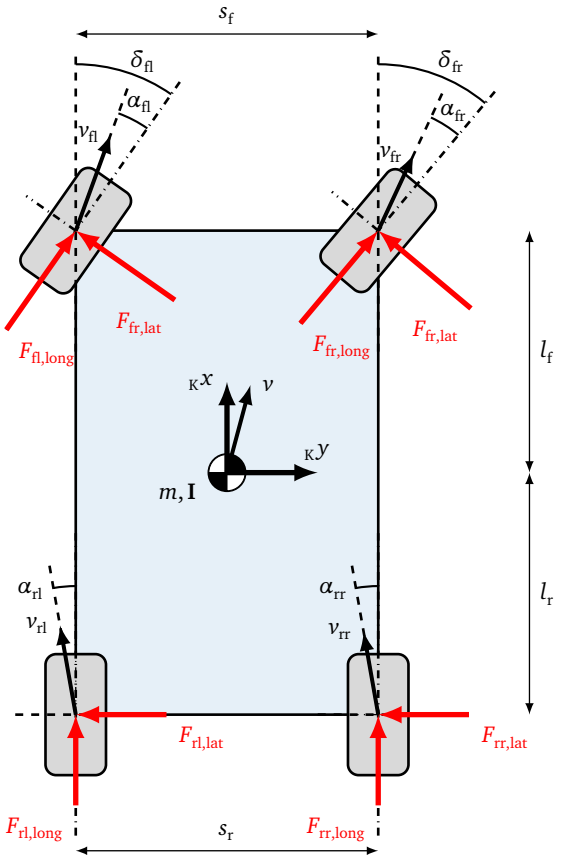
Nonlinear double track model

The vehicle dynamics model can be found within the *sim_vehicle_dynamics* repository under *models/vehicledynamics*.

Vehicle kinematics

The dynamic model of the vehicle is based on a double track model as depicted below. The model is implemented using the *Vehicle Dynamics Blockset* within MATLAB *Simulink*. A more detailed description of the double track model, coordinate conventions, internal model structure, input and output quantities can be found in the *Roborce Wiki*.



The model includes the following effects:

- horizontal and vertical vehicle dynamics with roll, yaw and pitch movement
- individual steering angles at the front axle wheels
- individual drive and brake forces at the four wheels
- vertical dynamics model with linear spring-damper-elements
- wheel rotational dynamics with separate brake actuator model
- aerodynamic model with longitudinal drag and lift forces
- computation of tire forces and moments according to the *MF-Tyre* 6.1 model
- road friction variation using the *MF-Tyre* model scaling factors
- computation of sensor position and orientation for vehicle fixed sensors like camera and lidar

The model is extendable to the following effects:

- linear suspension kinematics and antisway
- aerodynamic lateral forces and aerodynamic moments
- tire pressure dependency

The model does not include the following effects:

- nonlinear suspension kinematics and characteristics, e.g. nonlinear spring-damper-elements, separate bound and rebound forces, elasto-kinematics
- multibody interpretation of vehicle kinematics

The model uses the z-down-convention of the *Vehicle Dynamics Blockset* according to SAE J670. This is important for the correct specification and interpretation of input and output quantities.

Tire model

The nonlinear double track model uses the *MF-Tyre 6.1* model for computation of longitudinal, lateral and combined tire forces. The *MF-Tyre 6.1* model implements the generic *magic formula*

$$
\begin{aligned}
Y(X) &= y(x) + S_{\mathrm{v}} \\
y(x) &= D \sin(C \tan^{-1}(Bx - E(Bx - \tan^{-1}(Bx)))) \\
x &= X + S_{\mathrm{h}}
\end{aligned}
$$

where the coefficients B, C, D, E, S_{h} and S_{v} are functions of parameter variations relative to a nominal tire operation state themselves. The coefficients can be manipulated by user-individual scaling factors.

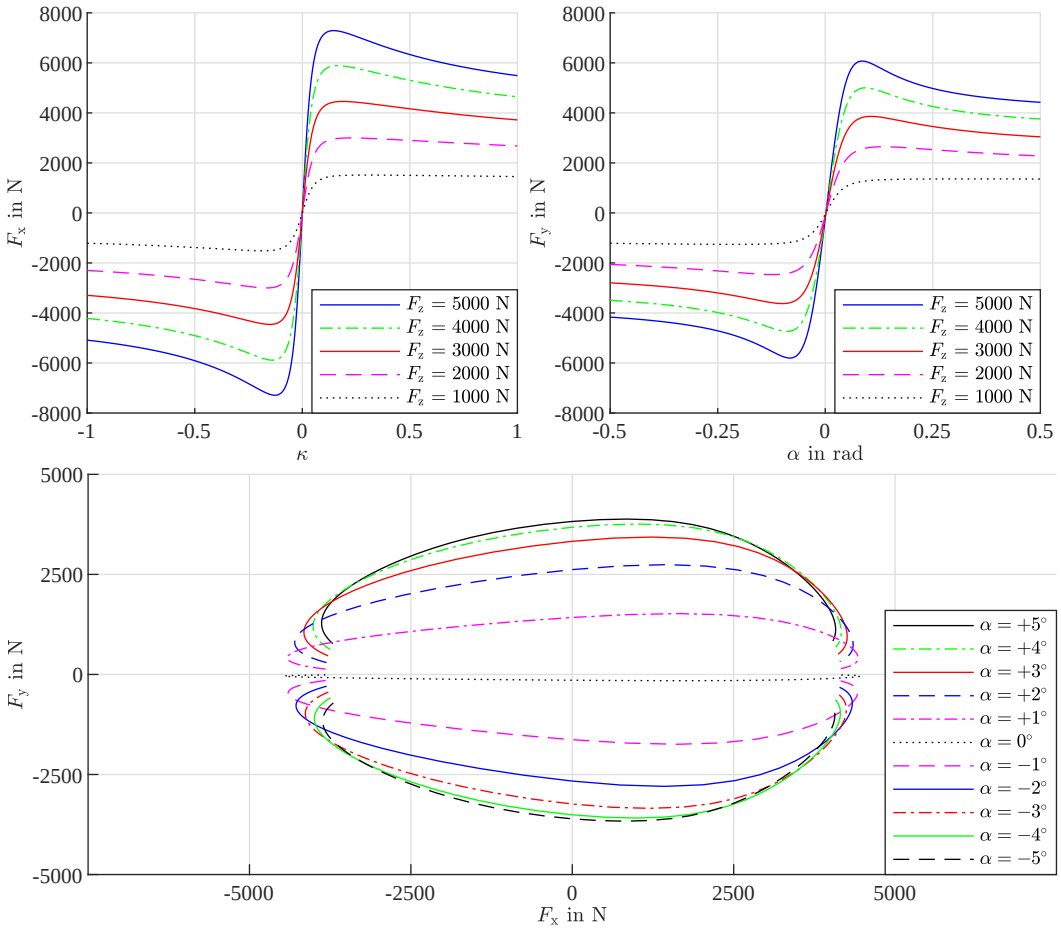
The model includes the following effects:

- Linear and nonlinear tire operating range
- Load degressivity and camber influence
- Combined longitudinal and lateral tire force computation
- Consideration of turnslip influence
- Rolling resistance moment, aligning torque and overturning couple
- Vertical tire model

The model does not include the following effects:

- Tire pressure dependency due to unavailable parameters
- Temperature modeling in the contact patch due to model incapability

An exemplary family of longitudinal, lateral and combined tire forces based on the *MF-Tyre 6.1* model is depicted below. The tire forces and moments are computed for each wheel separately.


8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
F_x in N
-1
-0.5
0
0.5
1
κ
$F_z = 5000$ N
$F_z = 4000$ N
$F_z = 3000$ N
$F_z = 2000$ N
$F_z = 1000$ N
F_y in N
-0.5
-0.25
0
0.25
0.5
α in rad
5000
2500
0
-2500
-5000
F_y in N
F_x in N
$\alpha = +5°$
$\alpha = +4°$
$\alpha = +3°$
$\alpha = +2°$
$\alpha = +1°$
$\alpha = 0°$
$\alpha = -1°$
$\alpha = -2°$
$\alpha = -3°$
$\alpha = -4°$
$\alpha = -5°$