# DRIFT CONTROL FOR CORNERING OF A VEHICLE


-presented by

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# Contribution

Manoj (ME17BTECH11013)- Mathematical Model and Presentation slides

Vinay(ME17BTECH11017)- Simulations and Results (MATLAB and Carsim)

Revanth(ME17BTECH11027)- CAD models (CAR and Steering System)

Punnam(ME17BTECH11022)-Final Report

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INTRODUCTION

# Cornering maneuver

- Drifting occurs when an expert driver intentionally maneuvers a vehicle to cause loss of traction in the wheels.
- It is characterized by large side-slip angles and near full saturation of the wheels.
- It is commonly seen in rally racing when a driver quickly turns a corner.

# Types of drift maneuvers

- Drifting represents a particularly interesting control maneuver because of the tire saturation and limited control authority in a highly unstable region.
- Drift maneuvers fall into one of two categories:
    1. Sustained drift focuses on stabilizing the vehicle about an unstable equilibrium state, resulting in a steady state circular drift
    2. Transient drift focuses on entering a drift state temporarily to perform a maneuver, like drift parking.

# Path planning

- In the free region,RRT algorithm is applied using a bicycl
model to find a path.
- In the drift region,a rule-based method is used with a hig
fidelity vehicle model to search for a path.
- Track segments are designated with a corner (purple) as
drift regions since rally racers typically drift along the
those corners. The segments before cornering are define
as free region. The transit region is defined to connect
free region and drift region.

# Free region

- For low side-slip segments of the track,the modified RRT is used to find a feasible trajectory.
- At each iteration, the RRT algorithm first generates a sample position,the sampled input accounts for input rate constraints by constraining the sampling domain to be around the previously applied input, which limits the input magnitude and ensures a smooth path.
- After propagating the node forward, the algorithm ensures the vehicle remains within the track boundary.

# Transit region

- In the transit region,two PI controllers are applied to connect the final state of the free region and the initial state of the drift region.
- The steering PI controller reduces the error between current yaw angle and initial yaw angle in the drift region.
- The rear-drive torque PI controller reduces the error between the current longitudinal speed and the initial one at the start of the drift region.

# Drift region

- The key idea of drift maneuvers is to saturate the rear tires through either a forward torque or a braking torque.
- Tire saturation from a large rear longitudinal force reduces the maximum available lateral force that friction can provide, allowing the vehicle to easily enter a drift state.

# Phases of Drift region

- The drift maneuver is described by three basic phases:

1) Turn-in phase: The driver turns in the corner and simultaneously applies a large positive rear-drive torque. The vehicle rotates about its vertical axis and starts to slide.

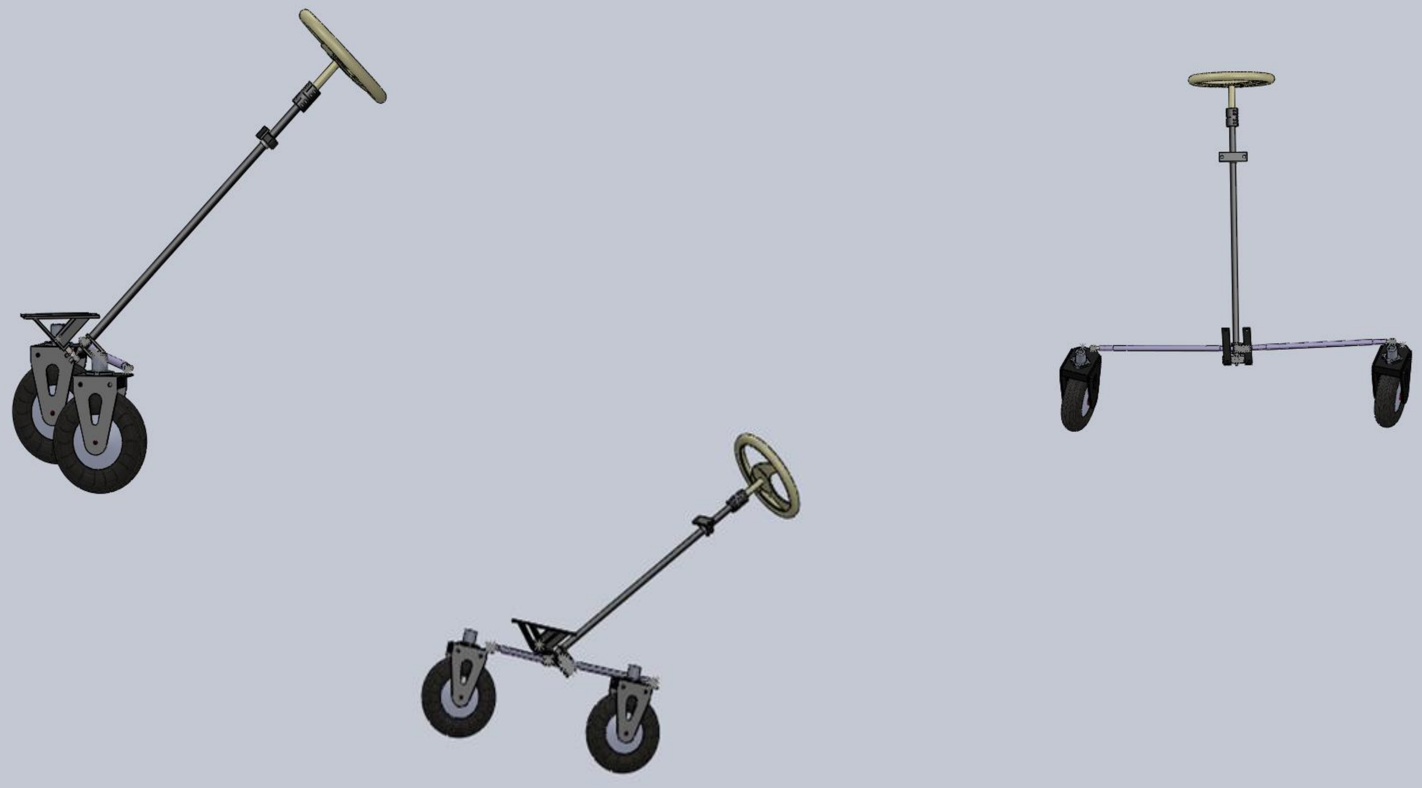
# Phases of Drift region

2) Counter-steering phase: The driver counter steers and simultaneously decreases the rear-drive torque, which is necessary to prevent the vehicle from spinning out.

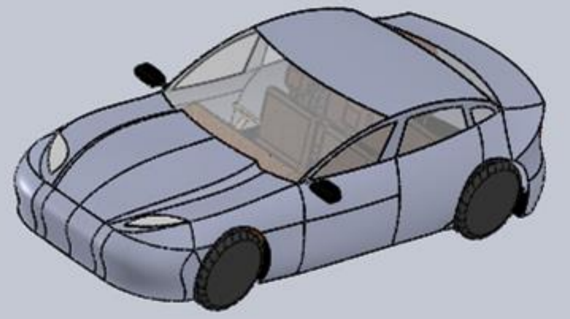
3) Exit phase: The driver stabilizes the vehicle, reducing the side-slip angle and de-saturating tire forces.

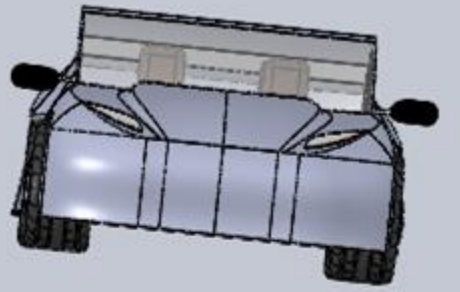
# CAD MODELS

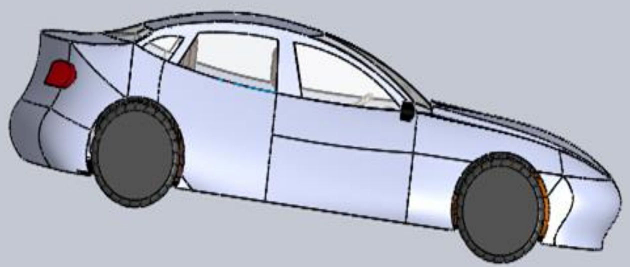
# Steering model : side , orthogonal , front views (left to right)



# Car model : orthogonal , side , front views (left to right)







# MATHEMATICAL MODEL

# Bicycle Model

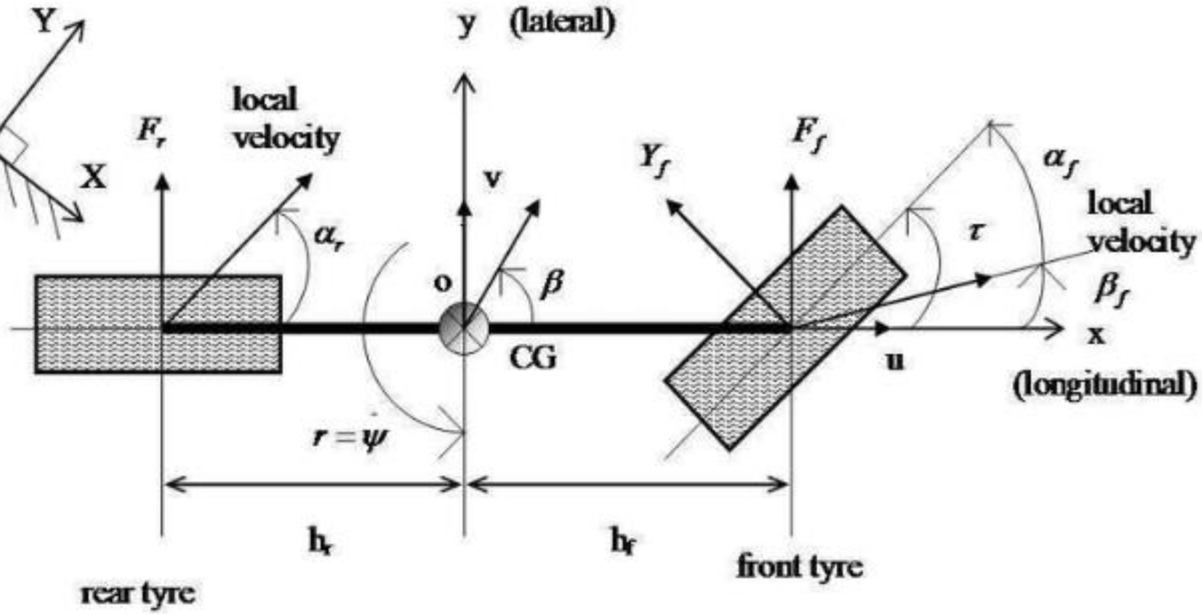
- It is used to model low side slip angle maneuvers.
- This model is obtained from four-wheel vehicle model by lumping the front two tires together and the rear two tires together.
- The state vector of this model is

$$z = [U_x, U_y, r, X, Y, \psi]$$

- The input vector of this model is

$$u = [\delta, F_x^R]$$

# Bicycle Model



# Equation Of Motion

$$\dot{U}_x = \frac{1}{m}\sum F_x + U_y r = \frac{1}{m}F_x^R + U_y r$$

$$\dot{U}_y = \frac{1}{m}\sum F_y - U_x r = \frac{1}{m}(F_y^F + F_y^R) -$$

$$\dot{r} = \frac{1}{I_z}\sum M_z = \frac{1}{I_z}(aF_y^F - bF_y^R)$$

$$\dot{X} = U_x \cos\psi - U_y \sin\psi$$

$$\dot{Y} = U_x \sin\psi + U_y \cos\psi$$

$$\dot{\psi} = r$$

# Equations Of Motion

$U_x$ : longitudinal velocity of vehicle

$U_y$ : lateral velocity of vehicle

r : yaw rate

X,Y describe the position of vehicle

$\Psi$ : yaw angle of the vehicle

$\boldsymbol{\delta}$ : steering angle

$F^R{}_X$ : longitudinal force acting on the wheel

Note : As the assumed model is rear wheel drive, $F_X^f$ is taken as zero.

# Pacejka Tire Model

The Pacejka model is referred to as the `magic tire model' as it is categorized as a semi-empirical model, because the parameters within the model are estimated from data and do not correspond to any physical terms.

The Analytical expression of the model is given by:

$$F_y(\alpha) = D\sin(C\tan^{-1}(B(1-E)\alpha + E\tan^{-1}(B\alpha)))$$

The Pacejka model remains one of the most popular models in the vehicle dynamics community for its ability to describe a wide spectrum of tires.

# Pacejka Tire Model

In many applications, the Pacejka model is simplified by removing the curvature factor, giving the following simplified model:

$$F_y(\alpha) = D \sin(C \tan^{-1}(B\alpha))$$

Where:

B is stiffness factor

C is shape factor

D is peak value

E is curvature value

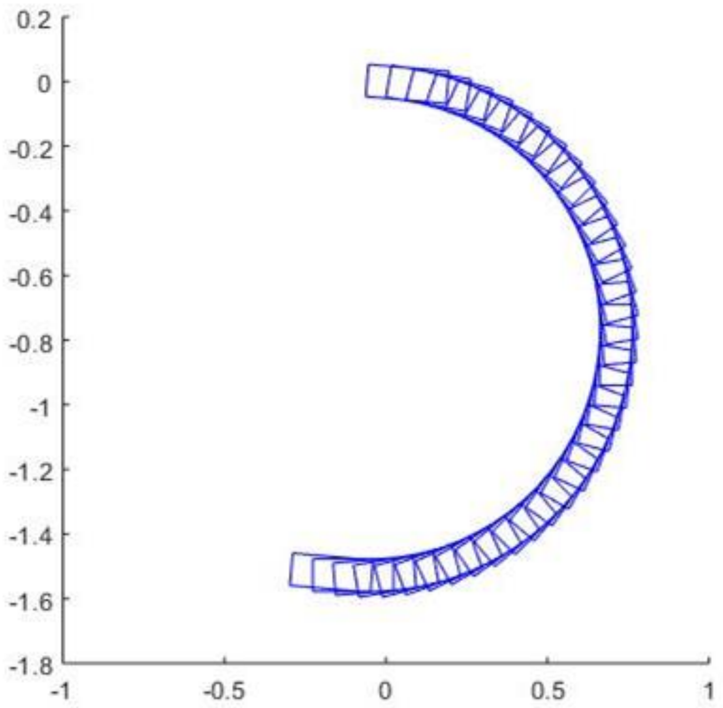
Pacejka Tire model is used in the bicycle model to obtain the lateral force acting on tires with the slip angle of the wheel.

The values of the parameters used are mentioned below.

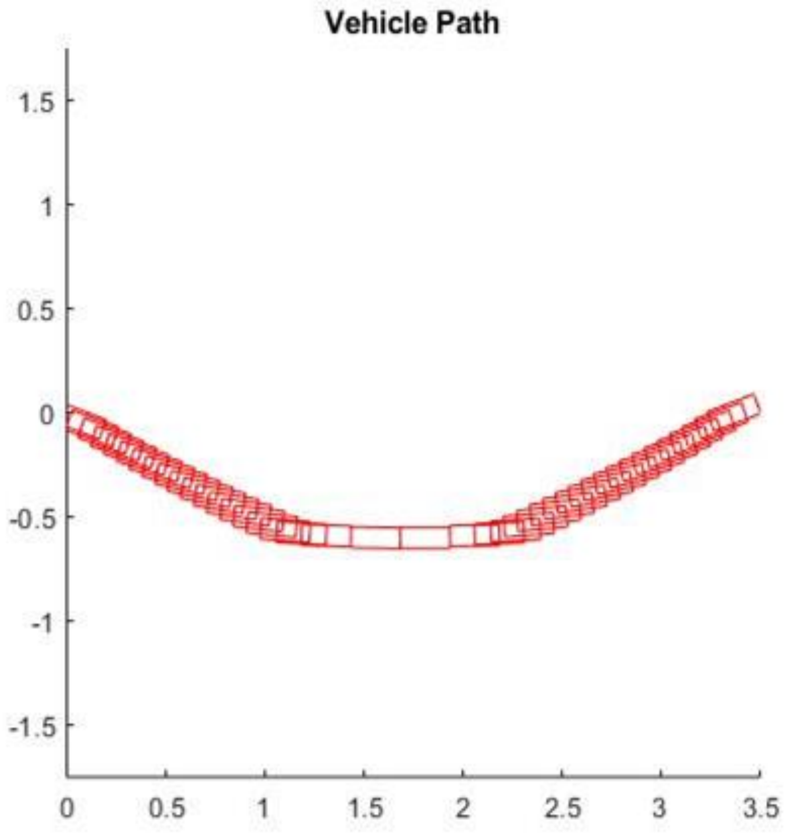
| Parameter | Carsim | RC-car | Parameter | Carsim | RC-car |
|---|---|---|---|---|---|
| $m$ [kg] | 1830 | 1.95 | $b$ [m] | 1.65 | 0.125 |
| $I_z$ [kg·m$^2$] | 3287 | 0.24 | $C_S^F$ [N/rad] | 36000 | 1.76 |
| $a$ [m] | 1.4 | 0.125 | $C_S^R$ [N/rad] | 36000 | 1.76 |

# RESULTS AND SIMULATIONS

# Vehicle Path (Bicycle model)

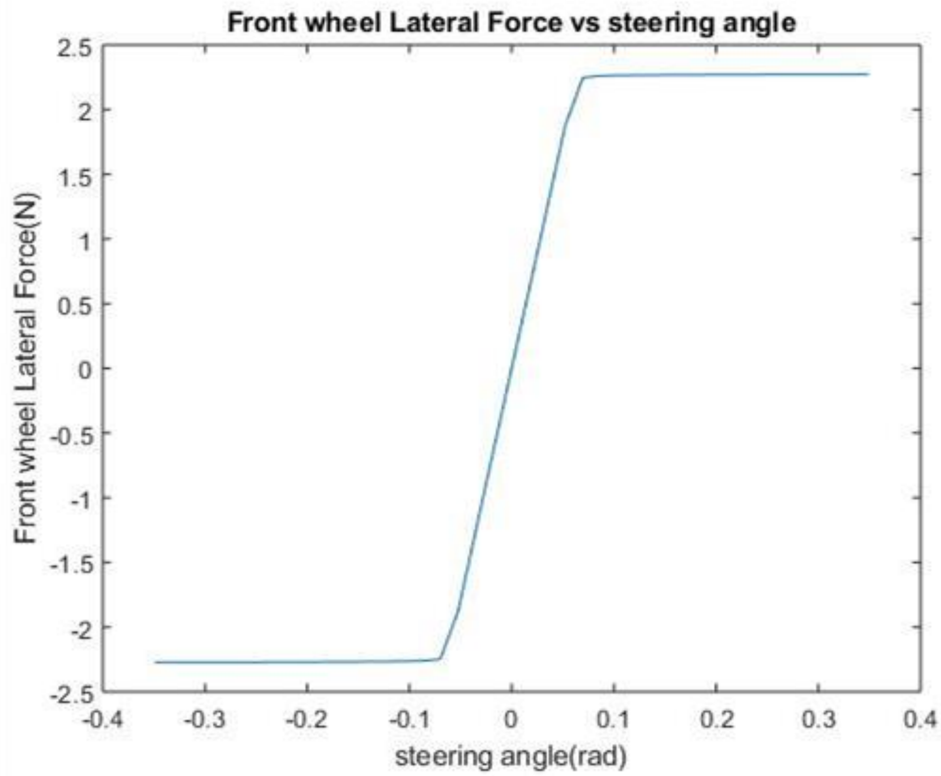


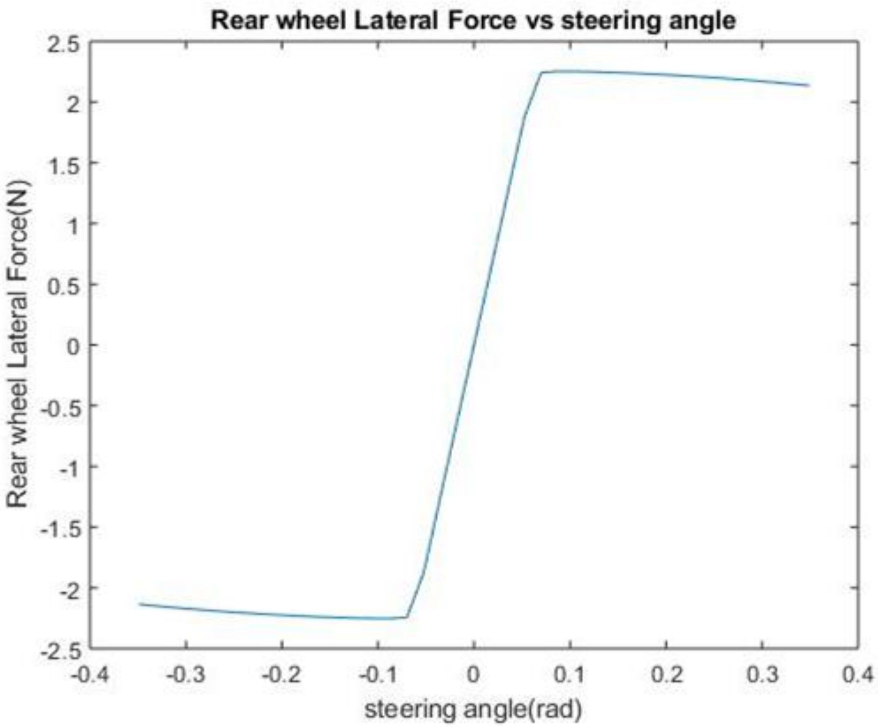

In this case, the steering angle of the vehicle is kept as constant (20 degrees) .Also the velocity is chosen as constant (1.2 m/s) and Pacejka tire model is implemented. For these chosen conditions slip angle at each point is obtained as constant and is of low value.

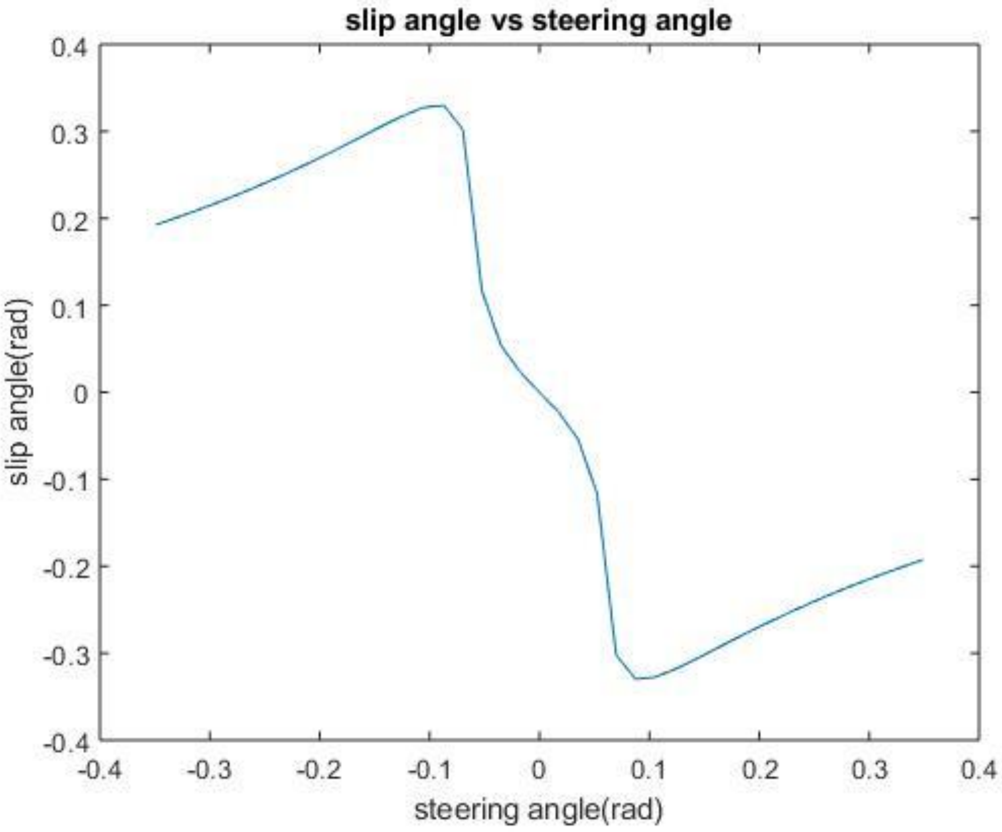



In this case, velocity of vehicle is kept as constant and steering angle is increased from -20 degrees to 20 degrees and the equations of motion are solved.

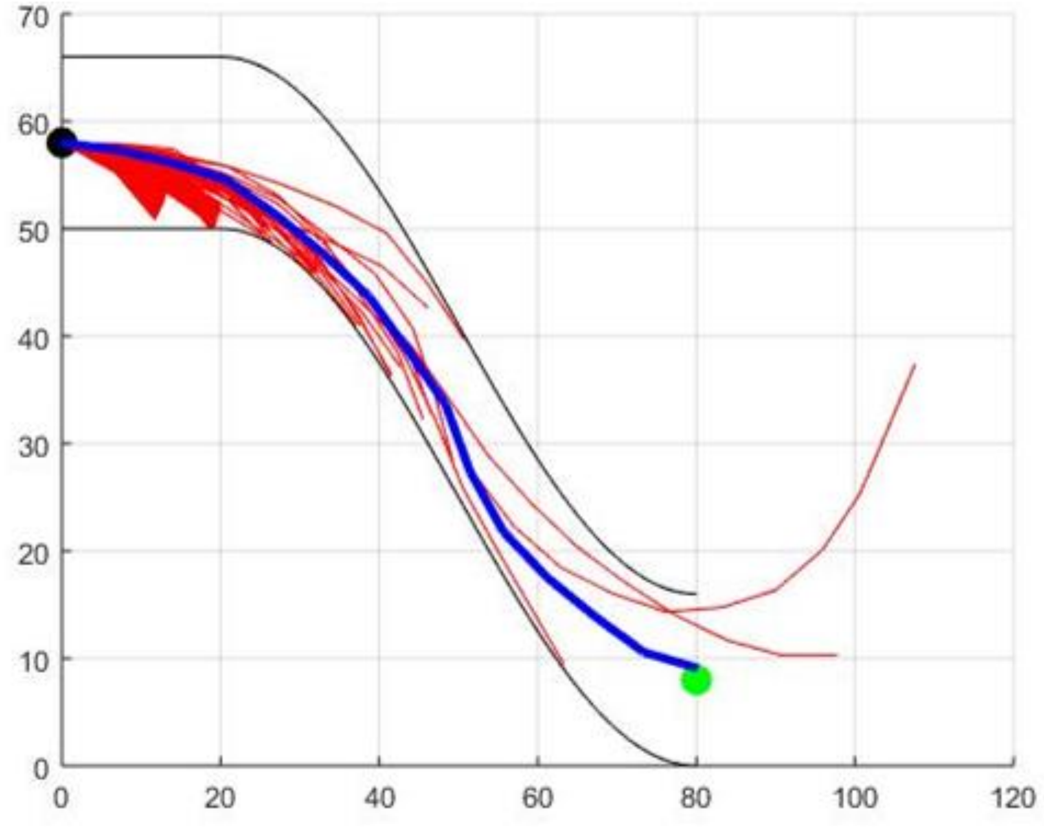
Pacejka tire model is use to describe the lateral forces acting on the wheels (tyres.)


Front wheel Lateral Force vs steering angle
Front wheel Lateral Force(N)
steering angle(rad)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4

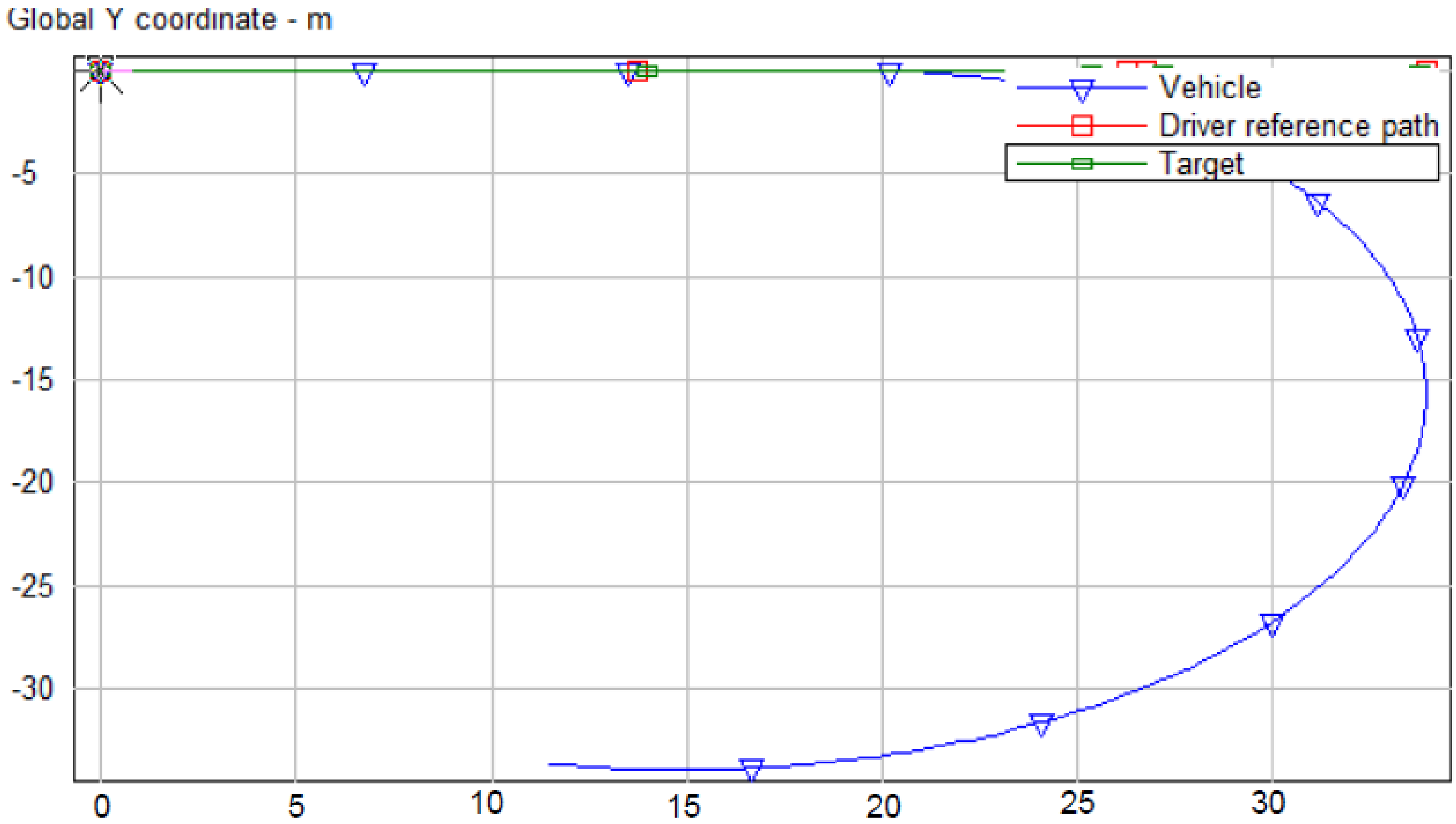

Rear wheel Lateral Force vs steering angle
Rear wheel Lateral Force(N)
steering angle(rad)
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4


slip angle vs steering angle
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
slip angle(rad)
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
steering angle(rad)

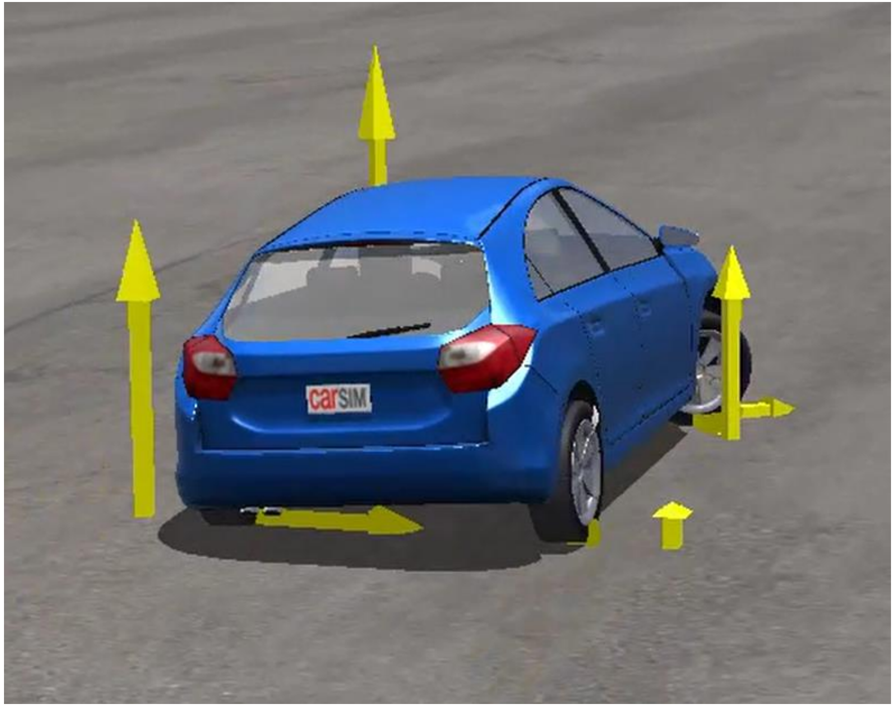
# Free Region (Path Planning)



# Drift Region (Path Planning)



# Vehicle Path simulation in Carsim



# References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2. Autonomous Drift Cornering with Mixed Open-loop and Closed-loop Control,Department of Automotive Engineering Tsinghua University, Beijing,China,Department of Mechanical Engineering, University of California,Berkeley, USA
3. Planning and Control of Drift Maneuvers with the Berkeley Autonomous Race Car by Jon Matthew Gonzales


THANK YOU