AUTOMATIC STEERING CONTROL

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Points of focus:

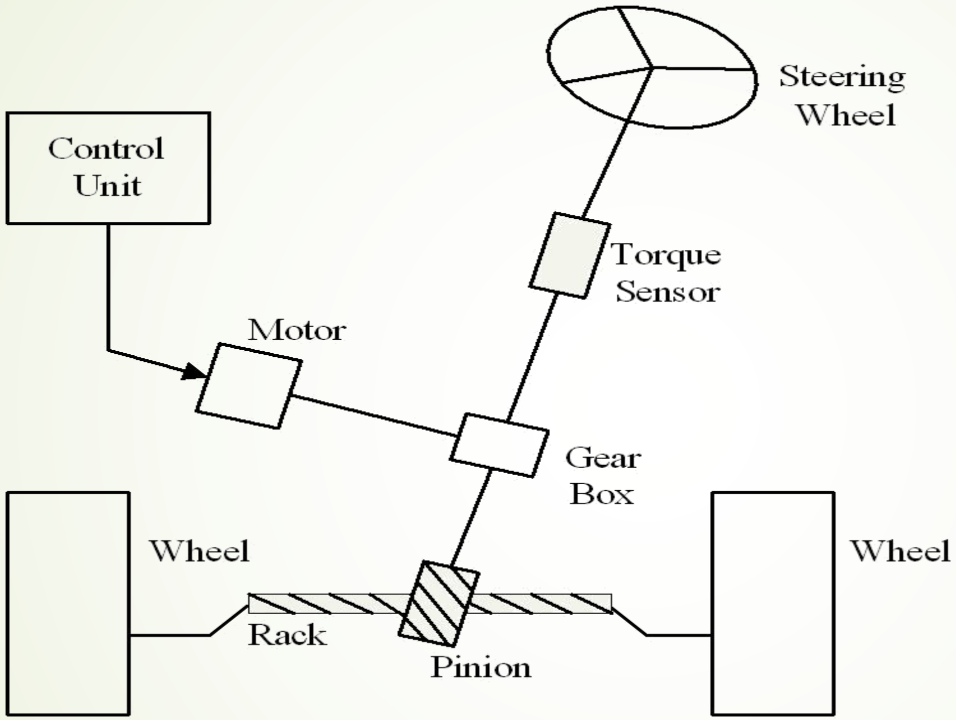
- INTRODUCTION
- VEHICLE MODEL
- STEERING SYSTEM MODEL
- PID CONTROLLER
- MATHEMATICAL MODELLING
- RESULTS
- CONCLUSIONS
- REFERENCES

INTRODUCTION:

- Intelligent and automated guided vehicles have always gained the interest of researchers all across the globe.
- Reduction in traffic congestion and over all number of accidents in the recent past can be attributed to the progress in the development of active safety measures.
- Path guided vehicle control systems with the presence of driver commands is more realistic explanation of vehicle path tracking problems.
- Mathematical models are developed for autonomous steering controller using PID controllers.

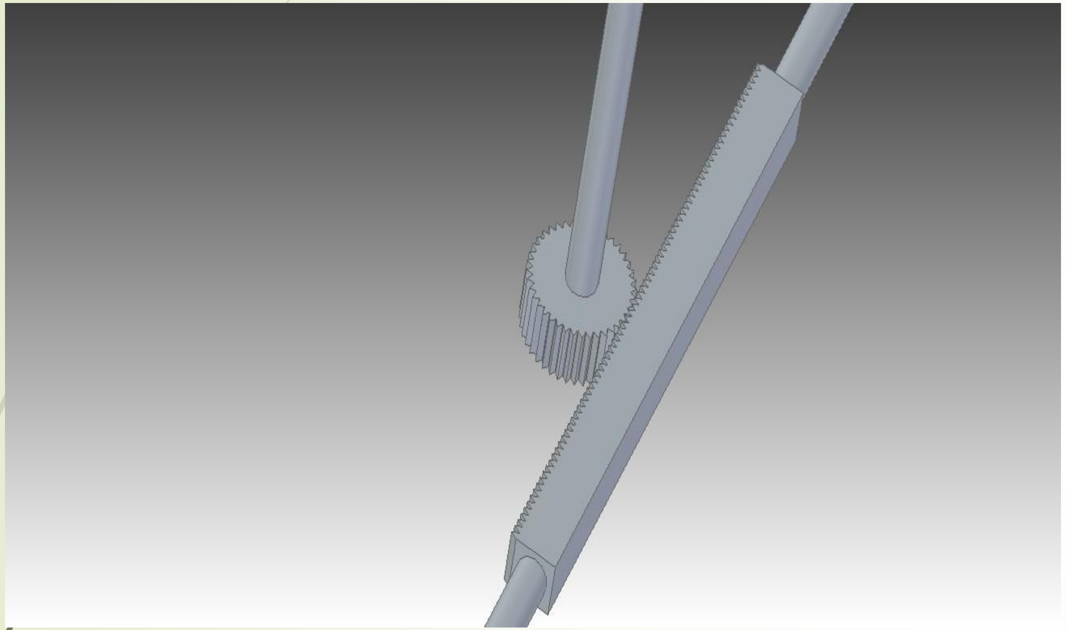
Vehicle Model:

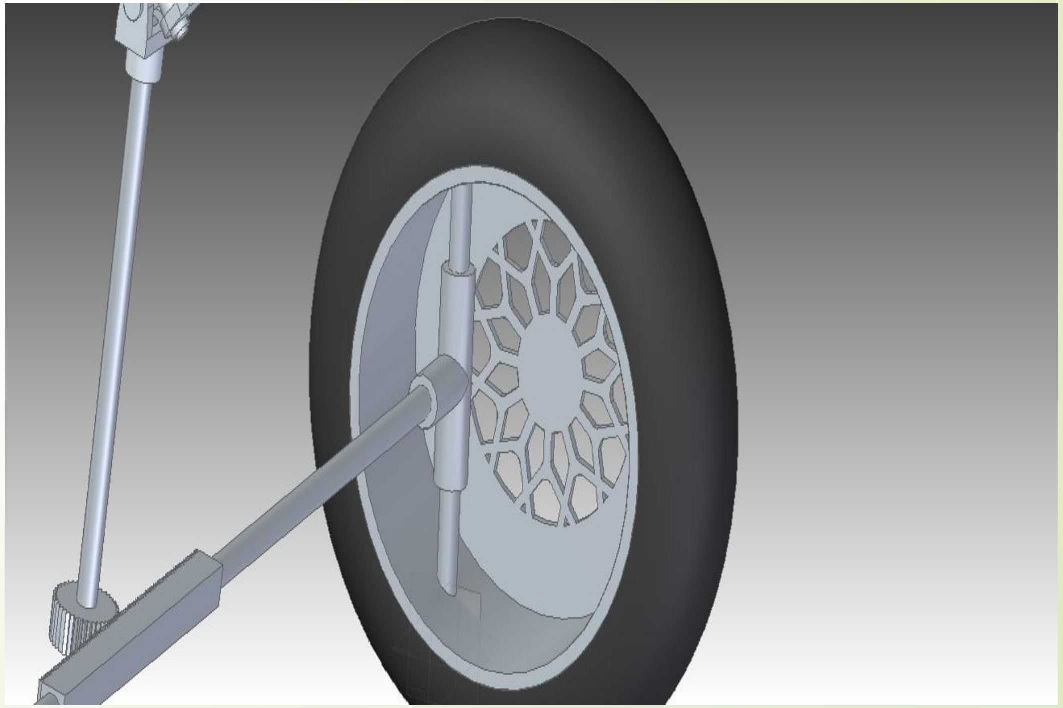
Steering Control System Model:



Source: http://www.intechopen.com/books/advances-in-mechatronics/integrated-control-of-vehicle-system-dynamics-theory-and-experimenticle-system-dynamics-theory-and-experiment&psig=AFQjCNHF_VKHdfbD8pxVUoNwKD755WngSA&ust=1460796582284373

Steering Control System Model:

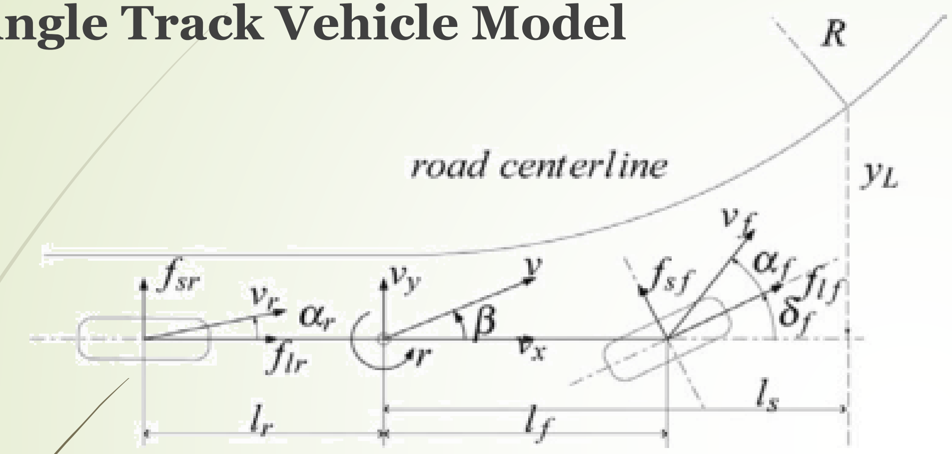




Steering Control System Model:

Schematic models:

Single Track Vehicle Model

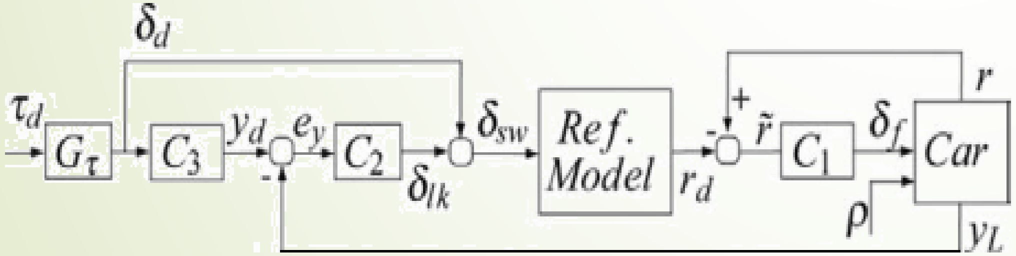


l_s : Look ahead distance,

$f_{l,s}$: Longitudinal and lateral forces,

C_1, C_2 and C_3 are controllers.

Integrated driver and control scheme



Source: Integrated driver and Active steering control for vision-based lane keeping; Riccardo, Stefano, Mariana

Controllers:

- The control design is divided into three sub-systems:
- **C_1 : PI active front steering control system**.

  $\delta_f = -K_{p1}(r-r_d) - K_{I1}a_0$; a_0 it is the additional state introduced by the dynamic control.

- **C_2 : PID control system.**

=> Considering the yaw rate reference signal (r_d) as a controlled input, we need to integrate the additional lateral offset measure to drive the signal e_y (y_d-y_l) to zero.

=> The dynamics of road curvature (ρ) are important to design the desired yaw rate reference as it might be considered as a disturbance to lateral offset.

=> No driver action results in y_d=0 and e_y is driven to zero.

$\delta_f = -K_{p2}\, e_y - K_{I2}\, a_2 - K_{I3}\, a_1 - K_d\, e_{yd}$; a_1 is necessary to obtain zero steady state tracking error.

$a_1^{\cdot} = e_y$; $a_2^{\cdot} = a_1$; $a_3^{\cdot} = -a_3/\lambda + e_y$; $e_{yd} = 1/\lambda\,(a_3^{\cdot})$; e_{yd} : lateral offset measurement

Controllers:

- The control design is divided into three sub-systems:
- **C_3 : PID control system**.

To obtain a complete control over of the vehicle lateral dynamics when:

$\lambda_d \neq 0$; Goal is achieve $e_y = 0$.

$e_y = y_d - y_l = 0$;

$C_3 = kP_o$; K = Design Parameter (It depends on rise time, settling time and overshoot); P_o = Transfer function between r_d and y_l

$= (d_3S^3 + d_2S^2 + d_1S + d_0)/(\ S2\ )\ (-S^3 + c_2S^2 + c_1S + c_0)$;

Mathematical Modelling:

$v_x = -v \sin(\Psi_v) + u \cos(\Psi_v);$

$v_y = u \sin(\Psi_v) + v \cos(\Psi_v);$

$y_{la}' = v_x \sin(\Psi_R) + (v_y + x_{la}\, \Psi_v') \cos(\Psi_R)\ ;$

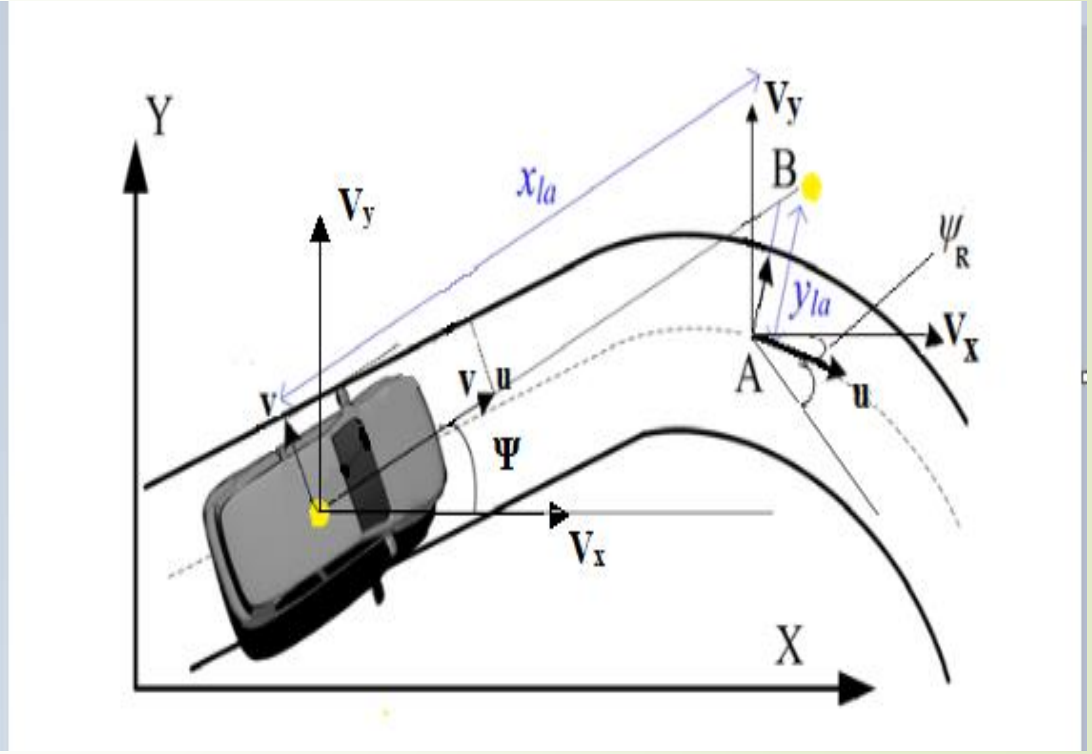
$=> y_{la}' = v + u\, \Psi_{vR} + x_{la}\, \Psi_v'\ ;$

$m(v_x' - r\, v_y) = f_{lf} \cos\delta_f + f_{sf} \sin\delta_f + f_{lr}\ ;$

$m(v_y' + r\, v_x) = f_{lf} \sin\delta_f - f_{sf} \cos\delta_f - f_{sr}\ ;$

$Jr' = l_f\, (f_{lf} \sin\delta_f - f_{sf} \cos\delta_f) + l_r\, f_{sr}\ ;$

(Note: ' means differential)



Mathematical Modelling:

$$\dot{x} = Ax + Bu + Ew$$
$$y = Cx$$

$$c_f = B_f C_f D_f$$
$$c_r = B_r C_r D_r$$

$$f_{si}(\alpha_i) = D \sin\{C \,\mathrm{atan}[(1-E)B\alpha_i + E \,\mathrm{atan}(B\alpha_i)]\}$$

$$\alpha_f = \frac{v_y + l_f r}{v_x} - \delta_f, \quad \alpha_r = \frac{v_y - l_r r}{v_x}$$

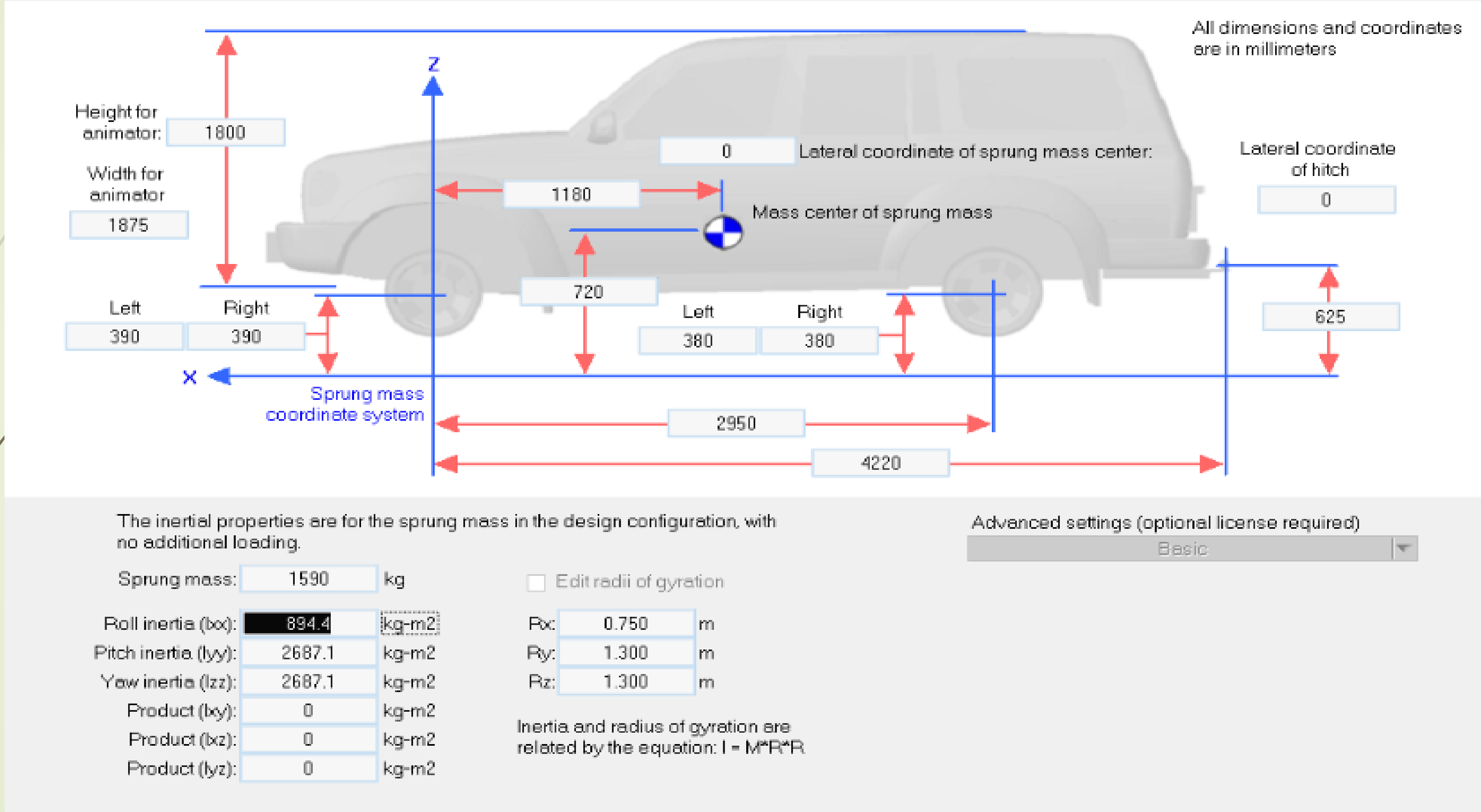
$$A = \begin{bmatrix} a_{11} & a_{12} & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ 1 & x_{la} & 0 & u \\ 0 & 1 & 0 & 0 \end{bmatrix}, \quad B = \begin{bmatrix} b_{11} \\ b_{21} \\ 0 \\ 0 \end{bmatrix}, \quad E = \begin{bmatrix} 0 \\ 0 \\ 0 \\ -u \end{bmatrix}, \quad C = \begin{bmatrix} 0 \\ 0 \\ 1 \\ 0 \end{bmatrix}$$

$$a_{11} = -(C_f + C_r) / mu, \qquad a_{12} = (l_f C_f - l_r C_r) / u - mu$$

$$a_{21} = -(l_f C_f - l_r C_r) / I_z u, \qquad a_{22} = -(l_f{}^2 C_f + l_r{}^2 C_r) / I_z u$$

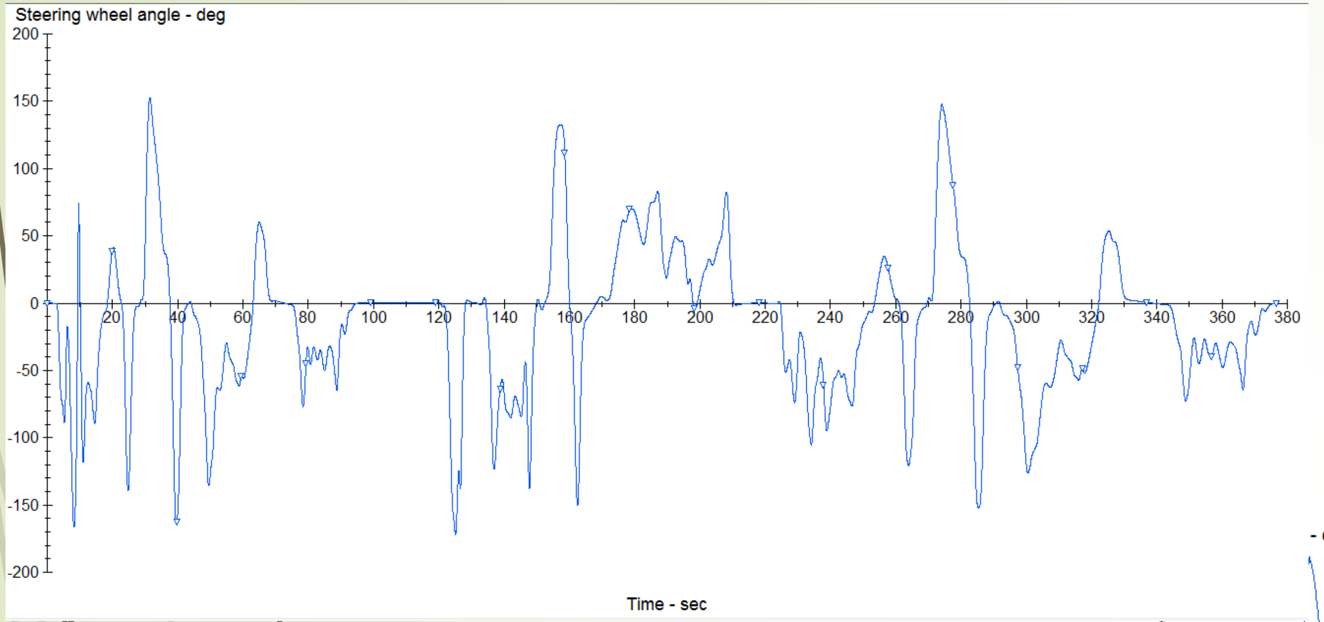
$$b_{11} = C_f / m, \qquad b_{12} = l_f C_f / I_z, \qquad u = \delta, \qquad w = 1 / R$$

Vehicle Parameters for linear model:

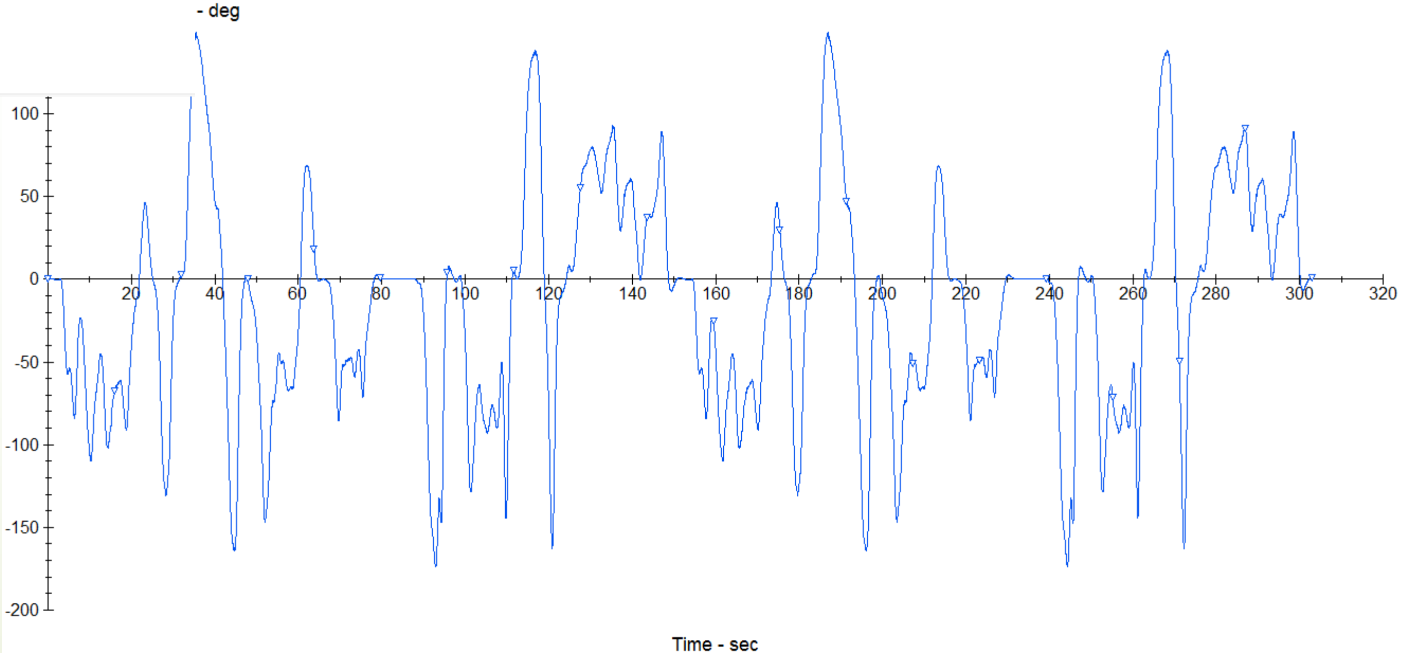


C_f = 2.864e+5 (N/rad); C_r = 1.948e+5 (N/rad)

RESULTS:

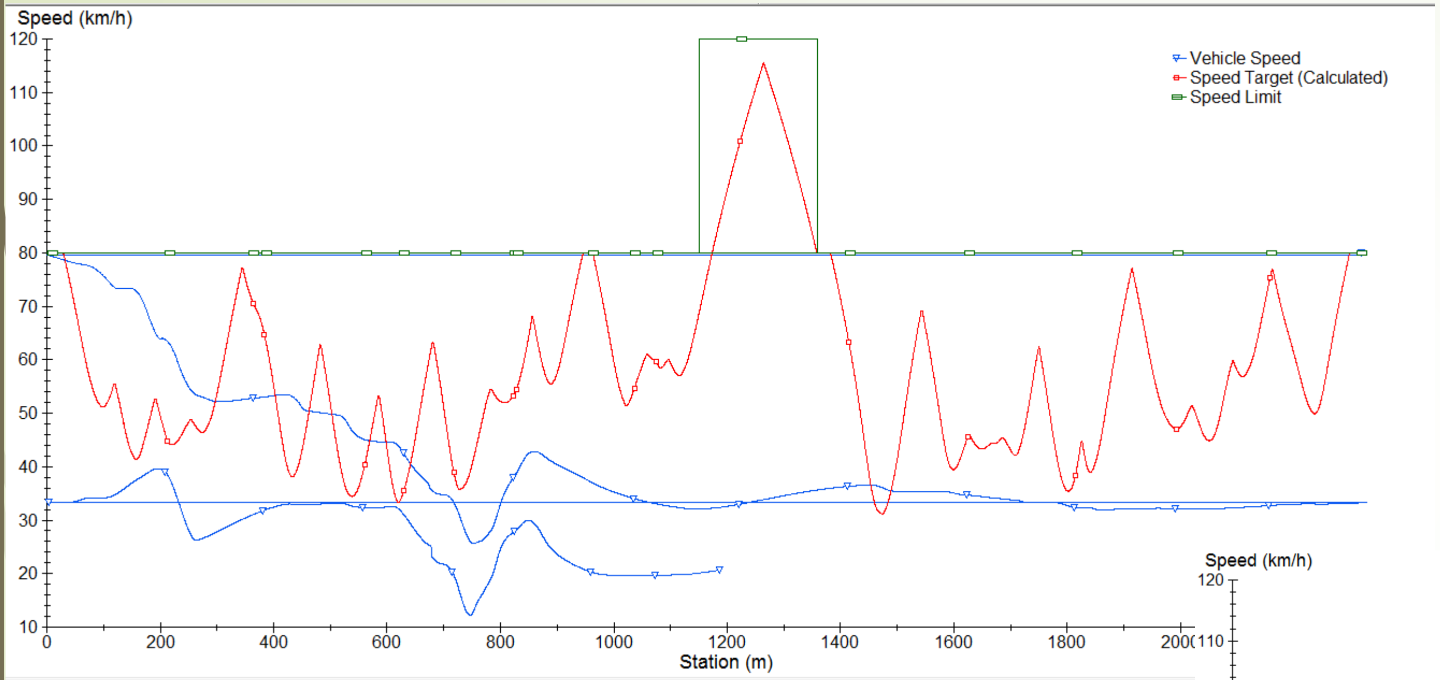


Steering angle vs time
(Without Controller)

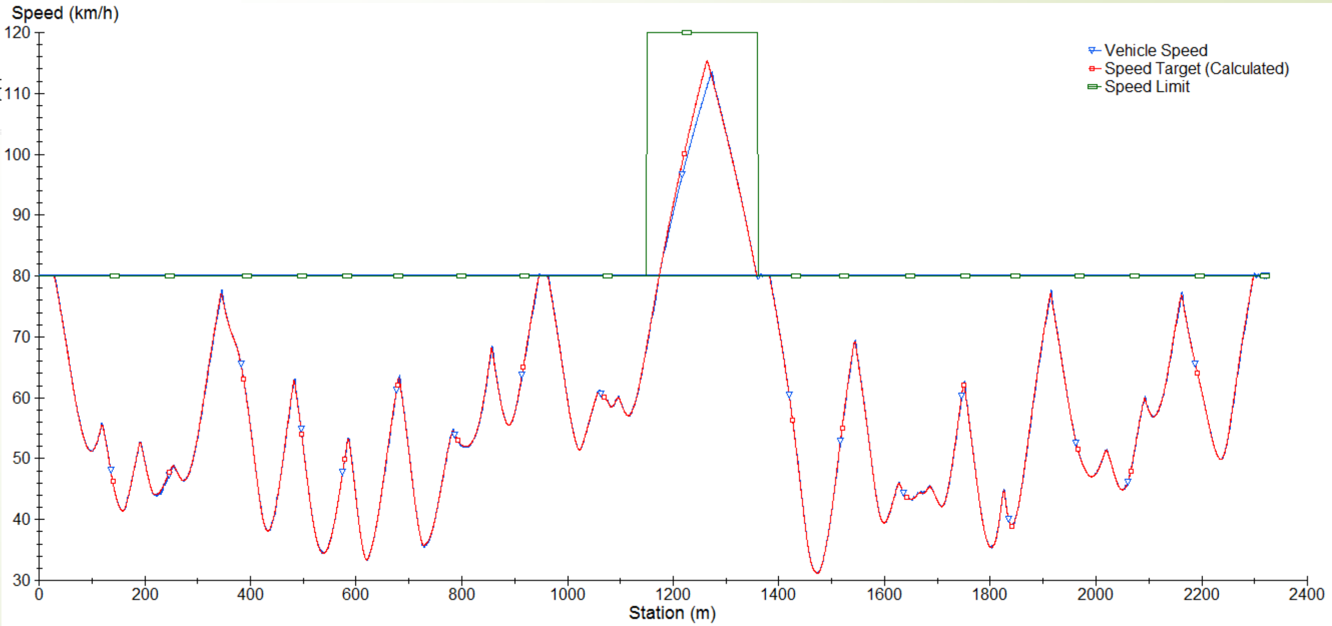


Steering angle vs time
(With Controller)

RESULTS:

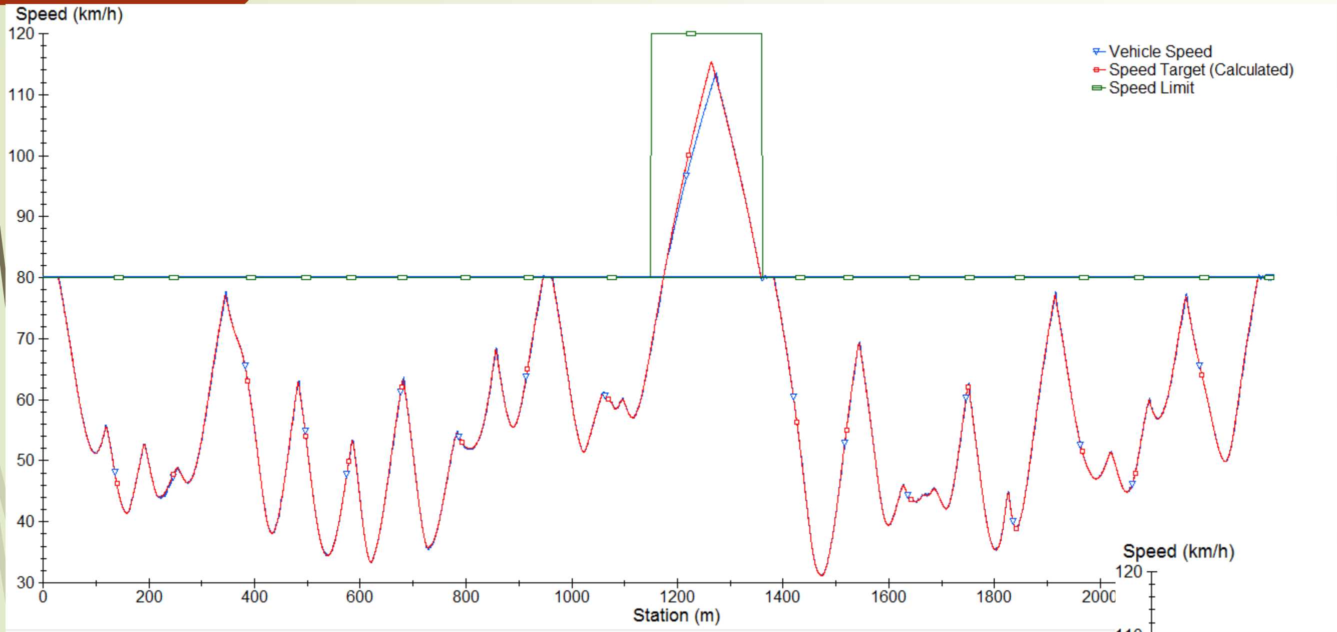


Speed variation
(Without Controller)



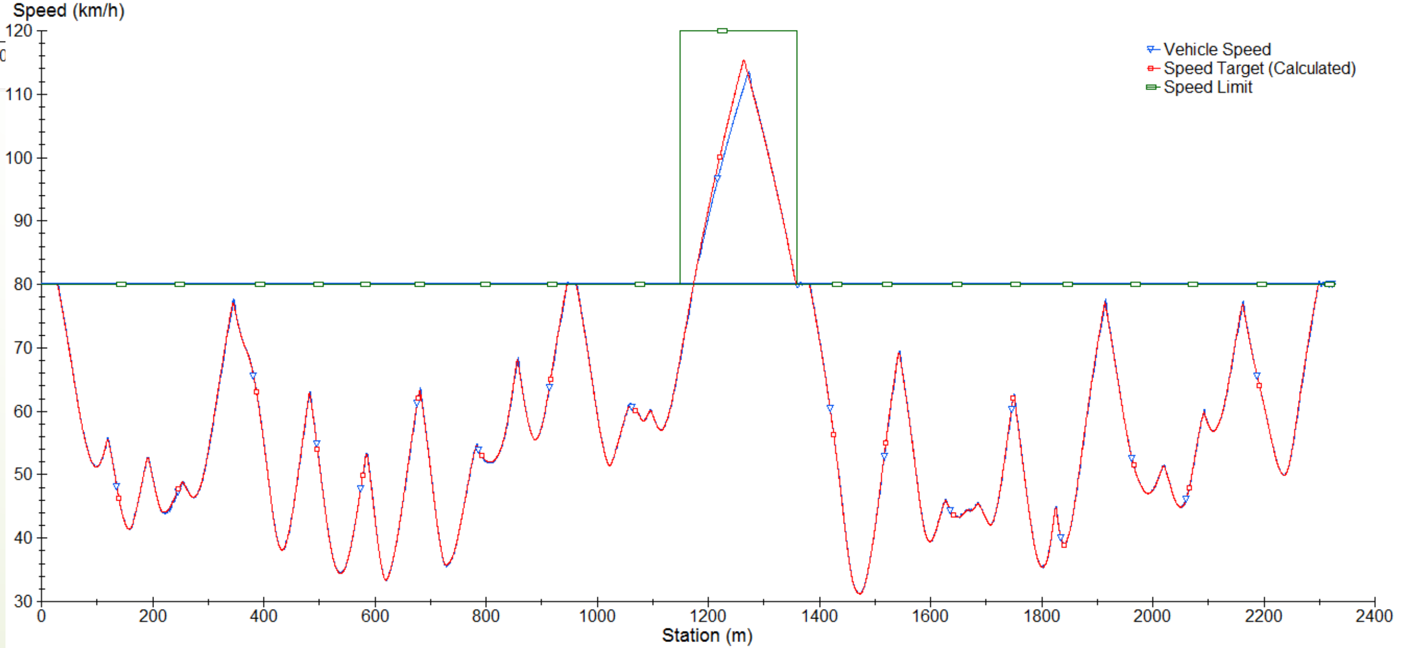
Speed variation
(With Controller)

RESULTS:

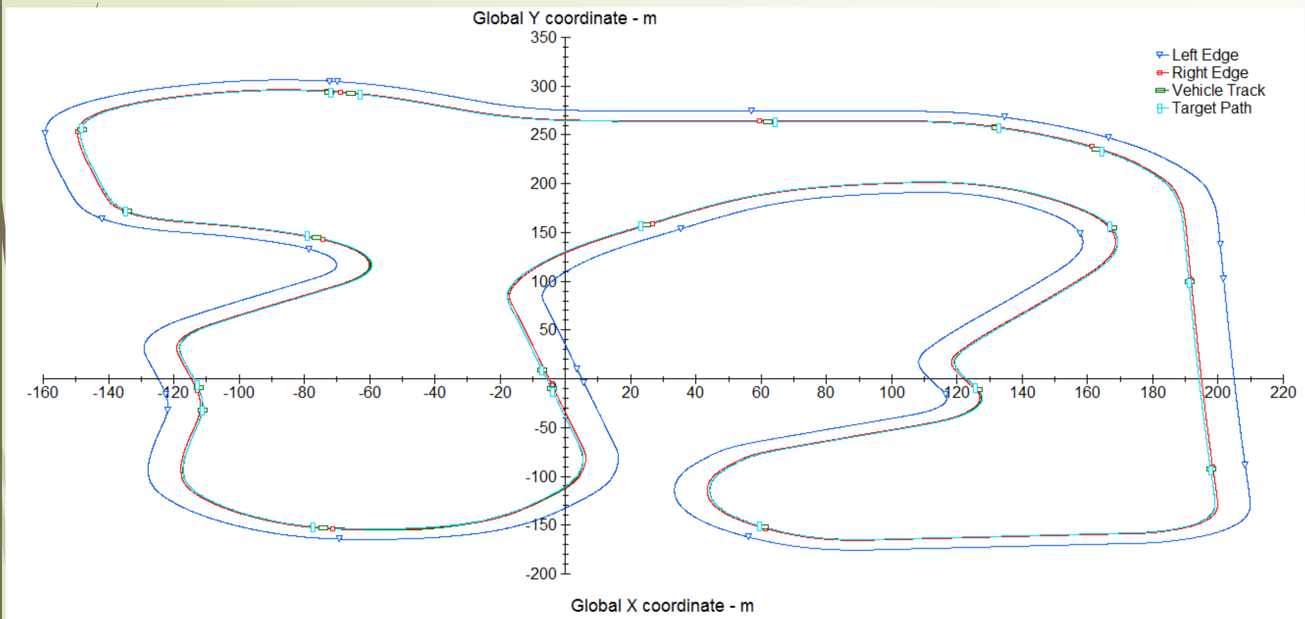


Speed variation
(With low values of Kp and Ki)

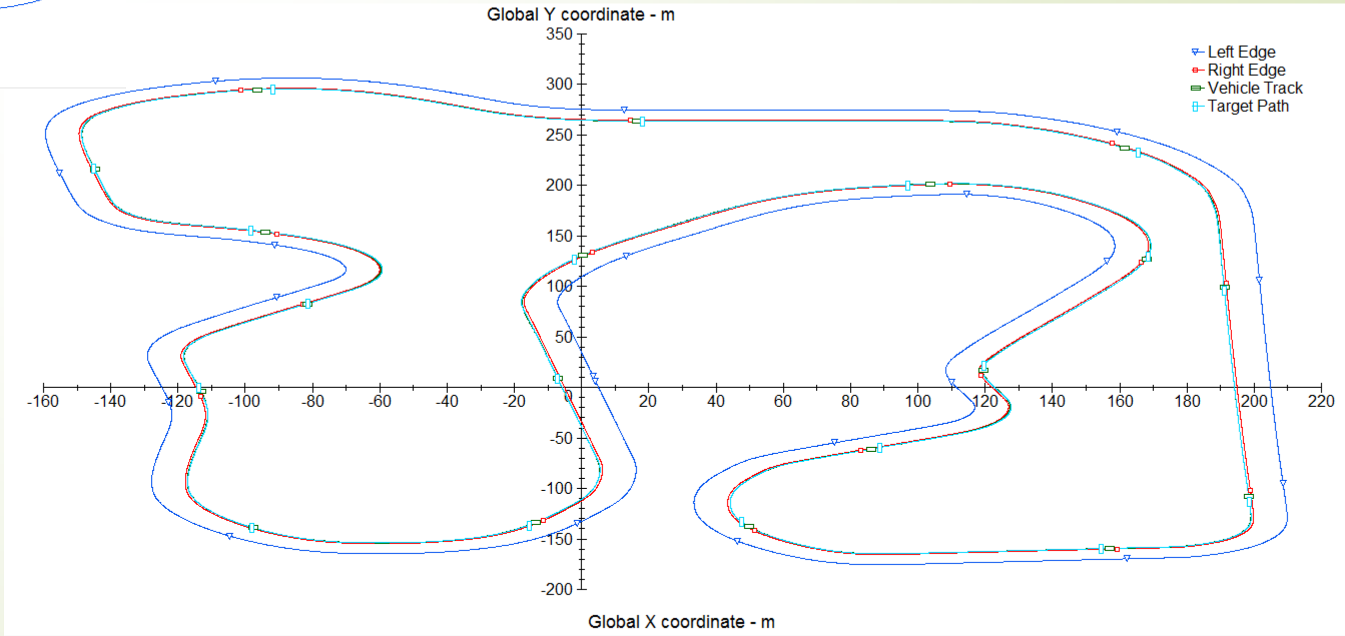
Speed variation
(With high values of Kp and Ki)



RESULTS:



Vehicle path
(Without Controller)



Vehicle path
(With Controller)

Conclusions:

- There are a lot of fluctuations in the steering angle when we are not using PI controller. But with the introduction of PI controller it became smooth.
- In the absence of the controller, actual velocity falls way below the target velocity
- By changing the K_I and K_P parameters, the error in the speed is reduced

References:

- Integrated Driver and Active Steering Control for Vision-Based Lane Keeping Riccardo Marino, Stefano Scalzi1, Mariana Netto, December 2011.
- Marino, Riccardo, Stefano Scalzi, and Mariana Netto. "Integrated driver and active steering control for vision-based lane keeping." European journal of control 18.5 (2012): 473-484.

Thank you