DRIVER MODEL

SRIDHAR (ME12B16M000010)
GOKUL (ME12B10176)
RAJESH (ME12B1005)
RAMAN (ME12B1030)

SOLID EDGE 3D MODEL

INTRODUCTION

- Human driver is the primary control element.
- Lateral and longitudinal control tasks such as path-following, obstacle avoidance and headway control are the inputs and steering and braking activities performed by the human driver are outputs.
- The ‘man-machine’ system cannot be separated into the purely ‘mechanical’ and purely ‘human’ components. The system must be treated as a whole.

Driver performance is characterized by the delay time, which consists of

- ***Reaction time*** – time required to assess the information
- ***Neuromuscular delay*** – time required for muscles to respond
- ***Actuation delay*** – time for actually performing the control action

Characteristics of the human driver

Physical limitations and certain attributes should be incorporated in modeling the control behavior of the human driver.

- **Physical Limitations**
  - **Human Time Delay and Threshold Limitations:** Humans are not ''linear'' elements, Sensed information (visual stimuli, motion cues, etc.) must also exceed certain thresholds prior to being detected. Other limitations are

- Required processing times for sensed information.
- Information transmission time.
- Cognitive requirements to anticipate or predict ahead.
- Perceptions of higher derivative (or rate) information.

  - **Visual Characteristics:** velocity and position information can be extracted separately from a scene by the human vision system, the two modes work together yet independently of one another**.** Perception of velocity impose costs of increased time delays in the range of 30 – 200

Characteristics of the human driver

- **Motion Influences:**

Much of the higher derivative information used by humans for control purposes is obtained from the vestibular (inner ear) and kinesthetic (body distributed) channels. Motion effects help to reduce uncertainties in observed responses and enhance prediction.

- **Auditory Information:**

Auditory information is seen as helpful for improving system performance. Auditory information, though, is most useful under high workload conditions as redundant information supplementing the visual channel.

- **Tactile and Haptic Information:**

Tactile and haptic information is conveyed to the driver through the steering wheel and throttle/accelerator pedals. Certain portion of information is also available through such channels by sensing small skin surface vibrations or circulating wind

Characteristics of the human driver

- **Ranking of Sensory Cue Influences for Human Drivers:** Top to bottom ranking of the primary sensory channels are **Vision, Vestibular and Kinesthetic, Tactile and Auditory**.
- **The ranking of specific cues associated with these sensory channels**
  - translational/rotary position and velocity information from the visual channel followed by,
  - translational/rotary velocity and acceleration information sensed by the vestibular
  - linear acceleration, force/torque information from the kinesthetic body senses
  - acceleration information derived from visual velocity differencing mechanisms followed by,
  - small amplitude vibratory information sensed by tactile senses
  - auditory information regarding velocity, movement, and accelerations

As the complexity of the controlled system increases, the difficulty increases for the human controller.

Characteristics of the human driver

- **Physical Attributes**

  - **Preview Utilization:**

The use of preview allows the human driver to not only provide anticipatory control responses but also conduct certain planning activities in response to developing situations.

  - **Adaptive Control Behavior:**

The ability to adapt not only different controlled vehicle dynamic plants but also altered operating conditions .

  - **Internal Vehicle Model Concept:**

This allows the driver to compare the time advanced expectation of the vehicle state at some future time with the directly observed previewed input requirement. This of course depends upon the driver having some basic understanding of the controlled vehicle dynamics in order to perform the projection.

DRIVER MODEL

- A driver model is a mathematical model which replicates the functionality of a driver like controlling , monitoring and stabilizing a vehicle.

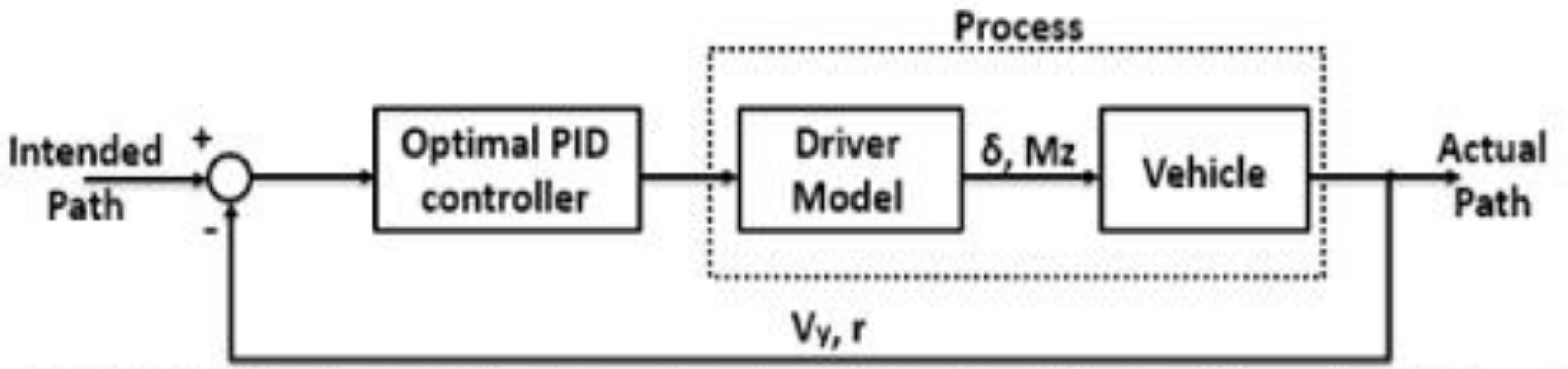


Fig.2 Path following controller structure for closed loop driver/vehicle system

Simple linearized driver model with and without delay using PID controller.

DRIVER MODEL

PID controller is the most common form of feedback

$$u(t) = \boldsymbol{K} \left(\boldsymbol{e(t)} + 1/\, T_i \int_0^t e(\tau)d\tau + T_d\, de(t)/\, dt \right)$$

‘u’ is the control signal and ‘e’ is the control error. The control signal is thus a sum of three terms the P-term (which is proportional to the error), the I-term (which is proportional to the integral of the error), and the D-term (which is proportional to the derivative of the error).

The controller parameters are proportional gain K, integral time T_i, and derivative time T_d.

DRIVER MODEL

Considering **reaction time** τ, ***neuromuscular delay*** T_D *and* ***prediction time*** T_L

Transfer function – y(s)/ u(s) – Output/ Input = $K_g (1+ T_L s)/(1+ T_D s)\, e^{-\tau s}$

Neglecting the prediction delay, neuromuscular delay - $y(s)/ u(s) = K_g e^{-\tau s}$

$$K_g e^{-\tau s} = K_g * 1/(1 + \tau s + 0.5\, \tau^2 s^2)$$

$$= K_g * 1/(1 + \tau s)$$

$$\tau s\, y(s) + y(s) = K_g\, u(s)$$

Taking inverse Laplace we get,

$$\tau\, y'(t) + y(t) = K_g\, u(t)$$

DRIVER MODEL

Considering the error in yaw angle *: u(t)* = - $[\varphi - \varphi_o]$

Hence driver model becomes

$$\tau\, y'(t) + y(t) = -\, K_g\, [\varphi - \varphi_o]$$

For constant speed handling model, *y(t)* is proportional to $\delta(t)$ *,therefore the driver model can be written as*

$$\tau\, \delta'(t) + \delta(t) = -\, K_g\, [\varphi - \varphi_o] = \delta(t + \tau)$$

LINEARIZED DRIVER MODEL WITHOUT DELAY

Vehicle model under neutral steering conditions, i.e., the equation governing the handling condition

$$J_z r' = N_r r + N_\delta \delta + M_{ze}$$

where $r = \varphi'$

$$J_z \varphi'' - N_r \varphi' + N_\varphi K_g \varphi(\mathrm{t}) = N_\delta K_g \varphi_o(\mathrm{t}) + M_{ze}$$

To have a stable solution, $N_r < 0$ & $N_\delta K_g > 0$

$$N_r > 2\,(J_z K_g N_\delta)^{1/2}$$

$$K_g < N_r^2 / (4\, J_z\, N_\delta)$$

LINEARIZED DRIVER MODEL WITH DELAY

If the delay is non-zero, stability criteria can be found by computing the eigen values of dynamic matrix, A

$$\begin{Bmatrix} r' \\ \delta' \\ \varphi' \end{Bmatrix} = A \begin{Bmatrix} r \\ \delta \\ \varphi \end{Bmatrix} + B_c \varphi_o + B_d M_{ze}$$

where A $= \begin{bmatrix} Nr/J_z & N_\delta/J_z & 0 \\ 0 & -1/\tau & -Kg/\tau \\ 1 & 0 & 0 \end{bmatrix}$

$$B_d = \begin{Bmatrix} 1/J_z \\ 0 \\ 0 \end{Bmatrix}$$

$$B_c = \begin{Bmatrix} 0 \\ K_g/\tau \\ 0 \end{Bmatrix}$$

LINEARIZED DRIVER MODEL WITH DELAY

$$s^3 \;+\; (1/\tau - N_r/J_z)\, s^2 \;+\; (-N_r/\tau J_z)\, s \;+\; N_\delta K_g/\tau J_z = 0$$

Based on Hurwitz criteria for (a.s³ + b.s² + c.s + d) = 0, we have the coefficients are greater than zero & (b.c – a.d) > 0

$$(1/\tau - N_r/J_z)\,.\,(-N_r/\tau J_z) - N_\delta K_g/\tau J_z > 0$$

which gives

$$\tau\,(1 - N_\delta K_g J_z/N_r^2) > J_z/N_r$$

for this condition to be true,

$$K_g < N_r^2/J_z N_\delta$$

else,

$$|\,\tau\,(1 - N_\delta K_g J_z/N_r^2)\,| < |\,J_z/N_r\,|$$

since J_z/N_r is a negative quantity.

LINEARIZED DRIVER MODEL WITH DELAY

$$\tau < J_z N_r / (N_r^2 - J_z N_\delta K_g)$$

To define the terms in terms of speed, we assume $v.\ N_r$ = parameter

Reduced delay $\tau' = \tau.\ v.\ N_r / J_z$

Reduced gain $K_g' = K_{g.}\ J_{z.}\ N_\delta / (v.\ N_r)^2$

we get

$$K_g' < (\tau' + v) / \tau' v^2$$

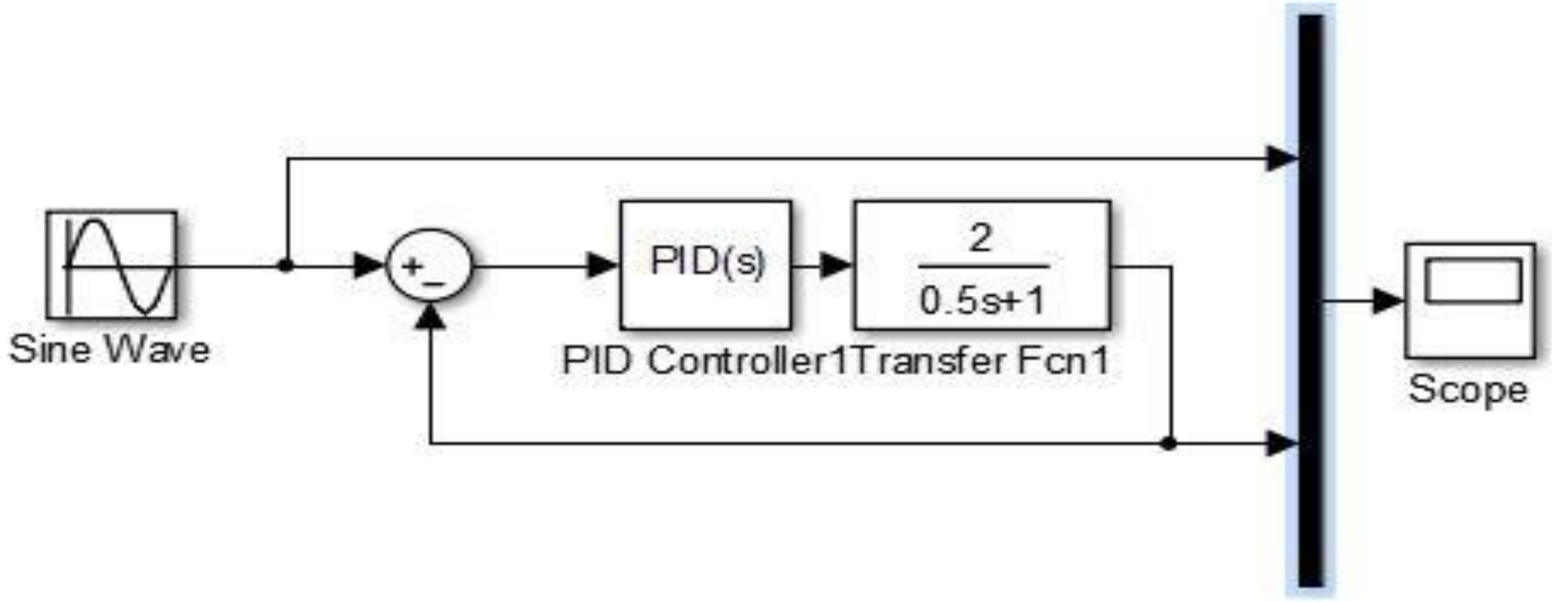
$$\tau' < v / (K_g' v^2 - 1)$$

Therefore at high speeds, the driver should react quickly because of lesser *time delay* τ'

SIMULINK RESULTS

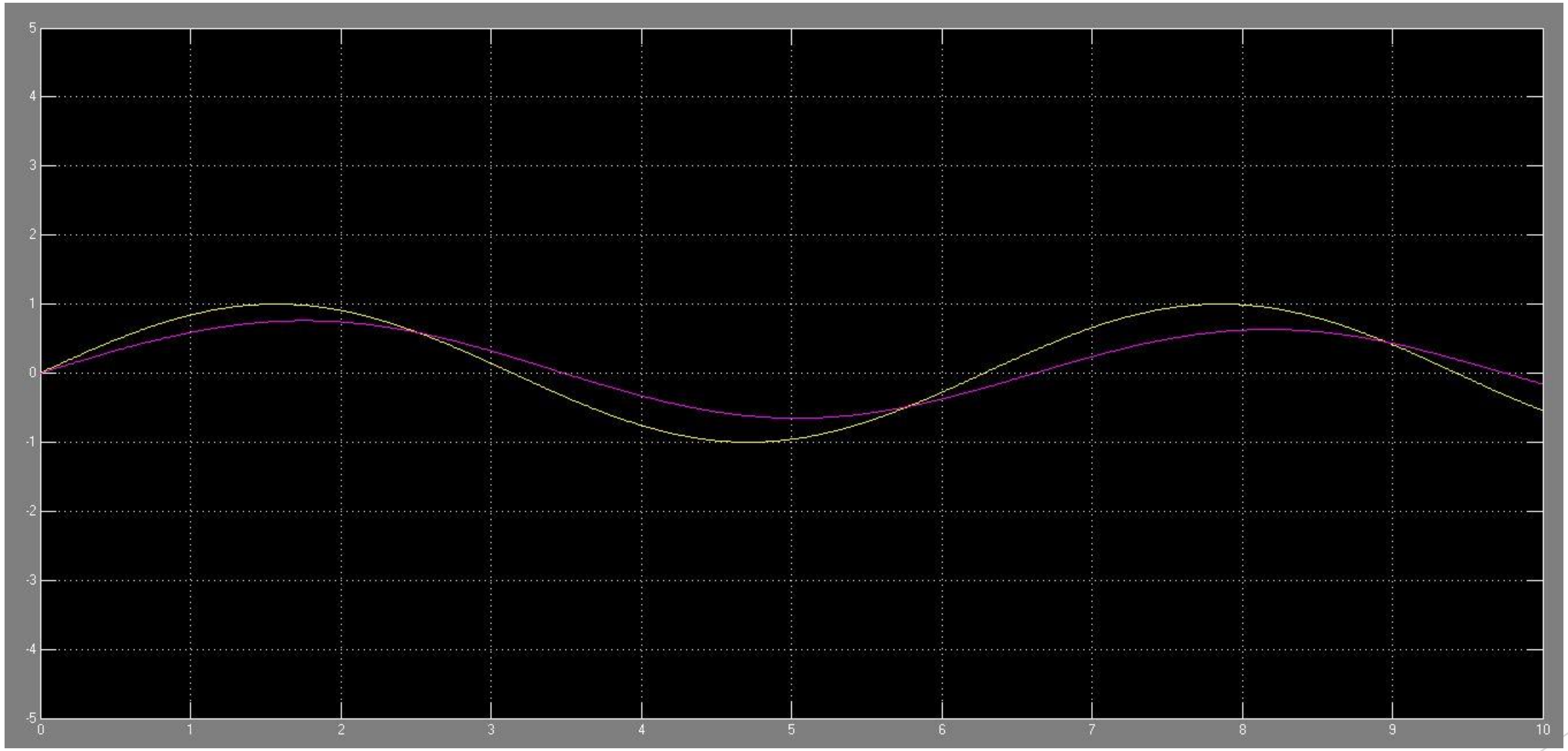
Neglecting neuromuscular delay (T_D) and prediction time (T_L)

Gain (K_g) = 2
Reaction time (τ) = 0.5
Transfer function = $K_g * 1/(1 + \tau s)$



Desired vs actual path

Simulink result for desired and actual path by Neglecting neuromuscular delay (T_D) and prediction time (T_L)



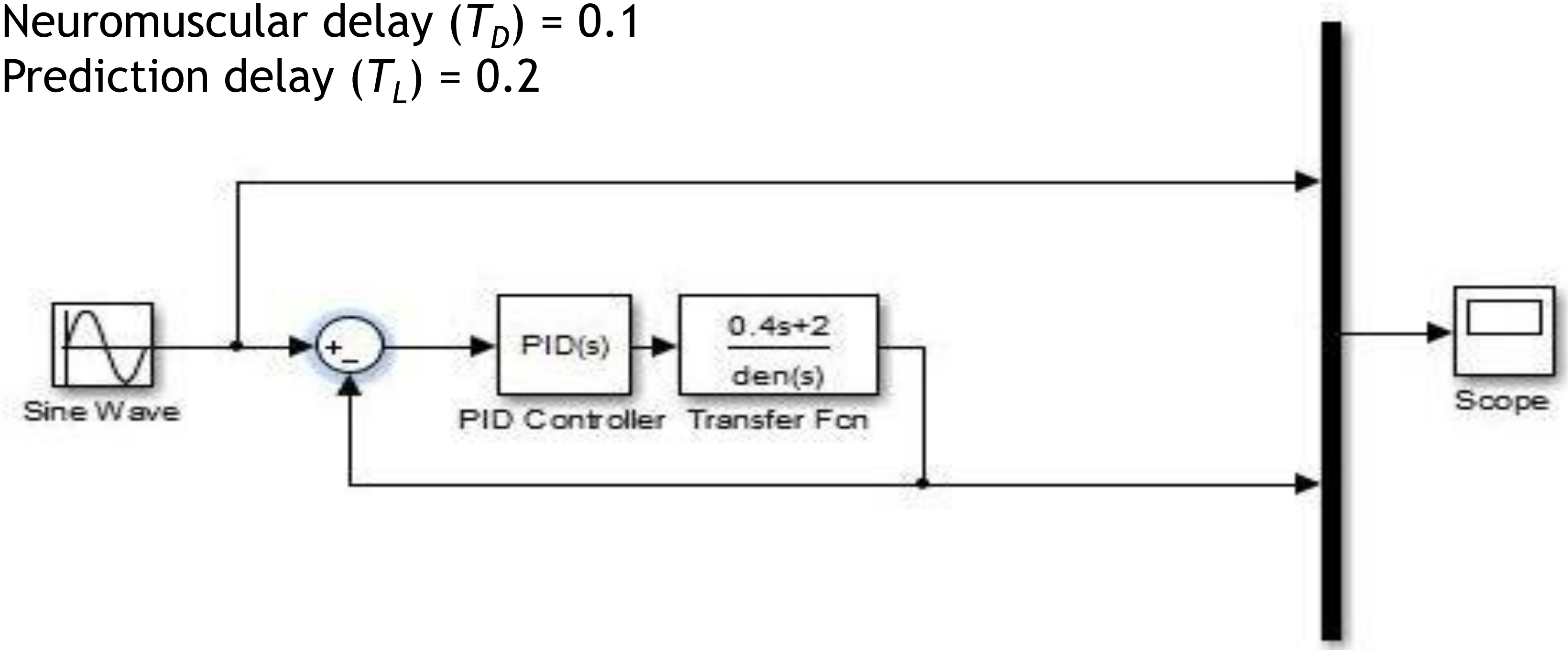
Yellow line is the desired path and violet line is the actual path

SIMULINK RESULTS

Considering neuromuscular delay (T_D) and prediction time (T_L)

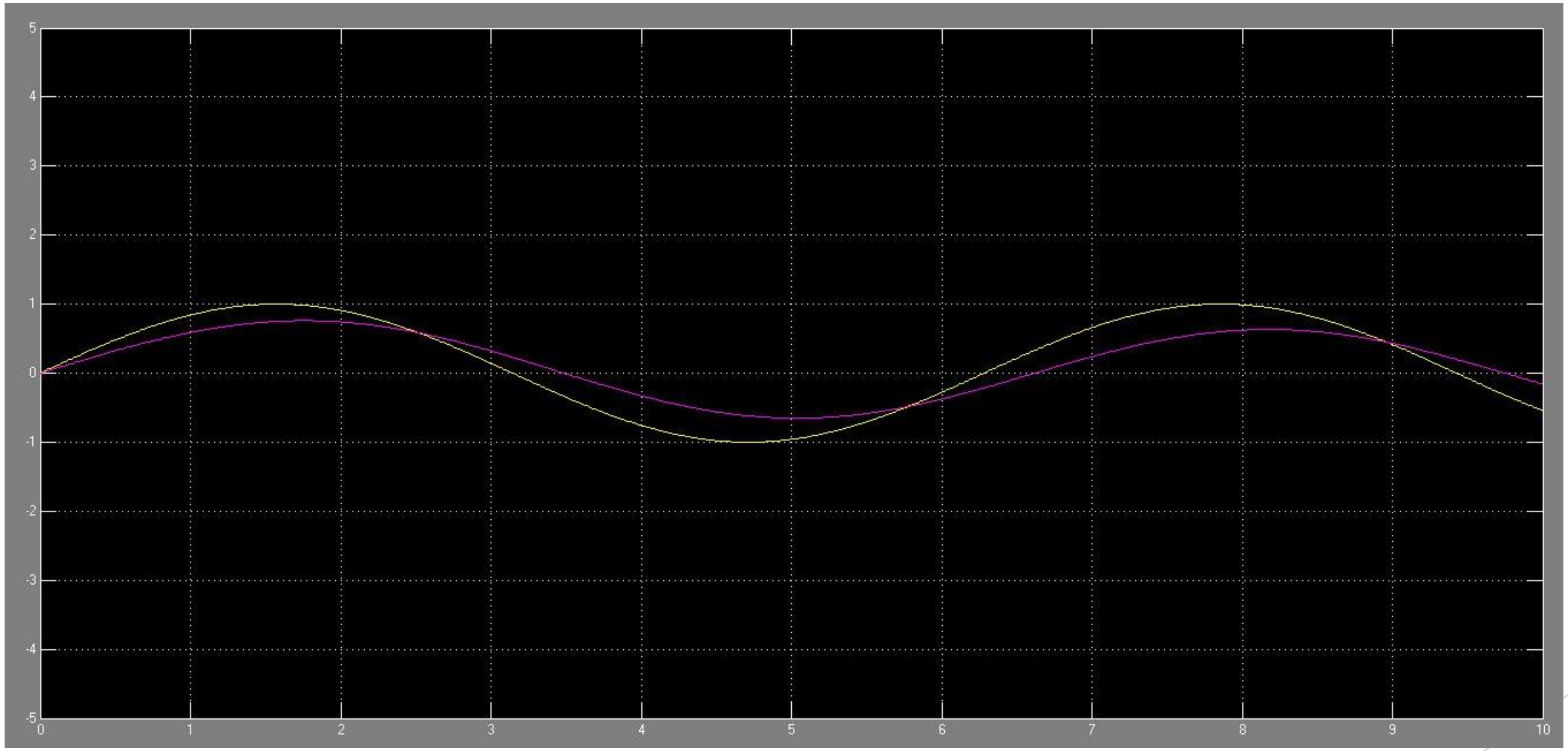
Gain (K_g) = 2
Reaction time (τ) = 0.5
Transfer function = $K_g\,(1+ T_L s)/(1+ T_D\, s)\; e^{-\tau s}$

Neuromuscular delay (T_D) = 0.1
Prediction delay (T_L) = 0.2



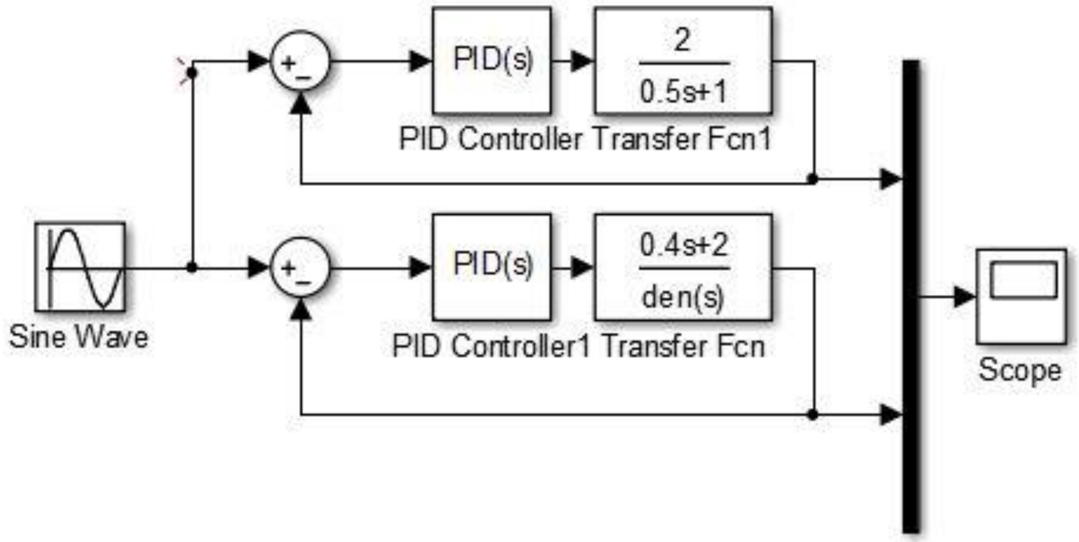
SIMULINK RESULTS

Simulink result for desired and actual by Considering neuromuscular delay (T_D) and prediction time (T_L)



Comparison of Transfer functions

- Comparing the outputs by considering and neglecting neuromuscular delay and prediction time



Gain $(K_g) = 2$

Reaction time $(\tau) = 0.5$

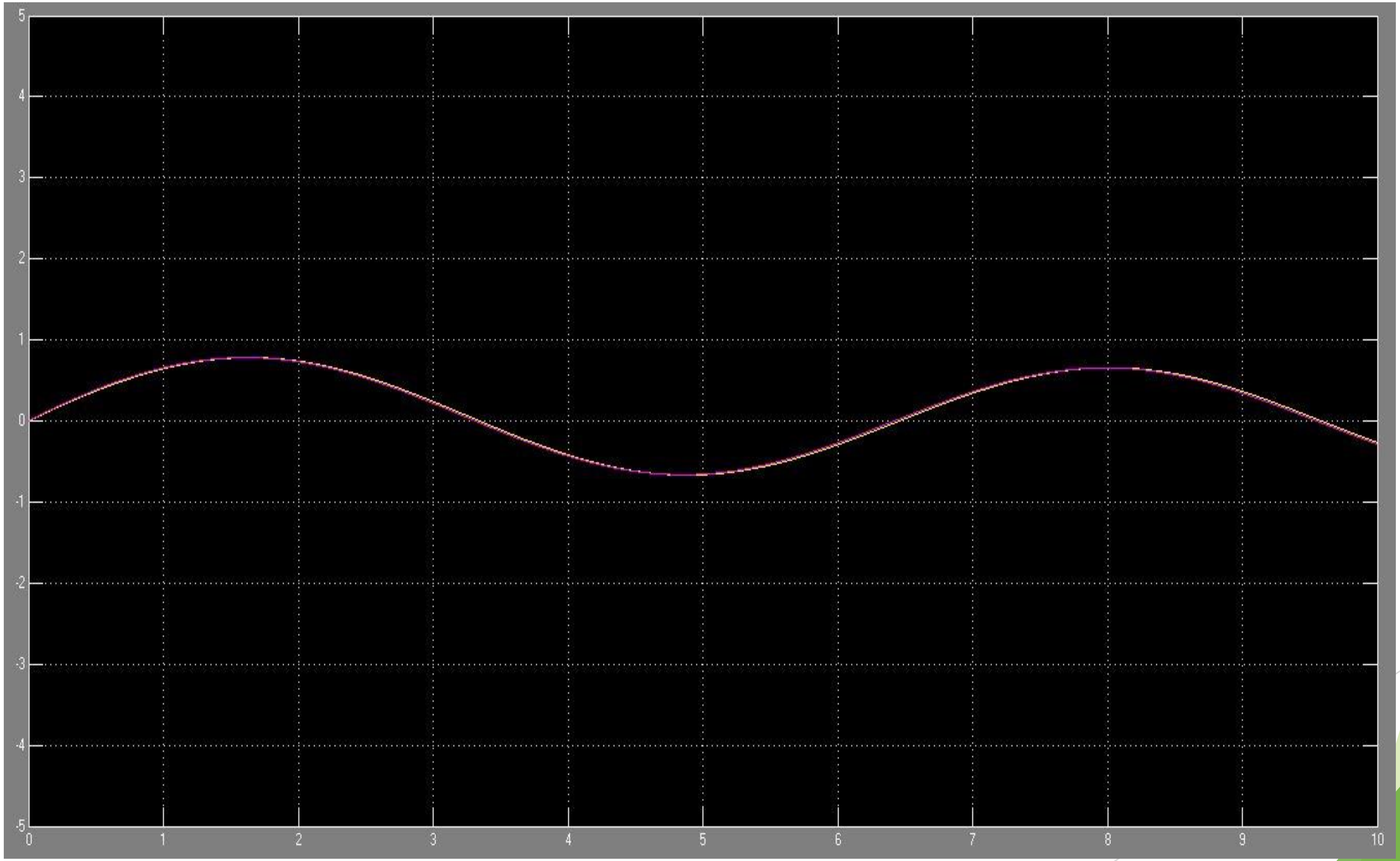
Transfer function1 $= K_g * 1/(1 + \tau s)$

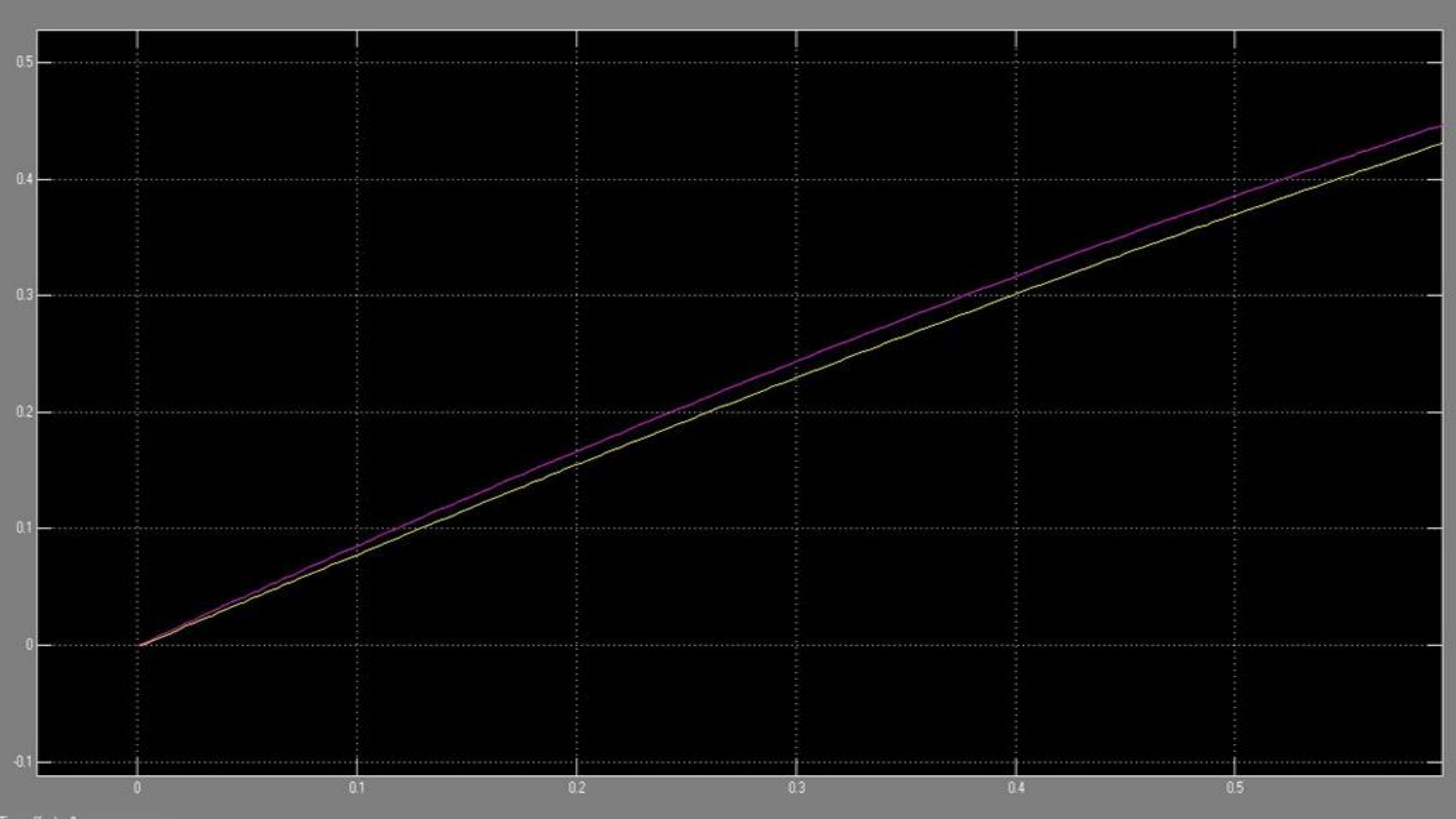
Transfer function $= K_g (1+ T_L s)/(1+ T_D s)\, e^{-\tau s}$

neuromuscular delay $(T_D) = 0.1$

prediction delay $(T_L) = 0.2$

Comparison of Transfer functions




0.5
0.4
0.3
0.2
0.1
0
-0.1
0
0.1
0.2
0.3
0.4
0.5

conclusion

- Observed slight difference in plot between output for considering and neglecting neuromuscular delay and prediction time.
-

reference

- Understanding and Modeling the Human Driver
  CHARLES C. MACADAM
- Driver steering control and a new perspective
  on car handling qualities.

  R S Sharp
- Sheridan, T.B.: Control Models of Creatures Which Look Ahead. In: Proceedings of the Fifth National
  Symposium on Human Factors in Electronics, 1964.
- Miller, D.C.a.E., J.I.: The Adaptive Response of the Human Controller to Sudden Ch
  Controlled Process Dynamics. IEEE Trans. Human Factors Electron. HFE 8 (3) (1967).

Thank you