TECHNOLOGIES FOR AUTONOMOUS VEHICLES

LANE KEEPING CONTROL – GROUP HOMEWORK

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State feedback lane keeping control simulation

In first instance, the vehicle is described by the state-space representation introduced in the module

$$\underbrace{\begin{bmatrix} \dot{e}_1(t) \\ \ddot{e}_1(t) \\ \dot{e}_2(t) \\ \ddot{e}_2(t) \end{bmatrix}}_{\dot{x}(t)} = \underbrace{\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & -\frac{C_f+C_r}{m_v\bar{V}_x} & \frac{C_f+C_r}{m_v} & \frac{C_r l_r - C_f l_f}{m_v\bar{V}_x} \\ 0 & 0 & 0 & 1 \\ 0 & \frac{C_r l_r - C_f l_f}{J_\psi \bar{V}_x} & \frac{C_f l_f - C_r l_r}{J_\psi} & -\frac{C_r I_r^2 + C_f I_f^2}{J_\psi \bar{V}_x} \end{bmatrix} \underbrace{\begin{bmatrix} e_1(t) \\ \dot{e}_1(t) \\ e_2(t) \\ \dot{e}_2(t) \end{bmatrix}}_{x\,(t)}}_{Ax(t)} + \underbrace{\begin{bmatrix} 0 \\ \frac{C_f}{m_v} \\ 0 \\ \frac{C_f l_f}{J_\psi} \end{bmatrix}}_{B_1} \delta(t) + \underbrace{\begin{bmatrix} 0 \\ \frac{C_r l_r - C_f l_f}{m_v \bar{V}_x} - \bar{V}_x \\ 0 \\ -\frac{C_r l_r^2 + C_f l_f^2}{J_\psi \bar{V}_x} \end{bmatrix}}_{B_2} \dot{\psi}_{des}(t)$$

$$\dot{x}(t) = Ax(t) + B_1\delta(t) + B_2\dot{\psi}_{des}(t)$$
$$y(t) = Cx(t), \qquad C = I_4$$

For control design, assume that the vehicle is moving at constant velocity

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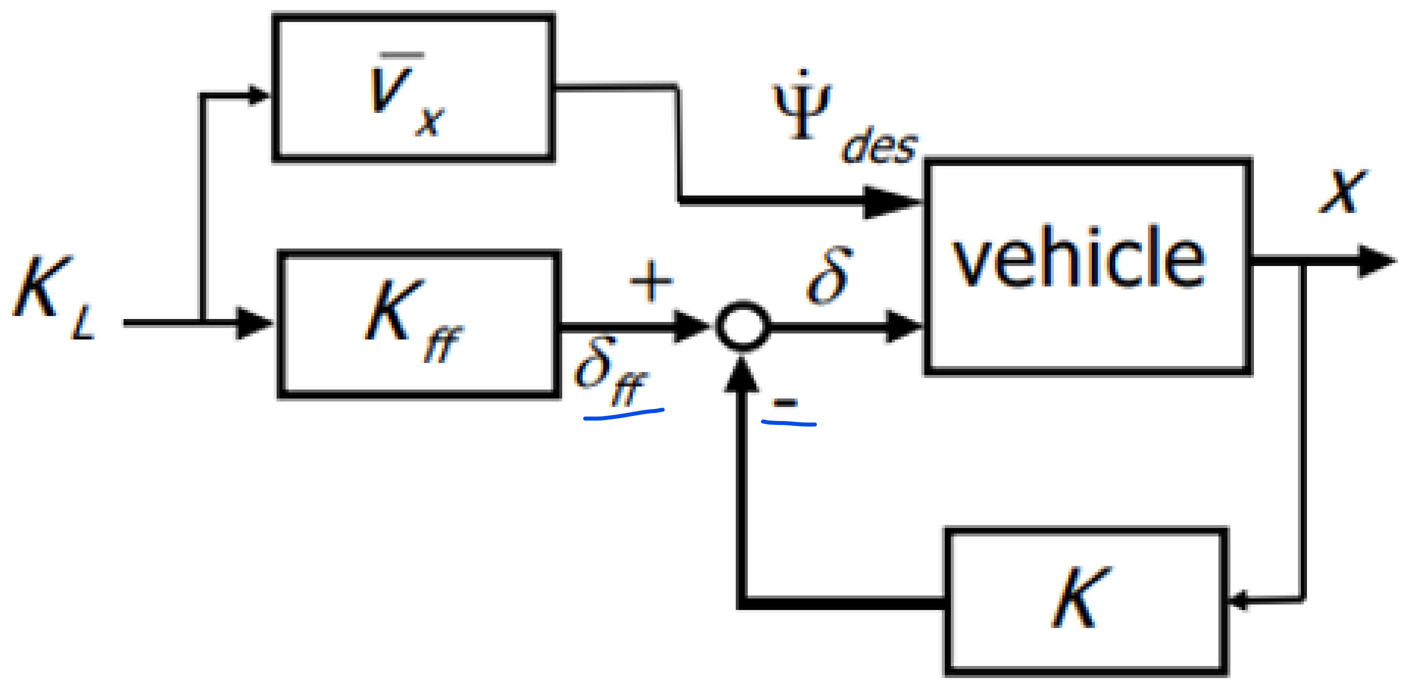
State feedback control architecture



Would be nice to plot the side slip angle, front slip angle, rear slip angle, actual traj. radius, comparisons with reference trajectory
Bare block diagram -> no full vision of how the vehicle is behaving

State feedback lane keeping control simulation

- Implement a linear state-space formulation of a single-track model suitable for lane keeping and path tracking control, and evaluate its response for various operating conditions

  check how properties (ex. eigenvalues real part) change with different vehicle speed
  Step-steering input to analyze response we get
  Basic discussion of response
  We could even use Model 2??

- Implement a linear state feedback lane keeping / path tracking controller including a feedforward contribution

- Use a pole placement methodology and/or a linear quadratic set-up for tuning the control structure

- How would you introduce an integral control contribution in the controller formulation?

  Either writing only words or actually design in the controller
  Excellent job -> push the boundaries !!!!!!!!!

- For the previous controllers, evaluate how the control gains vary as a function of vehicle speed, for reasonable pole placement or cost function weight specifications

Show in your report (controller should work at different speeds, when dynamic response changes with speed)
(ex. over/under damped yaw rate response)

Repeat design of control gain at diff. speed
Lane keeping controller -> variation of components of K as function of the speed

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- Evaluate the performance of different tunings of the previous controllers along the curvature profile of the following slide at the constant speed of 80 km/h, and (optionally) other speed and curvature profiles (e.g., skidpad or obstacle avoidance manoeuvres) relevant to the operating domain of the selected simulation model

  slowly increasing the speed in simulink

- Assess the significance of the feedforward and feedback steering angle contributions We should see that (exp in quasy steady-state), most of the action comes from the feedforward

  ??

- Plot the relevant vehicle response variables. For example, include the plots of the lateral and heading angle errors, yaw rate, sideslip angle, lateral acceleration, and front and rear slip angles, as well as the reference and actual vehicle trajectories

- Vary the rear axle cornering stiffness to assess how the variation of the level of vehicle understeer or oversteer modifies the control input profiles along the selected test Run simulation for some profile and check how control input vary when changing rear axle cornering stiffiness
  Tests with changed rear cornering stiffness and no change in control gain -> indication of robustness

- Consider the effect of the presence of a pure time delay of 0.01 s for the generation of the feedforward control input

  Reference curvature comes from a vision system (processing and conversions)
  Shift in time of Kl

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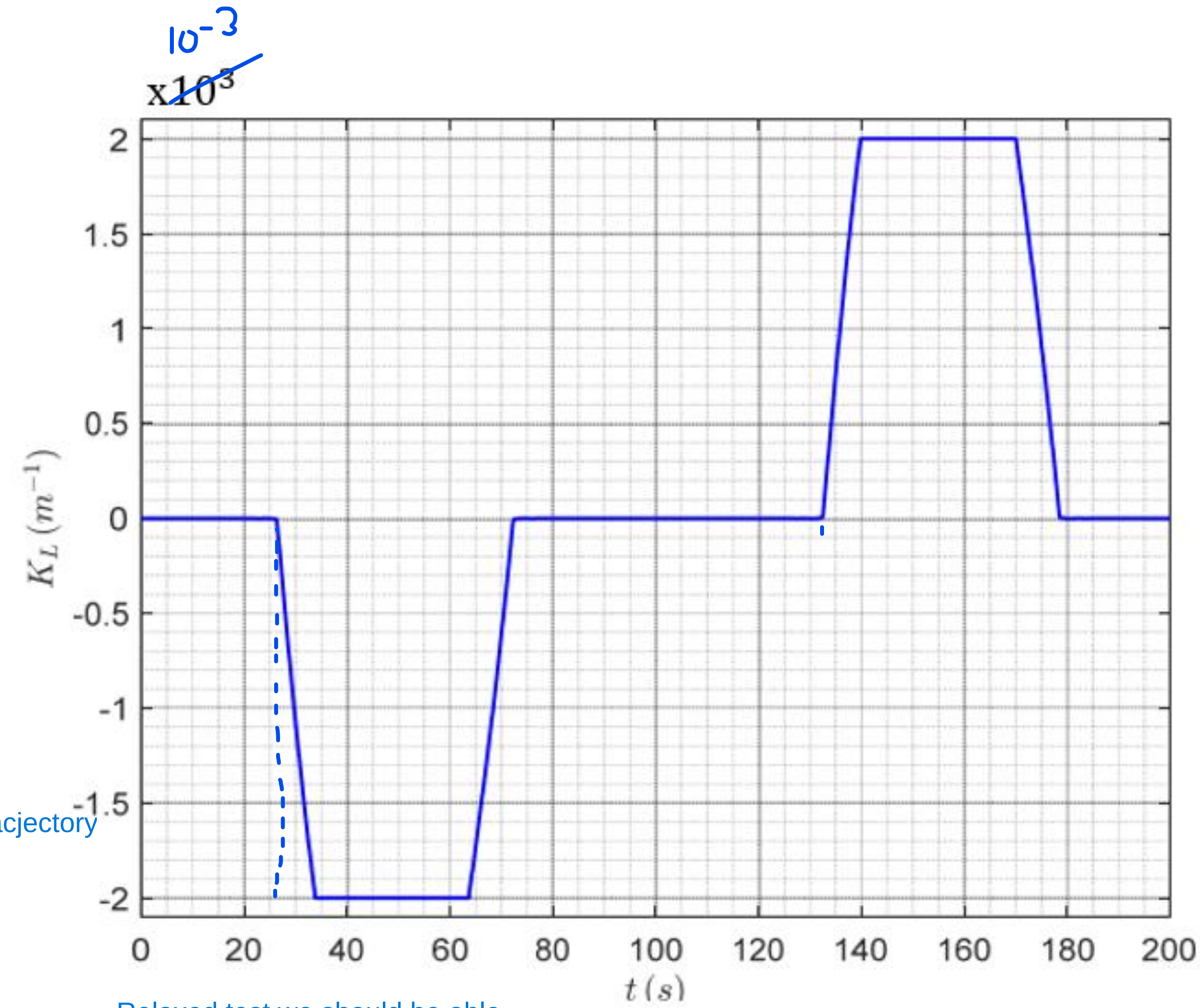
Example of relevant curvature profile

You can plot the actual desired tracjectory



Relaxed test we should be able

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Values of the baseline vehicle parameters, which can be varied during the analysis

Vehicle mass = 1575 kg

Yaw mass moment of inertia = 2875 kgm^2

Front semi-wheelbase = 1.3 m

Rear semi-wheelbase = 1.5 m

Front axle cornering stiffness = 2 x 60000 N/rad

Rear axle cornering stiffness = 2 x 57000 N/rad

Physical constraint

$|\delta(t)| \leq 25$ deg

State feedback lane keeping control simulation

- The work has to be implemented by groups of 2-3 students
- The deliverables are represented by the resulting simulation system and a short report, to be submitted on the teaching portal (zip with model, report, controller, etc.) Proper figures, short
- The submission deadline is 16 June 2024

Following week setup of short discussions

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