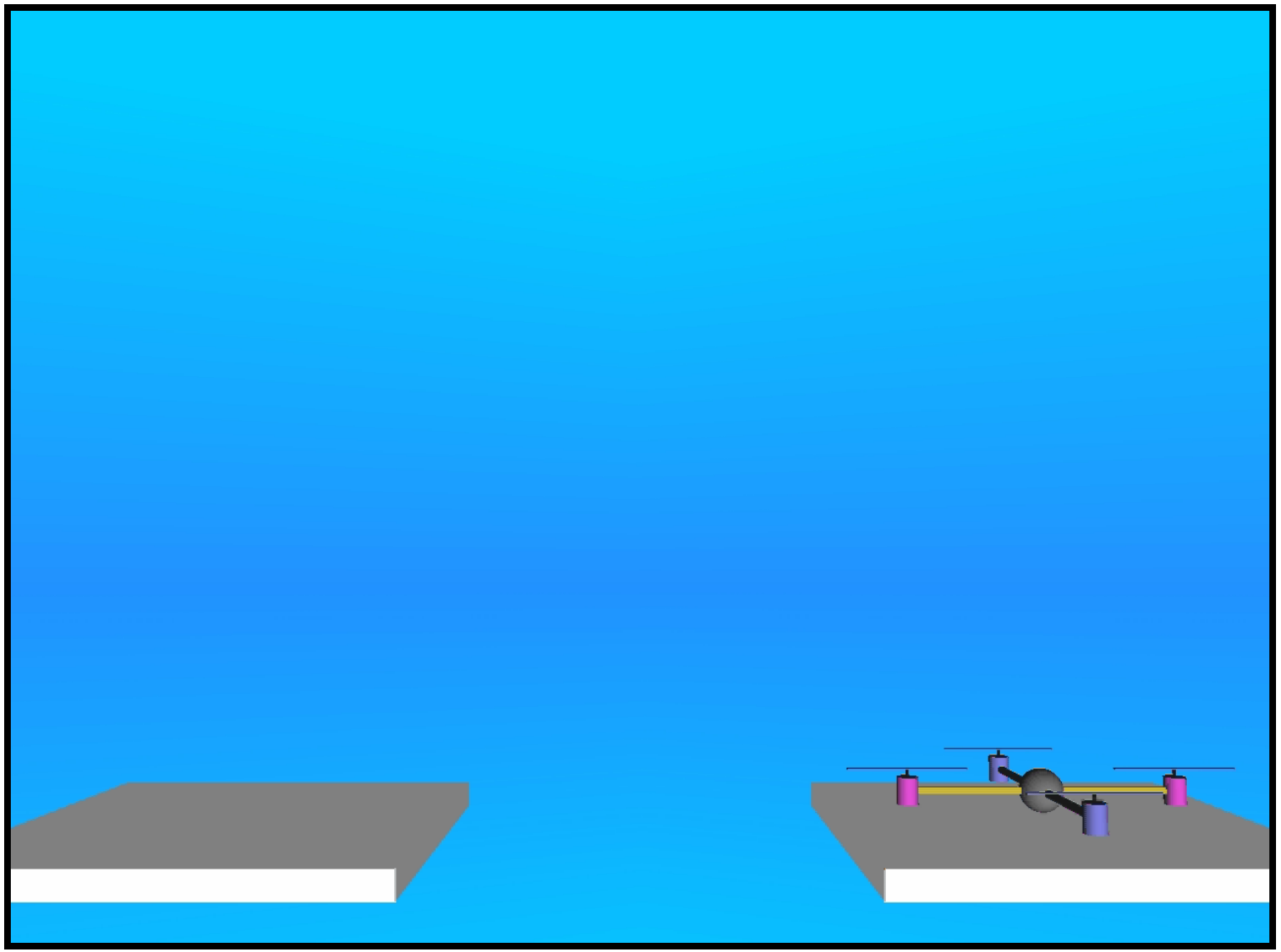
SIMULINK BLOCK DIAGRAM



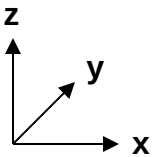


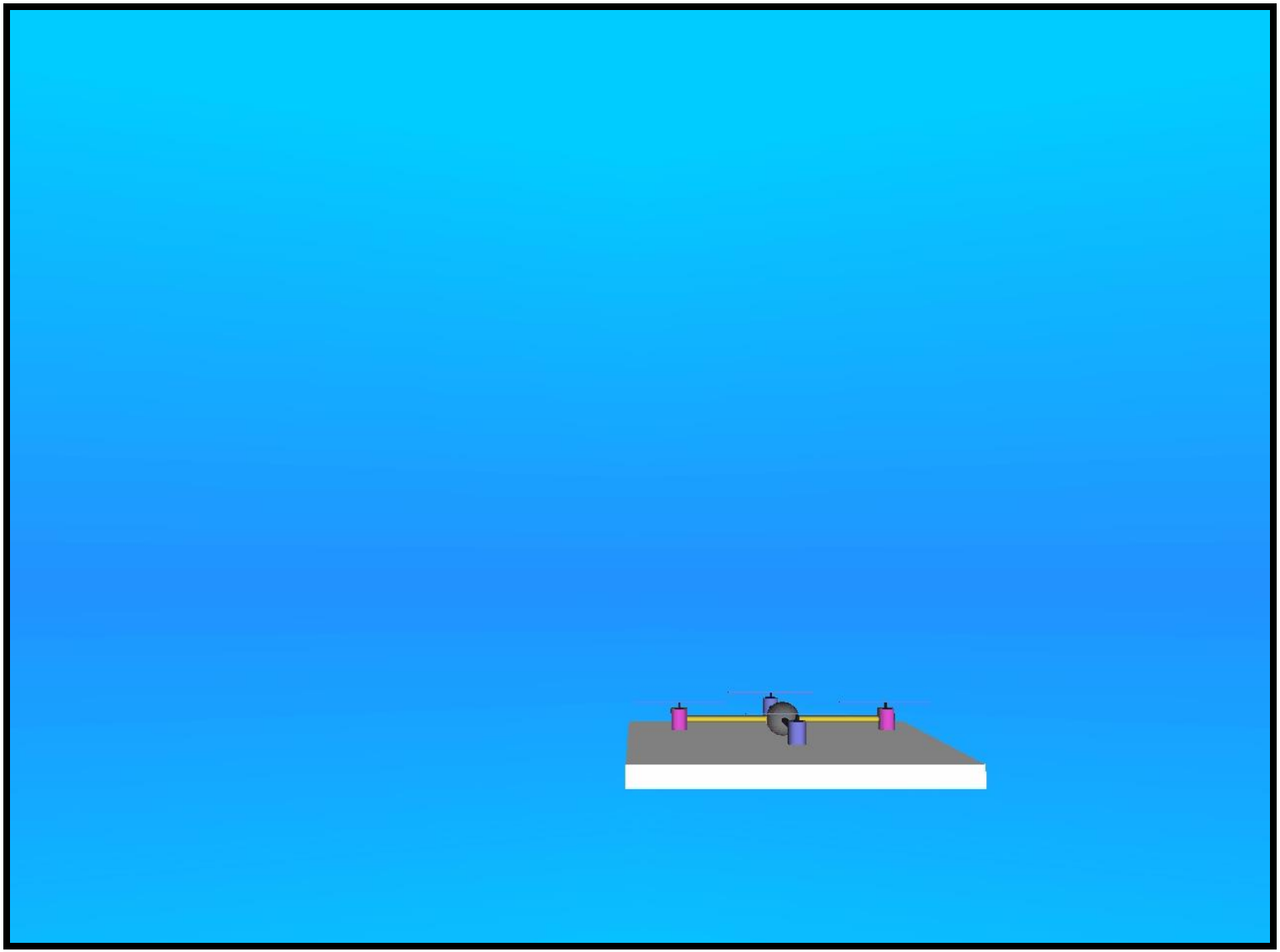
ANIMATION 1





ANIMATION 2





QUESTIONS ???