Longitudinal Control for Self-driving Cars

A. Giavaras

Contents

1 Longitudinal control

2 Questions

1. What is the order of the following transfer function?

$$G(s) = \frac{s-10}{s^2+2s+1} \tag{1}$$

   (a) This is the first order transfer function

   (b) This is the second order transfer function

   (c) This is the third order transfer function

   (d) This is the fifth order transfer function

   (e) None of the above

2. What are the poles and zeros of the following transfer function?

$$G(s) = \frac{s^2+3s-10}{s^2-2s-12} \tag{2}$$

   (a) The poles are -3 and 4; the zeros are 2 and -5

   (b) The poles are -4 and 3; the zeros are 5 and -2

   (c) The poles are 2 and -5; the zeros are -3 and 4

   (d) The poles are 5 and -2; the zeros are -4 and 3

   (e) None of the above

3. What might be your action as a system control engineer if you need to increase the overshoot of a control loop system? (Select all that apply)

   (a) Increase K_I

   (b) Decrease K_I

   (c) Decrease K_P

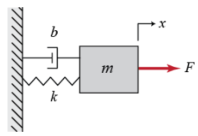
   (d) Increase K_D

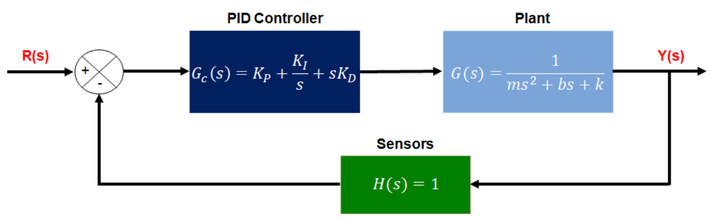
   (e) Increase K_P

   (f) Decrease K_D

4. Consider the Mass-Spring-Damper System shown in the figure below.

   As a system control engineer, you constructed the following closed loop transfer function to represent the Mass-Spring-Damper System. What is the correct transfer function for this closed loop?





(a) Transformation function 1

$$G(s) = \frac{K_D s^2 + sK_P + K_I}{K_P + \frac{K_I}{s} + K_D s} \tag{3}$$

(b) Transformation function 2

$$G(s) = \frac{K_P + \frac{K_I}{s} + K_D s}{K_D s^2 + sK_P + K_I} \tag{4}$$

(c) Transformation function 3

$$G(s) = \frac{ms^2 + bs + k + K_P \frac{K_I}{s} + K_D s}{K_P + \frac{K_I}{s} + K_D s} \tag{5}$$

(d) Transformation function 4

$$G(s) = \frac{K_D s^2 + sK_P + K_I}{ms^3 + (b + K_D)s^2 + (k + K_P)s + K_I} \tag{6}$$

(e) None of the above

5. You are given the step response of a few different PID controllers using the same gains for the same first order transfer function. Determine a possible set of controllers that generated these step responses:

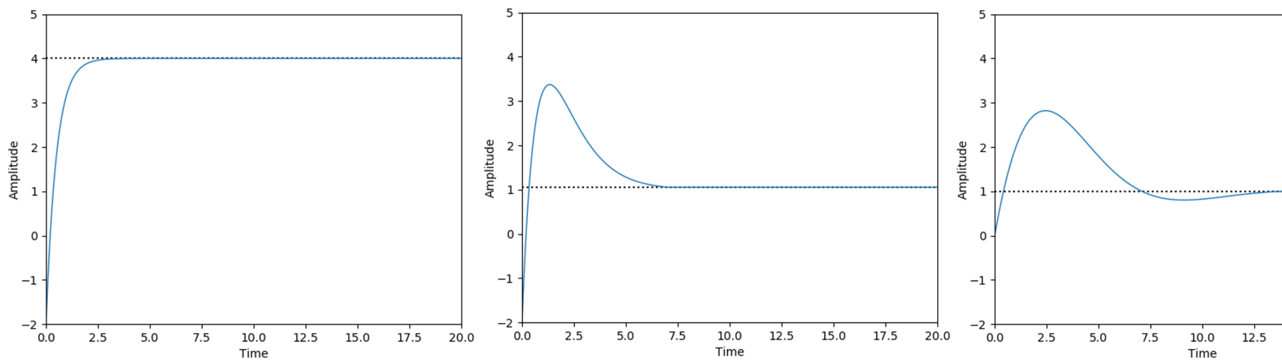
   (a) 1st response by PI; 2nd response by PD; 3rd response by PID

   (b) 1st response by PD; 2nd response by PI; 3rd response by PID

   (c) 1st response by PI; 2nd response by PID; 3rd response by PD

   (d) 1st response by PD; 2nd response by PID; 3rd response by PI

   (e) None of the above



6. What is the output of a typical output of a Longitudinal control module? (Select all that apply)

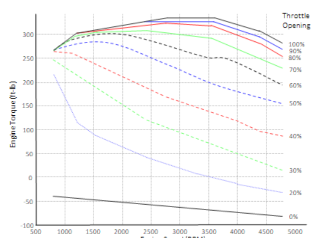
    (a) Reference velocity

    (b) Throttle angle

    (c) Steering angle

    (d) Brake position

7. Based on the engine map in the figure below, determine the throttle angle needed to produce 250 ft-lb of torque given that the current engine speed is 3500 RPM.

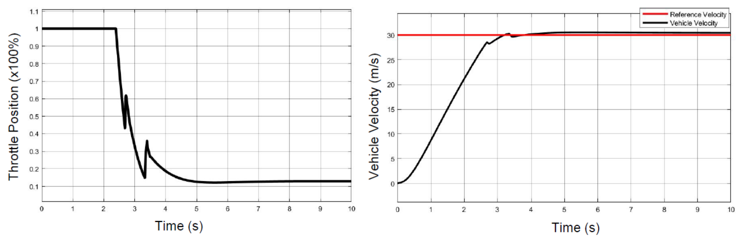


8. The results of a simulation of the control response to a step change in desired speed of a dynamic vehicle model with a PID controller are shown in the figures below. There are two spikes on these figures: one spike is between 2 and 3 seconds, another spike is between 3 and 4 seconds. What is the reason of these spikes?

    (a) Engine-transmission torque loss

    (b) Tire slip

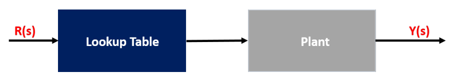
    (c) Nonlinear engine map



(d) High level controller simplification: changing the integral to a summation over fixed length time steps in the Integral term

(e) None of the above

9. What type of control system is shown in the figure below?



(a) Feedback control

(b) Feedforward control

(c) Feedback-feedforward control

(d) None of the above

10. What types of inaccuracies are corrected by a feedback controller?

(a) Disturbances

(b) Nonlinear engine map

(c) Errors in the plant model

(d) High level controller simplification: changing the integral to a summation over fixed length time steps in the Integral term

11. What assumptions are essential for creation of a longitudinal feedforward input? (Select all that apply)

(a) The tire slip angle and ratio are negligible

(b) The vehicle is at steady state

(c) The plant system is linear

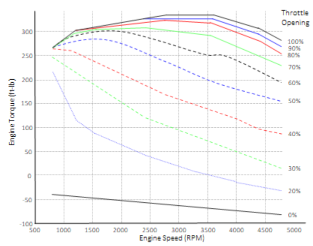
(d) Torque from the engine passes directly to the transmission without loss

12. What are the sources of the load torque considered for a longitudinal feedforward look-up table computation? (Select all that apply)

(a) Rolling resistance

   (b) Sliding resistance
   (c) Gravitational resistance
   (d) Cornering force
   (e) Aerodynamic resistance
   (f) Static friction

13. A vehicle is being operated on a highway with the reference velocity of $126 km/h$ (35 m/s) in gear 4 and it overcomes the total load torque of 300 ft-lb. This vehicle specification includes effective wheel radius of 0.35 m and 4th gear ratio of 2. What throttle angle is required for maintaining the the current speed of the vehicle? Use the below engine map for your computation.



References

[1] SAE *Taxonomy of Driving* $https://www.sae.org/standards/content/j3016\_201806/?PC = DL2BUY$

[2] SAE *SAE J3016 Taxonomy and Definitions Document* $https://drive.google.com/open?id = 1xtOqFVJvOElXjXqf4RAwXZkI\_EwbxFMg$

[3] Åström K. J., Murray R. M. *Feedback Systems. An Introduction for Scientists and Engineers*

[4] Philip , Florent Altche1, Brigitte dAndrea-Novel, and Arnaud de La Fortelle *The Kinematic Bicycle Model: a Consistent Model for Planning Feasible Trajectories for Autonomous Vehicles?* HAL Id: hal-01520869, https://hal-polytechnique.archives-ouvertes.fr/hal-01520869

[5] Marcos R. O., A. Maximo *Model Predictive Controller for Trajectory Tracking by Differential Drive Robot with Actuation constraints*