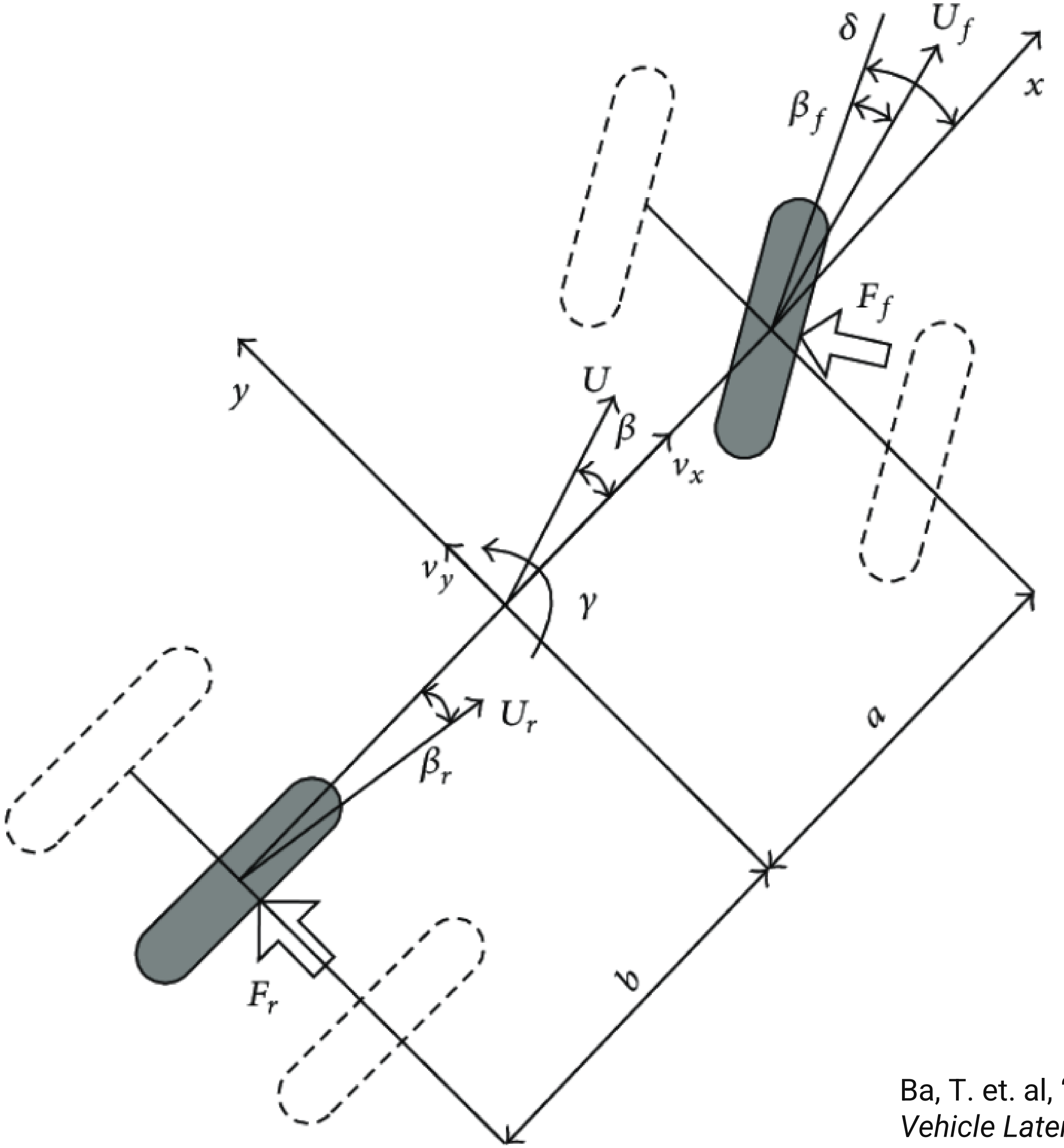
Design task 2: Lateral dynamics

Preliminaries

- Three configurations:
  - Configuration 1: $l_f = 0.37 * L$
  - Configuration 2: $l_f = 0.63 * L$
  - Configuration 3: $l_f = 0.45 * L$
- These three configurations to be used unless otherwise explicitly mentioned.

- Vehicle data
  - Mass = 1675 kg
  - Wheelbase =2.675 m
  - Steering ratio = 15.9
  - Cornering Stiffness **(for one wheel, not one axle)**: $C = c_0 F_z + c_1 F_z^2$, where c_0 = 30.7 $(\text{rad})^{-1}$, c_1 = **-**0.00235$(\text{N.rad})^{-1}$ and F_z is normal force (**for one wheel, not one axle**).



Ba, T. et. al, "*Application of Recursive Subspace Method in Vehicle Lateral Dynamics Model Identification*", Mathematical Problems in Engineering, 2016.

Objectives

- Model steady state lateral dynamics of a vehicle in the linear range (Task 1)
- Model and simulate the transient lateral dynamics of the vehicle in Simulink
- Model, simulate and understand the effect of load transfer and roll stiffness distribution
- Model, simulate and understand the effect of combined slip on vehicle handling

Task 1: Modeling of steady state linear lateral dynamics (5p)

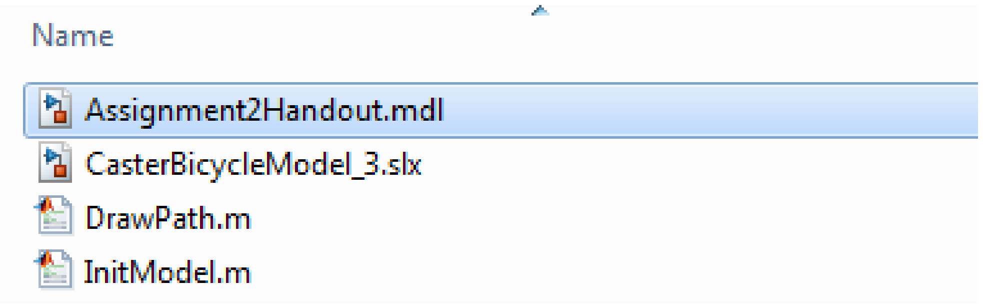
- Derive steady state cornering equations for a 2-degree of freedom single track vehicle at high speeds. Assume small slip and steering angles. comp. p. 292
- Determine the under-steer gradient and express the same in rad/(m/s^2). (Mind the unit!!) comp. p. 297
- Determine the critical and/or characteristic speeds.
- Determine the steering wheel angle required to get 4 m/s^2 lateral acceleration.
- Plot the steering wheel angle required vs speed curves for the three cases. Identify which of them (if any) are understeer, oversteer and (relatively) neutral steer.

Objectives

- Model steady state lateral dynamics of a vehicle in the linear range
- Model and simulate the transient lateral dynamics of the vehicle in Simulink (Task 2)
- Model, simulate and understand the effect of load transfer and roll stiffness distribution
- Model, simulate and understand the effect of combined slip on vehicle handling

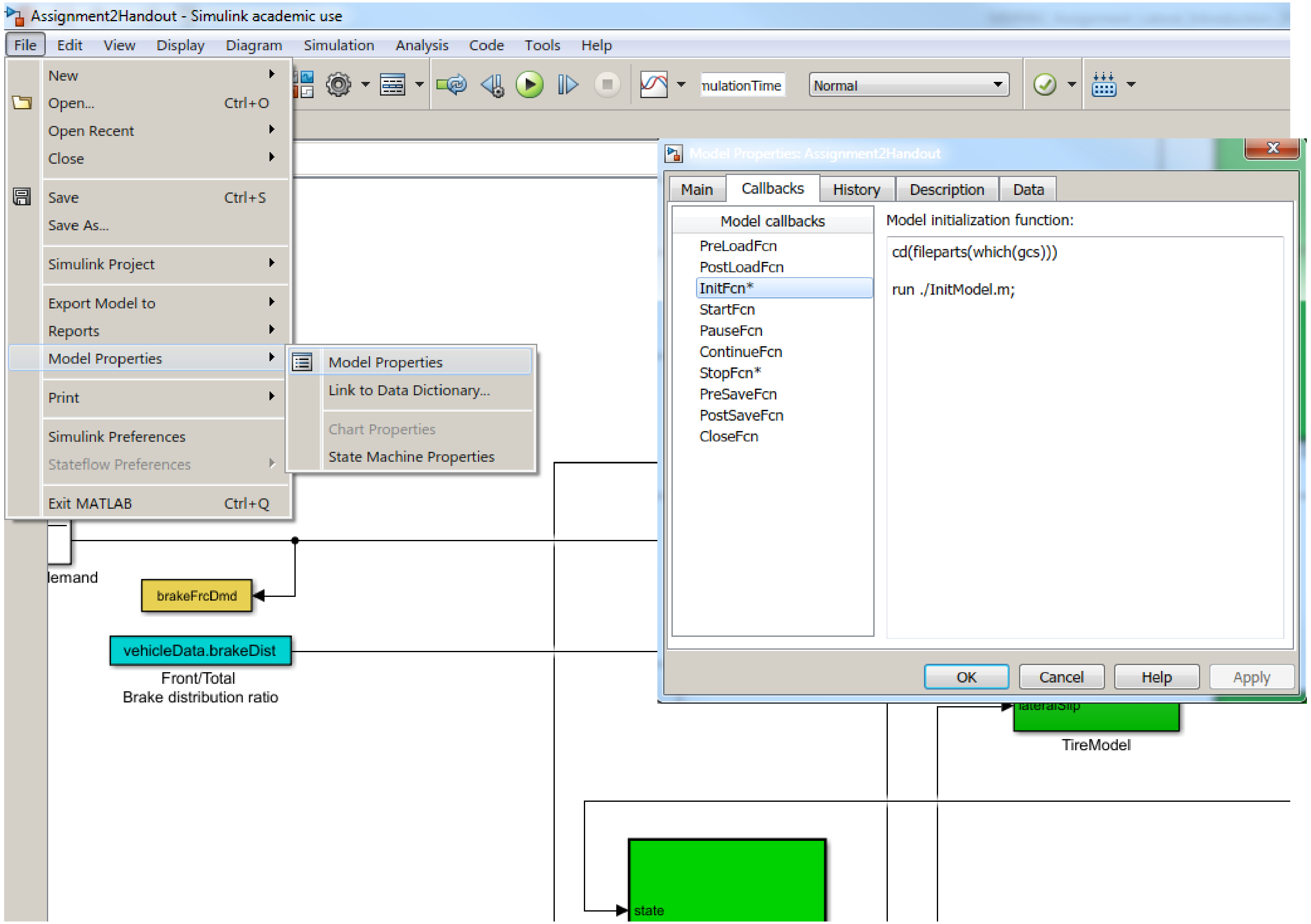
Task 2: Simulation of linear lateral dynamics (5p)

- Simulations done in Matlab/Simulink.
- A skeleton of the Simulink vehicle model is provided.



- Needs to be completed by filling in code in some of the blocks.
- Areas where code needs to be completed are marked with question marks (??).

Task 2: Simulation of linear lateral dynamics (5p)



Task 2: Simulation of linear lateral dynamics (5p)

- Write down the lateral slip equations and equations of motion in the x-y plane for a single track vehicle model at high speed. Ignore aerodynamic drag and rolling resistance.
- Run the simulation for the three configurations specified with the steering angles determined in task 1.4. Verify that the vehicle reaches 4 m/s^2 of lateral acceleration in each case.
- Which vehicle setup is the quickest to respond to steering?

See directly in Simulink!

Objectives

- Model steady state lateral dynamics of a vehicle in the linear range
- Model and simulate the transient lateral dynamics of the vehicle in Simulink
- Model, simulate and understand the effect of load transfer and roll stiffness distribution (Task 3)
- Model, simulate and understand the effect of combined slip on vehicle handling

See directly in Simulink!

Task 3: Effect of load transfer and roll stiffness distribution (5p)

- Lateral load transfer requires us to consider each wheel on each axle. But we only have a one track model with axles (not wheels).

- Essentially, two track model for load transfer, one track model for the rest.

Objectives

- Model steady state lateral dynamics of a vehicle in the linear range
- Model and simulate the lateral dynamics of the vehicle in Simulink
- Model, simulate and understand the effect of load transfer and roll stiffness distribution
- Model, simulate and understand the effect of combined slip on vehicle handling (Task 4)

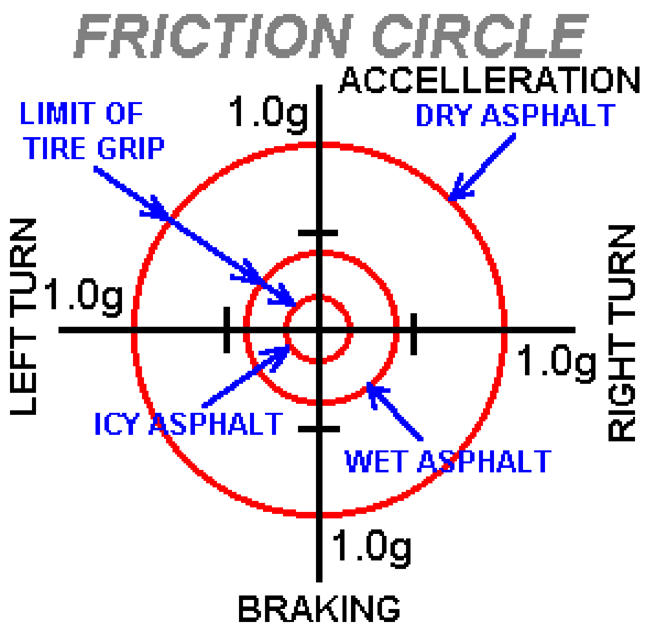
- *Simplified models used. Not accurate at limits of vehicle handling.*

Task 4: Effect of combined slip (5p)

- Implement a simple combined slip formulation by correcting the axle lateral stiffness depending on the amount of traction force available.

$$C_{corrected} = \left(\frac{\sqrt{(\mu F_z)^2 - F_x^2}}{\mu F_z}\right) \times C$$

  - C is the axle lateral stiffness
  - The correction factor is derived from the mathematical representation of the friction circle.
  - This correction has to be added in the 'LatForce' block.



Useful commands/tips

- Make sure to save all files before starting a simulation to ensure that all changes are reflected in the simulation.
- After a simulation, if you need to store data so that you can compare it with the results of another simulation, you can use the '`save`' command. The command is used as follows:
  `'save <filename> <variable 1> <variable 2> <variable 3>…'`
- In some cases, it might be of help to write a short Matlab script that loops through the simulation for different cases. The simulation can be started from a Matlab script using the `sim(<path to model>)` command.

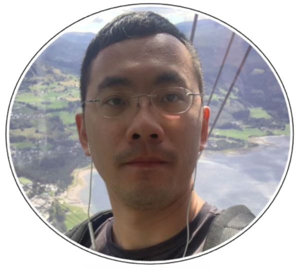
Task 5: Driving experience in simulator (5p)

The idea is to give you a feeling and understanding of the vehicle dynamics properties based not on numbers and plots, but on you own experience.

- You will drive the model you developed during previous tasks.
- It need to be adapted in order to be used in the HIL application.
- You will drive number of experiments with different vehicle parameters so you can see how they affect the motion.
- You will also have chance to drive a high-fidelity vehicle model.

Assistants

Sachin Janardhanan



Yansong Huang

sachin.janardhanan@chalmers.se
yansong.huang@chalmers.se

Caster:

Admin:

Sam Azadi

Instructors:

4-6 instructors

Maximum: 25 points

Pass: 10 points

Deadline: 2022-12-15 (23:59 hrs)

When submitting your final report in Canvas, please submit a separate pdf-file for the report and one separate zip file for the code. (One set for each group)

Thank you!

Questions?