Driver model

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3D CAD Model Of Mahindra Scorpio

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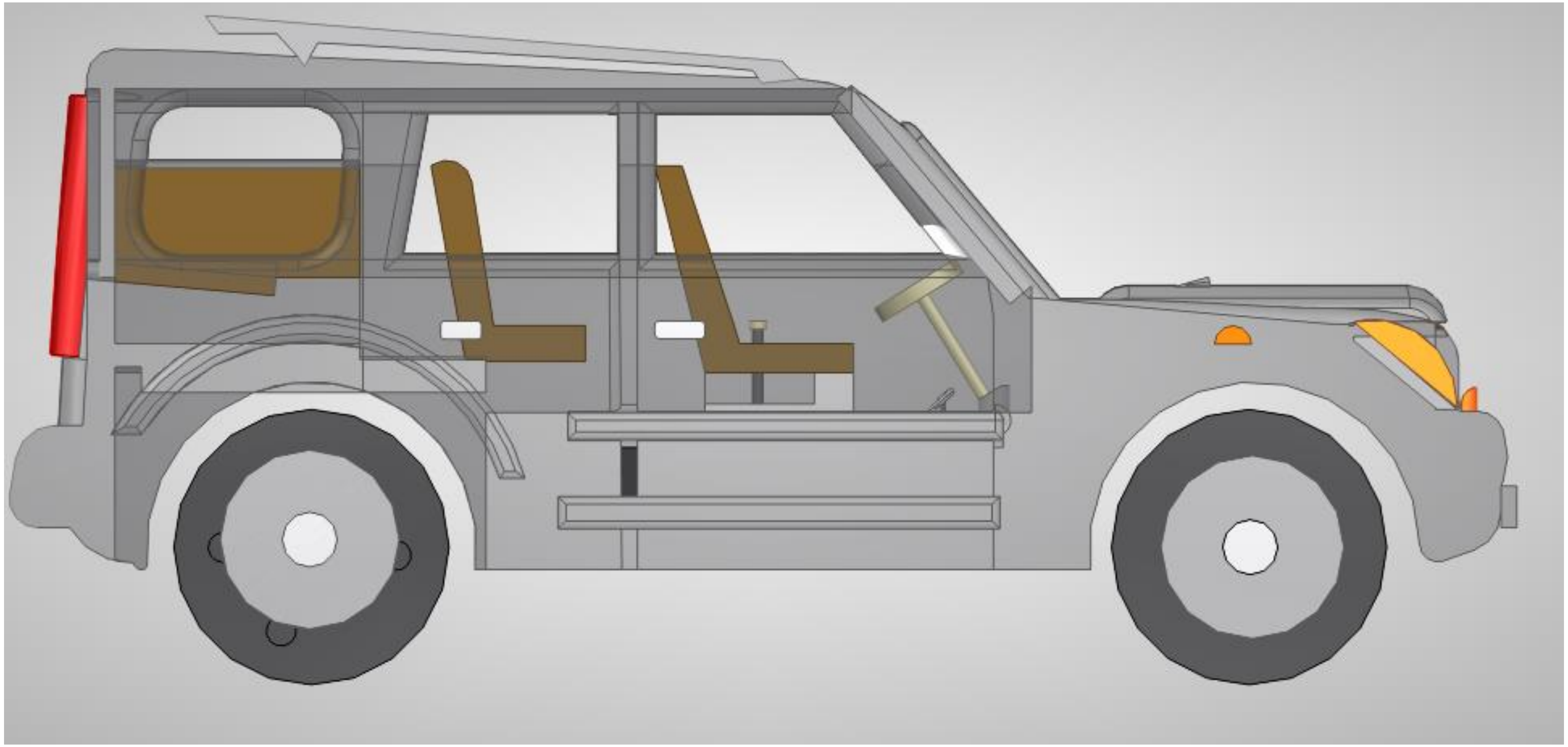
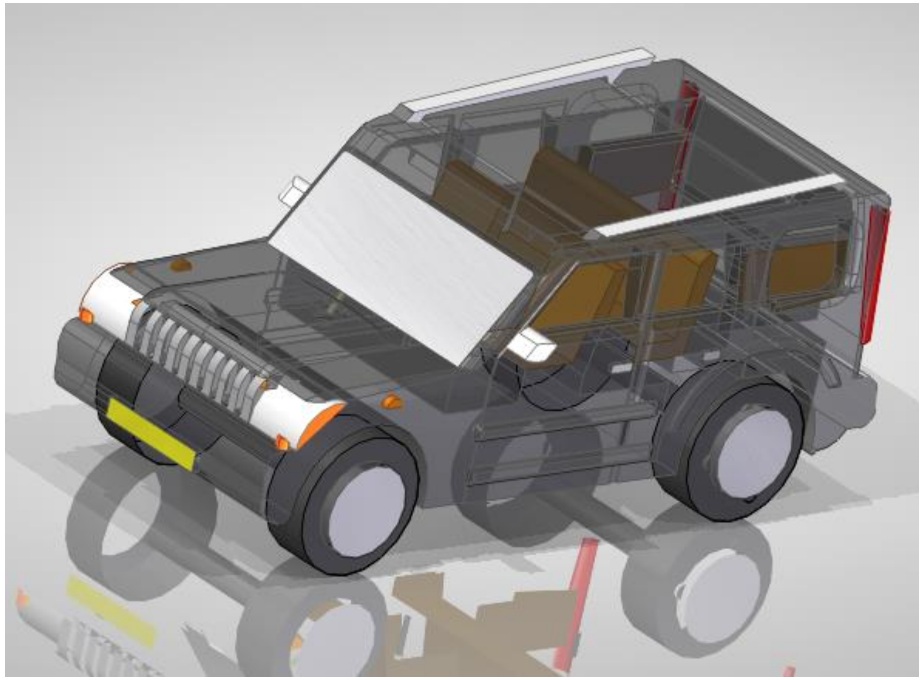
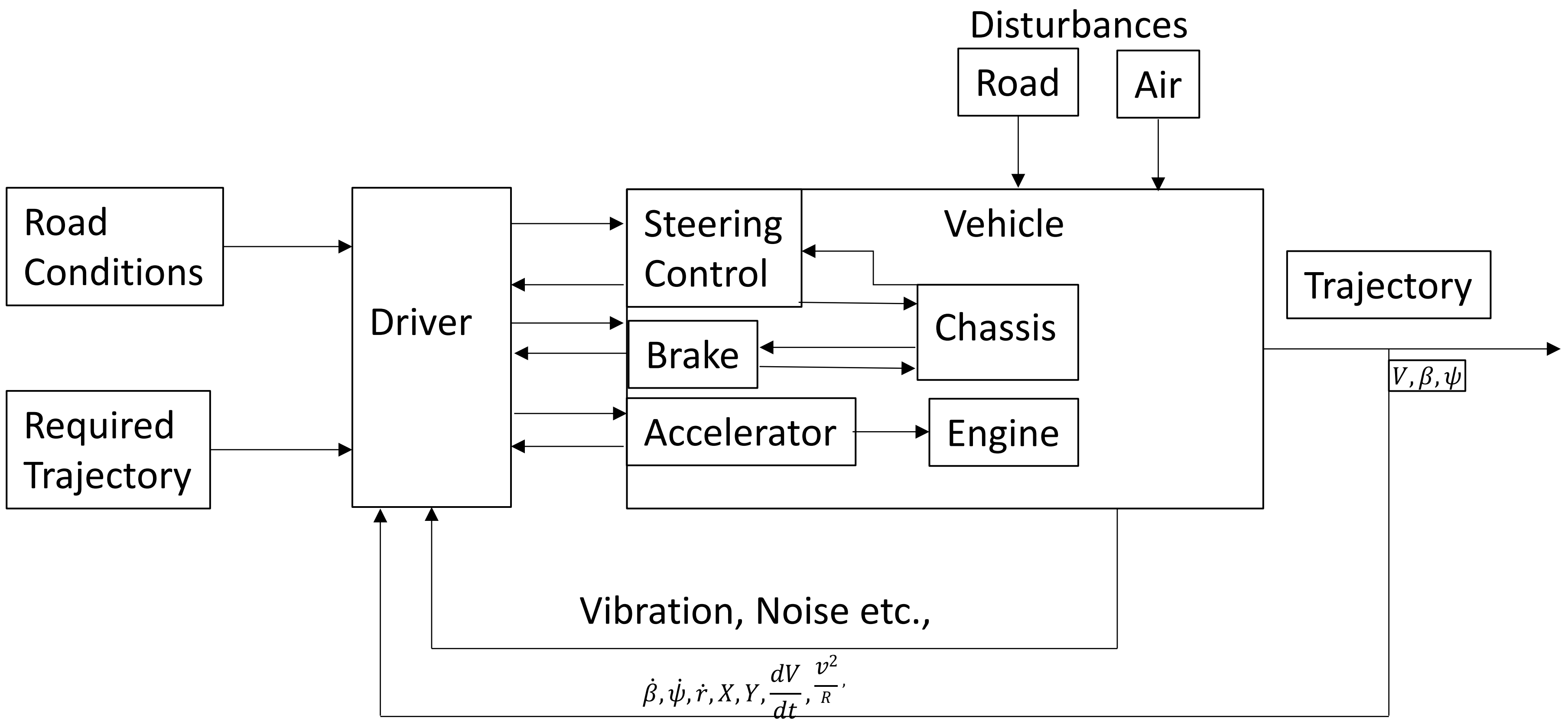




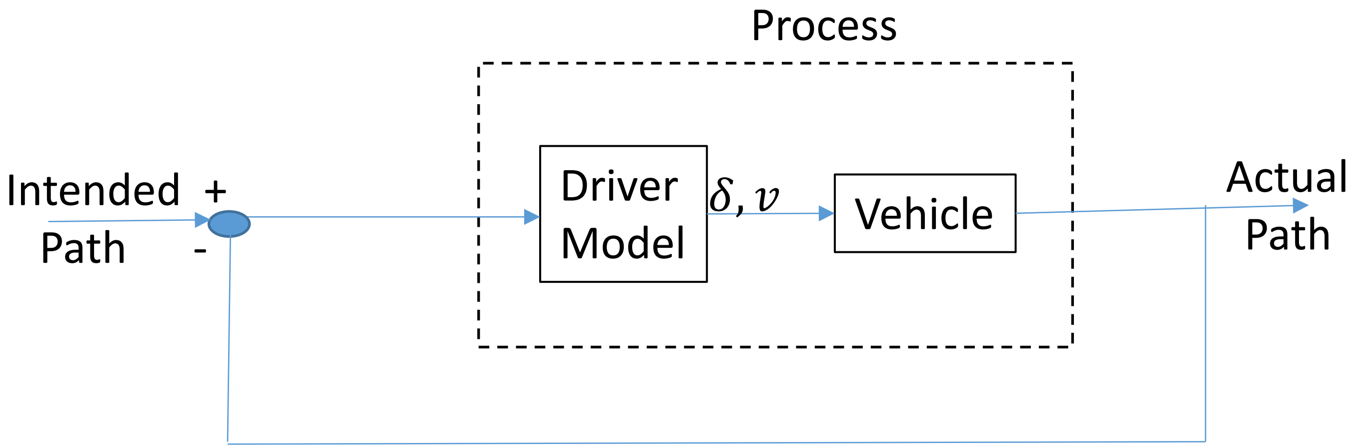
Introduction

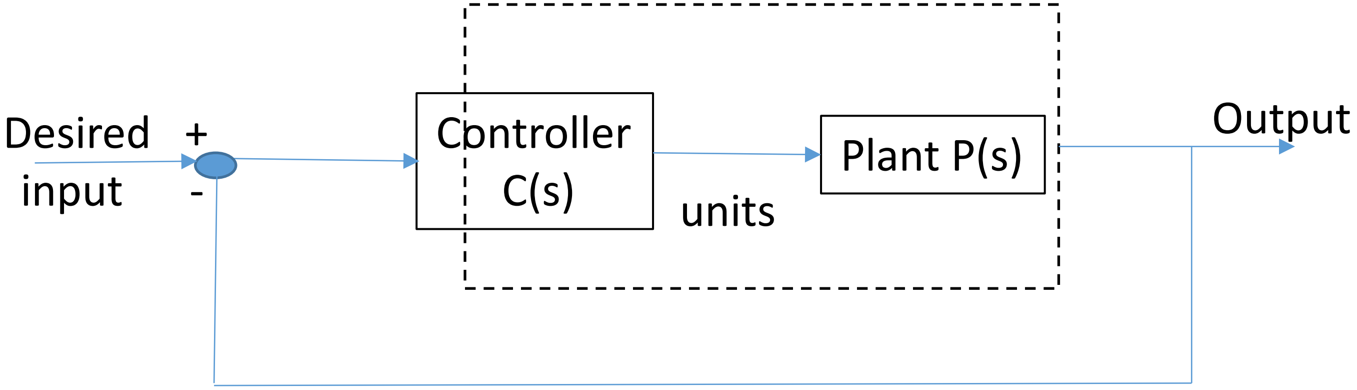
- A driver model is a mathematical model which replicates the functionality of a driver(controlling , monitoring and stabilizing a vehicle)during various maneuvers .



Simplified scheme of the simplified vehicle-Driver System

Driver – vehicle 1-D model





Proposed driver models

- Driver model(PID controller):
  - Simple linearized driver model with and without delay
  - Path following driver model.
  - Path following driver model which minimizes lateral deviation and heading error according to a previewed path function and improves stability by regulating yaw and lateral disturbances during maneuvers.

- Vehicle Model
  - Rigid body model under neutral steering condition.

- Simple linearized driver model with out delay

$$\delta(t+\tau) = -K_g[\varphi(t) - \varphi(t)]$$

$$\tau\delta\dot{(t)} + \delta(t) = -K_g[\varphi(t) - \varphi(t)]$$

$$J_z\dot{r} = N_r r + N_\delta \delta + M_{z_e}$$

$$J_z\ddot{\varphi} - N_r\dot{\varphi} + N_\varphi K_g = N_\delta K_g \varphi_o(t) + M_{z_e}$$

$$|N_r| > 2\sqrt{J_z K_g N_\delta}$$

$$K_g < \frac{{N_r}^2}{4J_z N_\delta}$$

- Simple linearized driver model with delay

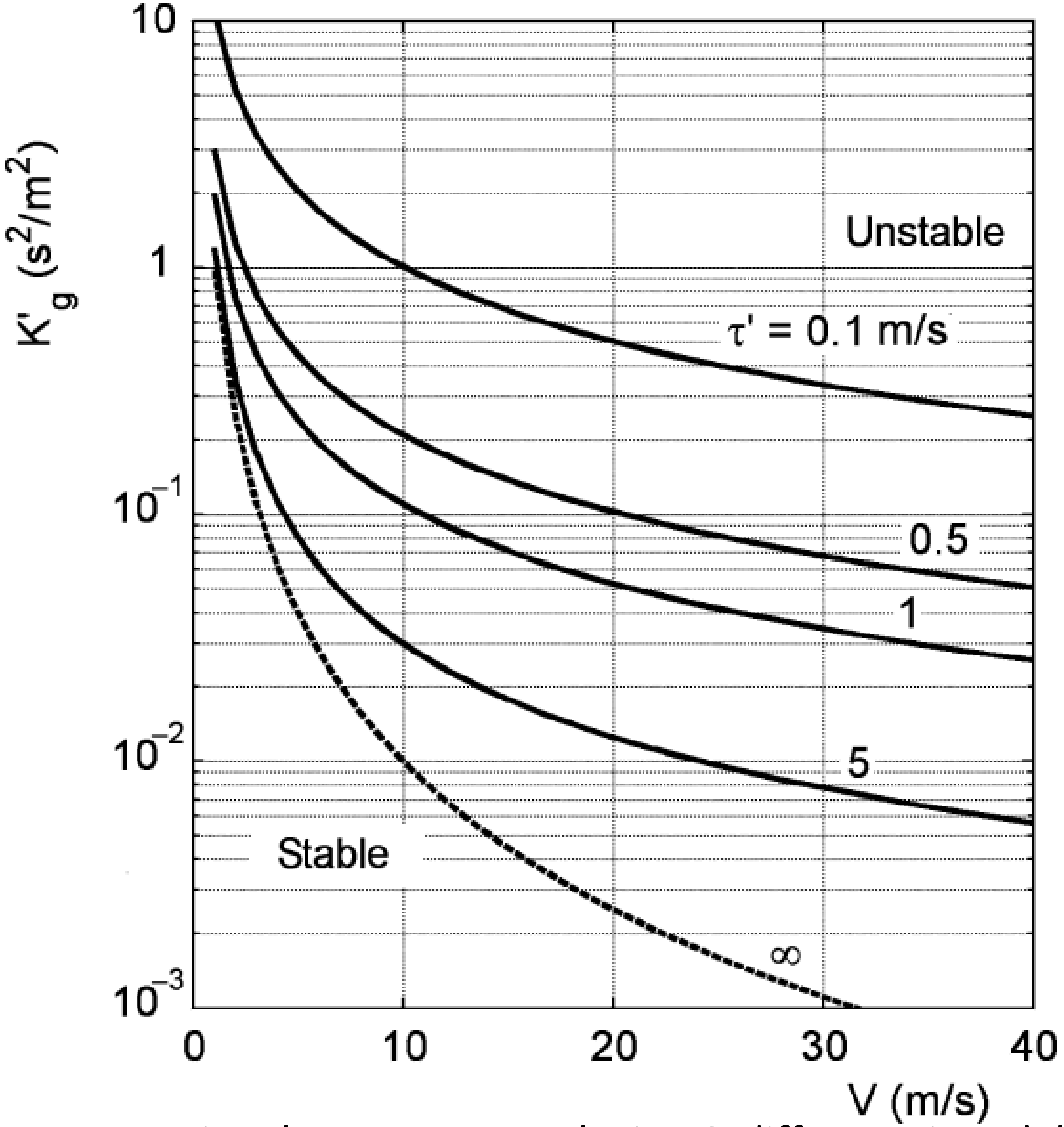
$$\begin{Bmatrix} \dot{r} \\ \dot{\delta} \\ \dot{\varphi} \end{Bmatrix} = A \begin{Bmatrix} r \\ \delta \\ \varphi \end{Bmatrix} + B_c \varphi_o + B_d M_{z_e}$$

$$A = \begin{pmatrix} {}^{N_r}/_{J_z} & {}^{N_\delta}/_{J_z} & 0 \\ 0 & {}^{-1}/_{\tau} & {}^{-K_g}/_{\tau} \\ 1 & 0 & 0 \end{pmatrix}, \quad B_d = \begin{pmatrix} {}^{1}/_{J_z} \\ 0 \\ 0 \end{pmatrix}, B_c = \begin{pmatrix} \dot{r} \\ \dot{\delta} \\ \dot{\varphi} \end{pmatrix}$$

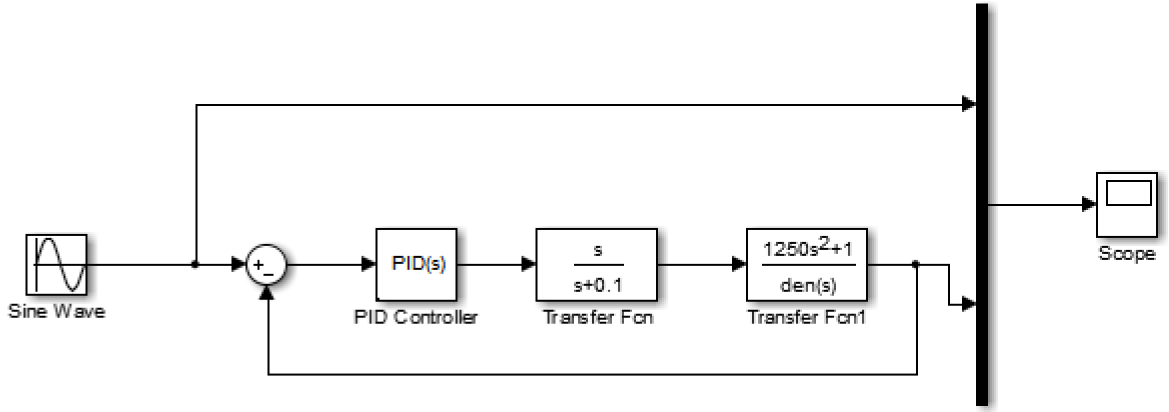
$$s^3 + P\left(\frac{1}{\tau} - \frac{N_r}{J_z}\right) s^2 - \frac{N_r}{\tau J_z} s + \frac{N_\delta K_g}{\tau J_z} = 0$$

$$K_g < \frac{{N_r}^2}{J_z N_\delta}$$

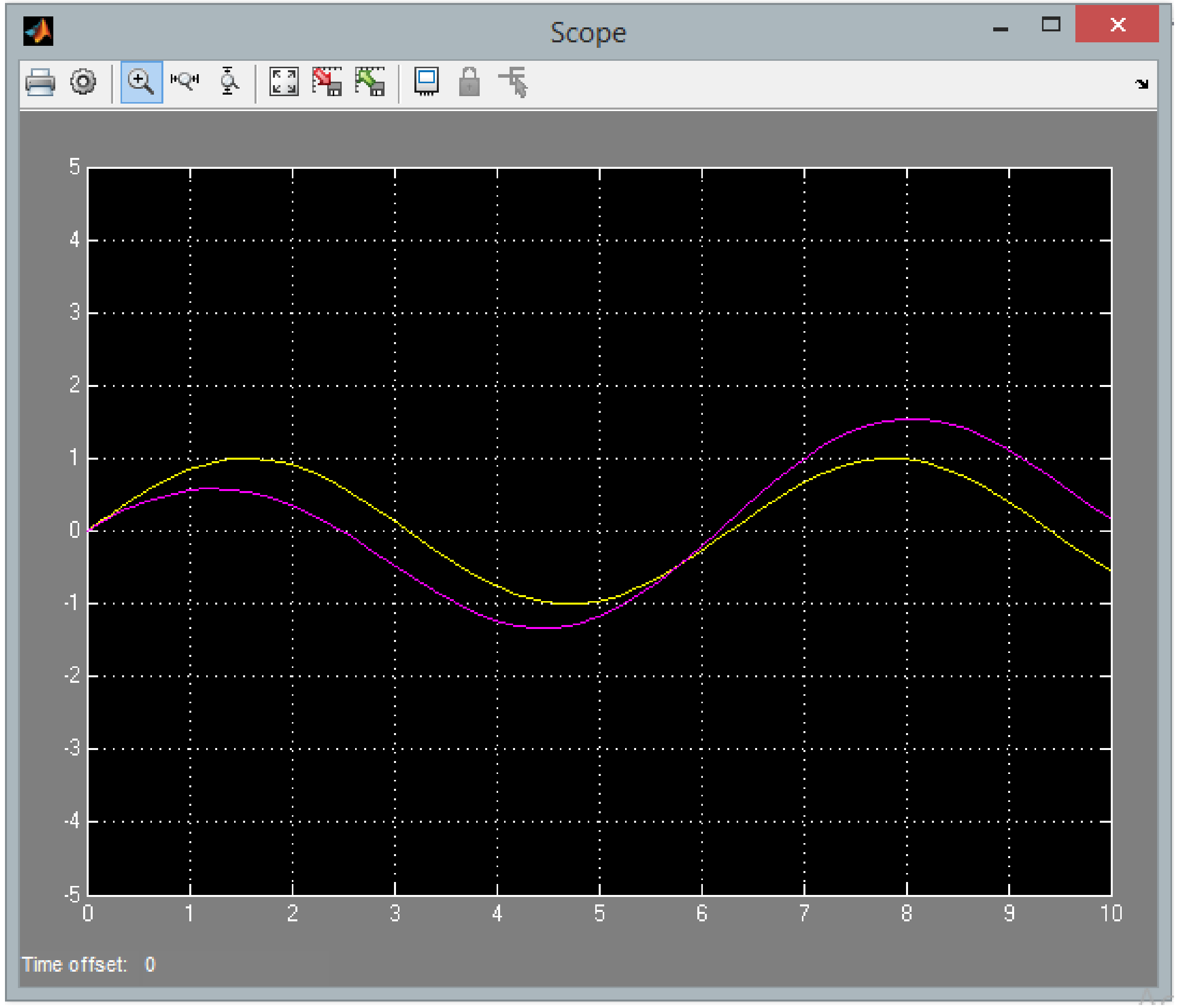
$$\tau < \frac{J_z {N_r}^2}{{N_r}^2 - J_z N_\delta K_g}$$



Proportional Constant Vs Velocity @ different time delays



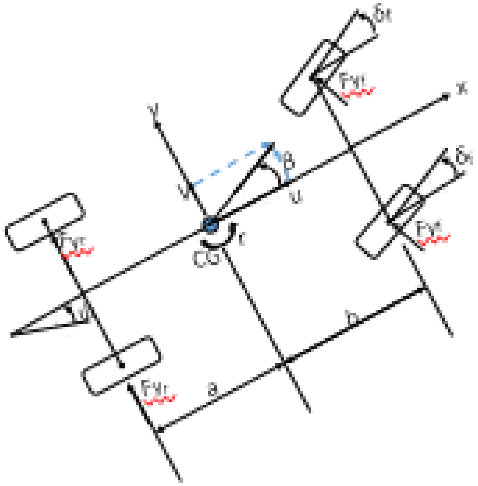
Path

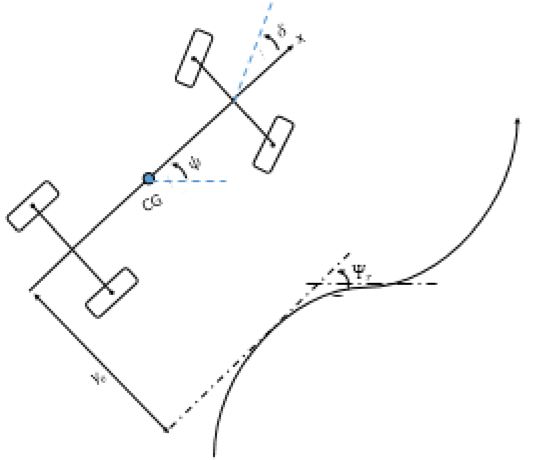


Simple linearized Driver model with Delay

→Yellow is the desired path
→Violet is the Actual path

Path fallowing driver model.





$$\dot{s} = \frac{v1\cos(\bar{\theta})}{1 - dc(s)}$$

$$\dot{d} = v1\sin(\bar{\theta})$$

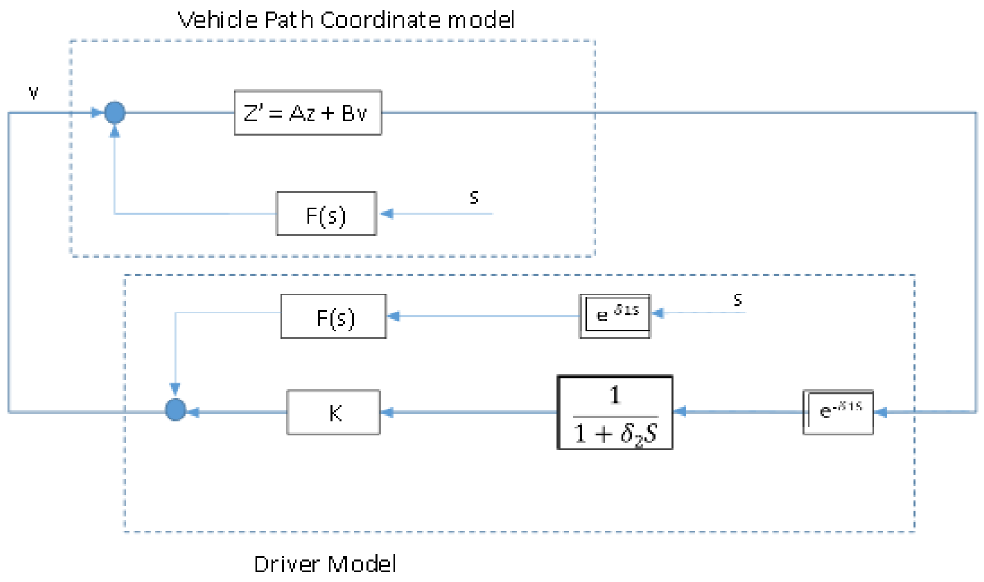
$$\dot{\bar{\theta}} = v1\left(\frac{\tan(\phi)}{l} - \frac{c(s)\cos(\bar{\theta})}{1 - dc(s)}\right)$$

$$c(s) = \frac{d\theta_t}{ds}$$

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \\ \dot{\phi} \end{bmatrix} = \begin{bmatrix} \cos(\Theta) \\ \mathrm{Sin}(\Theta) \\ \mathrm{Tan}(\Theta)/l \\ 0 \end{bmatrix} v_1 + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} v_2$$

Z’ = Az + Bv $\qquad z = \begin{bmatrix} d \\ \tilde{\theta} \end{bmatrix},$

$$Z' = \frac{\partial z}{\partial s} \quad A = \begin{Bmatrix} 0 & 1 \\ 0 & 0 \end{Bmatrix} \quad B = \begin{Bmatrix} 0 \\ 1 \end{Bmatrix}$$



$$\int_0^{\infty} (z^T Q z + r v^2) e^{2\lambda s ds}$$

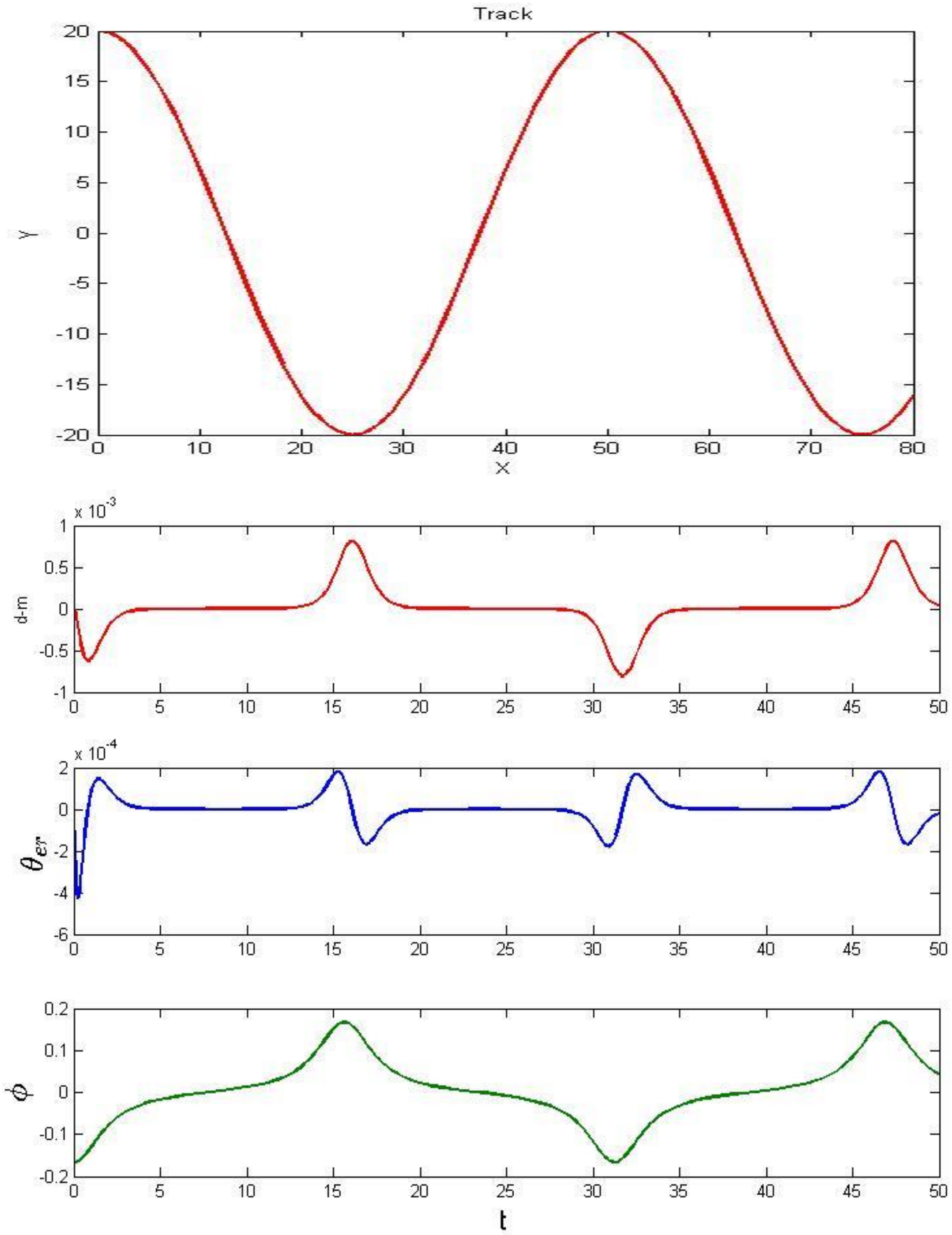
P(A + λI) + ($AT + \lambda$I)P – 1/r PBB’TP + Q = 0

$$Q = \begin{pmatrix} |v1| & 0 \\ 0 & |v1| \end{pmatrix}$$

V = -Kz

$$\phi = l(f(s) - Kz)$$

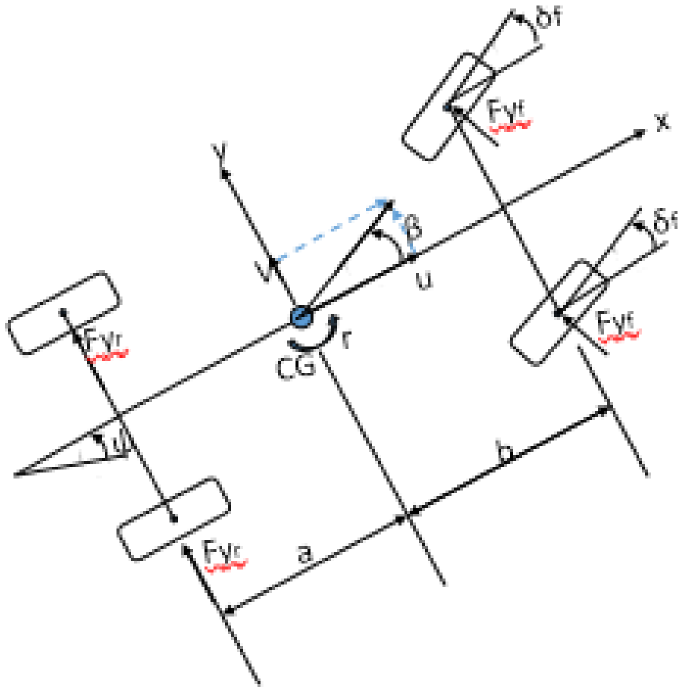
Results



Implementation of delay into driver model

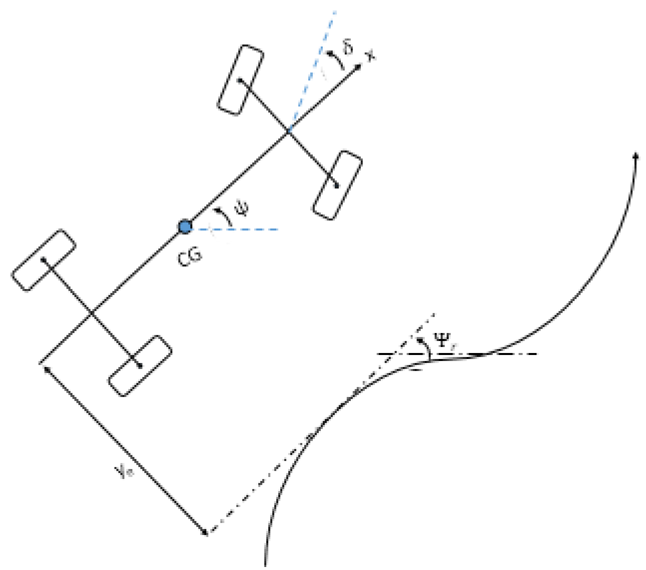
- A vehicle path following analysis and improvement of vehicle handling process
- Introduce control system to ensure the vehicle follows desired path
- Desired yaw rate and slip angle to get desired path
- Delay associated with diver , Neural response delay
- Sensor delay
- Consider preview distance

- The equations of vehicle dynamics are:
  - $M(\dot{V}y + Ur) = Fyr\ cos\delta r + Fxr\ \ sin\delta + Fyf\ cos\delta f\ \ + Fxf\ sin\delta f$
  - Iz$\dot{r} = aFyf\ cos\delta f + aFxf\ sin\delta f\ \ - bFyr\ sin\delta r\ \ - bFyr\ cos\delta r$



$$\dot{y}e = U\ sin\psi + Vy\cos\psi$$
$$\dot{\psi} = \dot{\psi}v\ \ - \dot{\psi}r$$

Vehicle model



$$\dot{X}1 = A1X1 + E1\delta + B1Mz + K\,(\frac{1}{R(t)})$$

$$X_1 = \begin{bmatrix} y_e \\ V_y \\ \psi \\ r \end{bmatrix} \quad A_1 = \begin{bmatrix} 0 & 1 & U & 0 \\ 0 & a_{11} & 0 & a_{12} \\ 0 & 0 & 0 & 1 \\ 0 & a_{21} & 0 & a_{22} \end{bmatrix} \quad E_1 = \begin{bmatrix} 0 \\ e_1 \\ 0 \\ e_2 \end{bmatrix} \quad B_1 = \begin{bmatrix} 0 \\ 0 \\ 0 \\ b \end{bmatrix} \quad K = \begin{bmatrix} 0 \\ 0 \\ -U \\ 0 \end{bmatrix}$$

$$a_{11} = -2\frac{C_{\alpha f} + C_{\alpha r}}{MU} \quad a_{12} = -2\frac{bC_{\alpha r} + C_{\alpha f}}{MU} - U \quad a_{21} = 2\frac{bC_{\alpha r} - \alpha C_{\alpha f}}{I_z U}$$

$$a_{22} = -2\frac{a^2 C_{\alpha f} + b^2 C_{\alpha r}}{I_z U} \quad e_1 = 2\frac{C_{\alpha f}}{M} \quad e_2 = -2\frac{aC_{\alpha f}}{I_z}$$

Driver model

- $H(s) = \frac{d(s)}{Ed(s)} = \frac{h}{N}\left[\frac{\tau 1S+1}{\tau 2S+1}\right)\frac{1}{\tau rS+1}e^{-\tau ds}$ reff: Rosettes 2003
- Lead constant ,lag constant, reaction and delay time.
- $yep = ye + L\,\psi$
- First order Pade polynomial approximation
- $e^{-\tau ds} = \frac{1-\frac{\tau d}{2}s}{\left(1+\frac{\tau d}{2}s\right)}$

Human driver equation in time variant space.

- $\ddot{\delta} = W[-\ddot{y}e + L\psi) + \frac{2\tau 1}{\tau 2}(\dot{y}e + L\psi] + \frac{1}{\tau n\tau 2}\left[-(\tau n + \tau 2\,)\dot{\delta} - \delta\right]$
- W= $\frac{h}{N}.\frac{1}{\tau n}\frac{1}{\tau 2}$

Closed Loop driver model

- $\dot{X} = AX + BMz + K\left[\frac{1}{R}\right]$

$$X = \begin{bmatrix} ye \\ v \\ \psi \\ r \\ \delta \\ \dot{\delta} \end{bmatrix} \quad A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & a_{11} & 0 & a_{21} & e_1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & a_{21} & 0 & a_{22} & e_2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ a_{16} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ b \\ 0 \\ Wb \end{bmatrix} \quad K = \begin{bmatrix} 0 \\ 0 \\ -U \\ 0 \\ 0 \\ -WU^2 - \frac{2W\tau_1}{\tau_d} LU \end{bmatrix}$$

curvature is taken as sinusoidal path

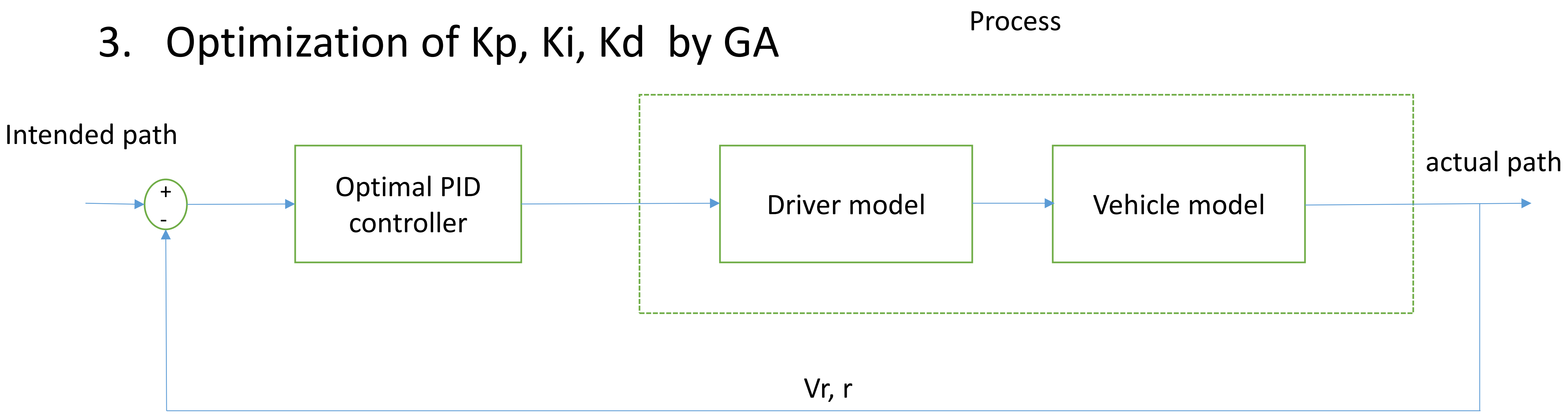
$$a_{61} = W \quad a_{62} = W(a_{11} + La_{21}) + \frac{2W\tau_1}{\tau_d}, \quad a_{63} = -\frac{2W\tau_1}{\tau_d} U + WL$$

$$a_{64} = W(a_{21} + La_{22} + U) + \frac{2W\tau_1}{\tau_d} L, \quad a_{65} = \frac{-1}{\tau_n . \tau_1} + e_1 + Le_2, \quad a_{66} = \frac{(\tau_n + \tau_2)}{\tau_n . \tau_2}$$

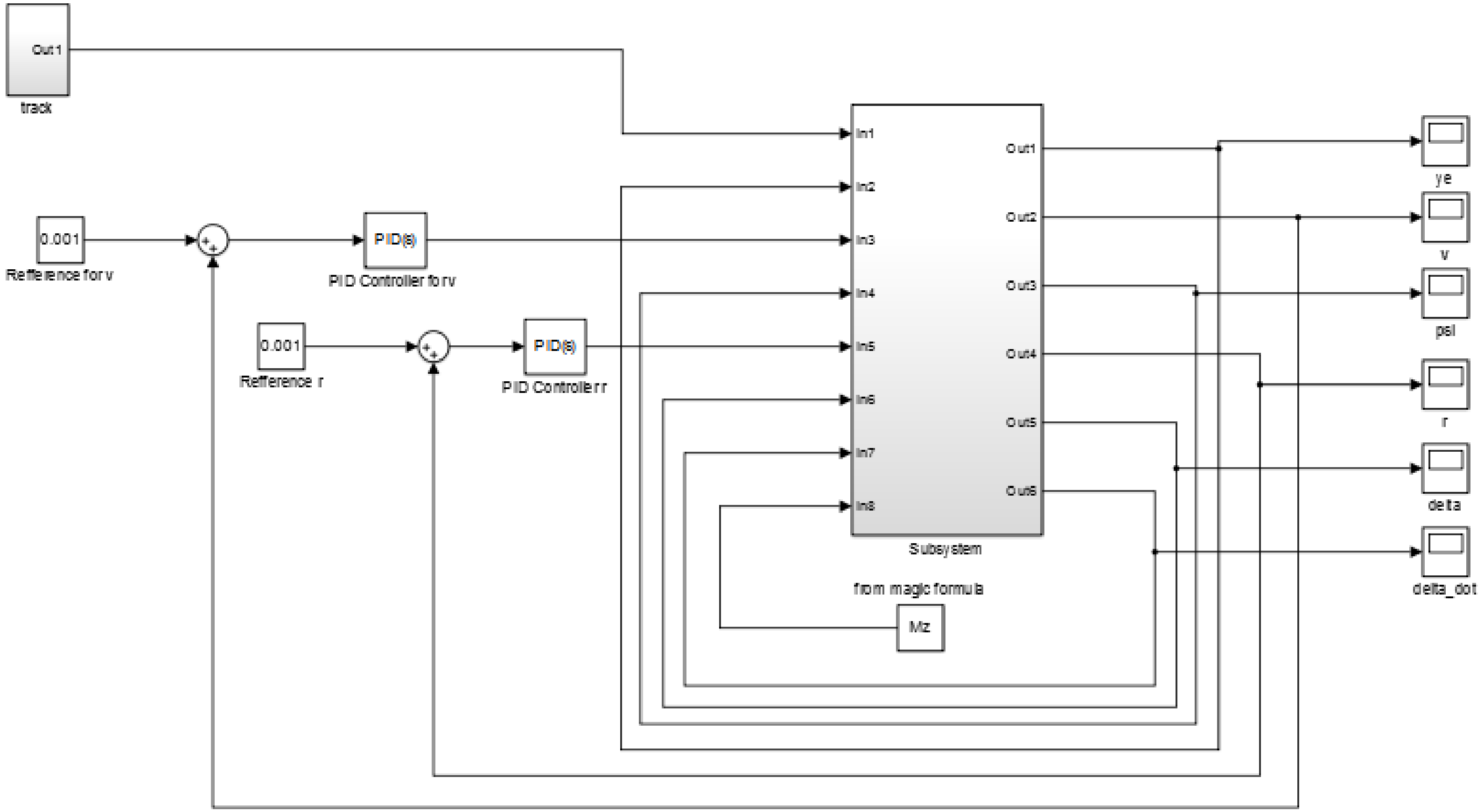
Controller

Introduce PID controller for

1. yaw rate
2. slip angle to get desired path
3. Optimization of Kp, Ki, Kd by GA



Matlab Simulink model



Conclusion

- Formulated driver model in order to make vehicle in desired path.
- 1- Simple model with delay case has been studied, and used PID controller
- Modeled in Simulink
- 2- No delay case has been studied by considering preview distance
- Optimized proportional controller has been used with the help of Riccati equation by minimizing cost function .
- Modeled and solved using Matlab ODE solver
- 3- Introduced delays to driver model and
- Modeled in Matlab Simulink along with mathematical modeling .

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THANK YOU