1. 請簡單描述前饋(Feedforward)與迴饋(Feedback)控制器，對於改善一個控制系統的穩定性與性能響應，能達到怎樣的效果(10%)

2. 簡單敘述何謂反積分器終結(integrator antiwindup)，以及使用反積分器終結有何作用 (10%)

3. A vertical takeoff aircraft is an inherently unstable vehicle and requires an automatic stabilization system. The block diagram of the overall system is shown in the Figure.1. The dynamics of a vehicle is approximately represented by the transfer function:

$$G(s) = \frac{10}{(s^2 + 0.36)}$$

The actuator and filter are represented by the transfer function:

$$G_1(s) = \frac{K(s+7)}{(s+3)}$$

(a) Obtain the Bode plot of the loop transfer function $G_1(s)G(s)H(s)$ when the gain K=2. (8%)
(b) Determine the gain and phase margins of this system (4%)
(c) Determine the steady-state error of a wind disturbance of $T_d(s) = 1/s$. (8%)
(d) Estimate the maximum amplitude of the resonant peak of the closed-loop frequency response (4%)
(e) Estimate the damping ratio of the system (3%)

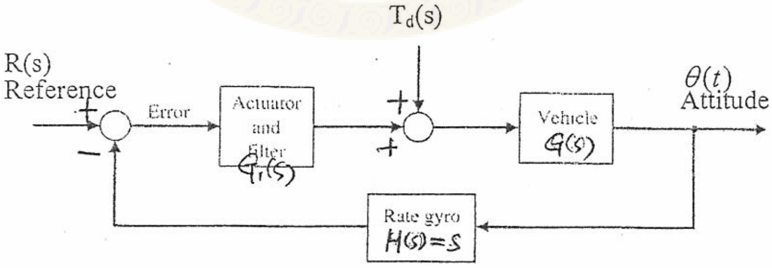

Figure 1. A vertical takeoff aircraft stabilization system

4. Consider the vehicle steering system as shown in Figure 2. The nonlinear equations of motion for the system are given as

$$\frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \\ \theta \end{bmatrix} = \begin{bmatrix} v\cos(\alpha(\delta)+\theta) \\ v\sin(\alpha(\delta)+\theta) \\ \frac{v_0}{b}\tan\delta \end{bmatrix}, \qquad \alpha(\delta) = \arctan(\frac{a\tan\delta}{b})$$

where x_1, x_2, θ are the position and orientation of the center of mass of the vehicle, v_0 is the velocity of the rear wheel, b is the distance between the front and rear wheels and δ is the angle of the front wheel. The function $\alpha(\delta)$ is the angle between the velocity vector and the vehicle's length axis.

Suppose that we are concerned with the lateral deviation of the vehicle from a straight line. For simplicity, we let the equilibrium point $\theta_e = 0$, which corresponds to driving along the X-axis. We can then focus on the equations of motion in the Y-axis and θ directions. If we introduce the state $x=\begin{pmatrix} x_2 \\ \theta \end{pmatrix}$ and $u=\delta$. The system is then in standard from with

$$\dot{x} = f(x,u) = \begin{bmatrix} v\sin(\alpha(u)+x_2) \\ \frac{v_0}{b}\tan u \end{bmatrix}, \text{where } \alpha(u) = \arctan(\frac{a\tan u}{b})$$

$$y = h(x,u) = x_1$$

(a) Please compute the linearized model around the equilibrium point $x=(0,0)^t$. (15%)

(b) Please simplify the linearized model by introducing normalized variables by introducing a new normalized state $z = (x_1/b,\ x_2)^t$ and the new time variable $\tau = v_0t/b$. (8%)

(c) Please discuss the controllability and observability of the linearized model. (5%)

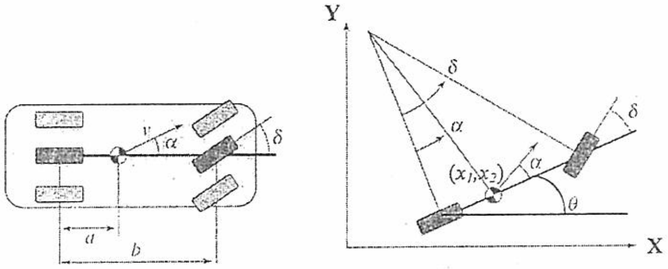

Figure 2 Vehicle steering dynamics

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5. Figure 3 shows a single-link robot driven by a DC servomotor. To amplify the torque τ_m generated by the motor, a gear transmission with gear ratio n (i.e. n= teeth number of Gear 2 / teeth number of Gear 1) is used between the motor shaft and the robot link. Let I_m be the moment of inertia of the motor shaft and Gear 1 combination, and I_L be the moment of inertia of the robot link together with Gear 2. A rotational damper of coefficient b_m is placed at the end of Gear 1 to model the possible viscous friction.

(a) What is the relation between the motor speed ω_m and the link speed ω_L, and determine the equivalent moment of inertia referred to the motor shaft. (5%)

(b) Using τ_m as the control input and the rotation angle (say, θ) of the link as output, obtain the transfer function describing the dynamic relation between the torque τ_m and the output angle θ. (5%)

(c) If $I_m=0.01 Kg\cdot m^2$, $I_L=1 Kg\cdot m^2$, $n=20$, $b_m=0.001\ Kg\cdot m^2/s$, please a PD feedback controller (assuming that the output angle θ can be measured) for the DC-servomotor so that the angular positioning performance of the single-link robot to a unit step can achieve the specifications of rising time ≦ 0.01*sec*, overshoot ≦ 10% and steady state error ≦ 1% (15%)

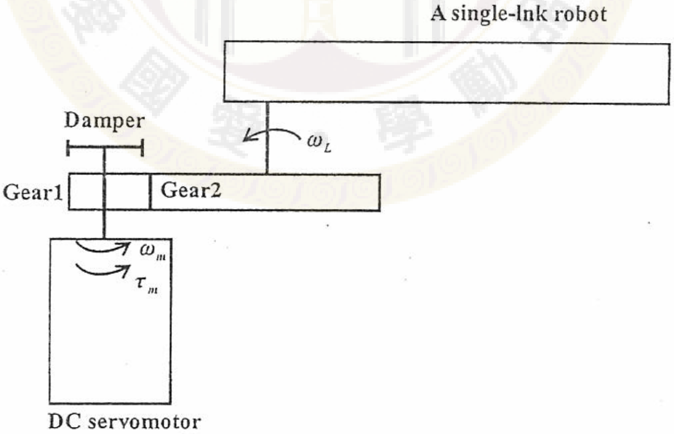

Figure 3 A horizontal single-link robot driven by a DC servomotor