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

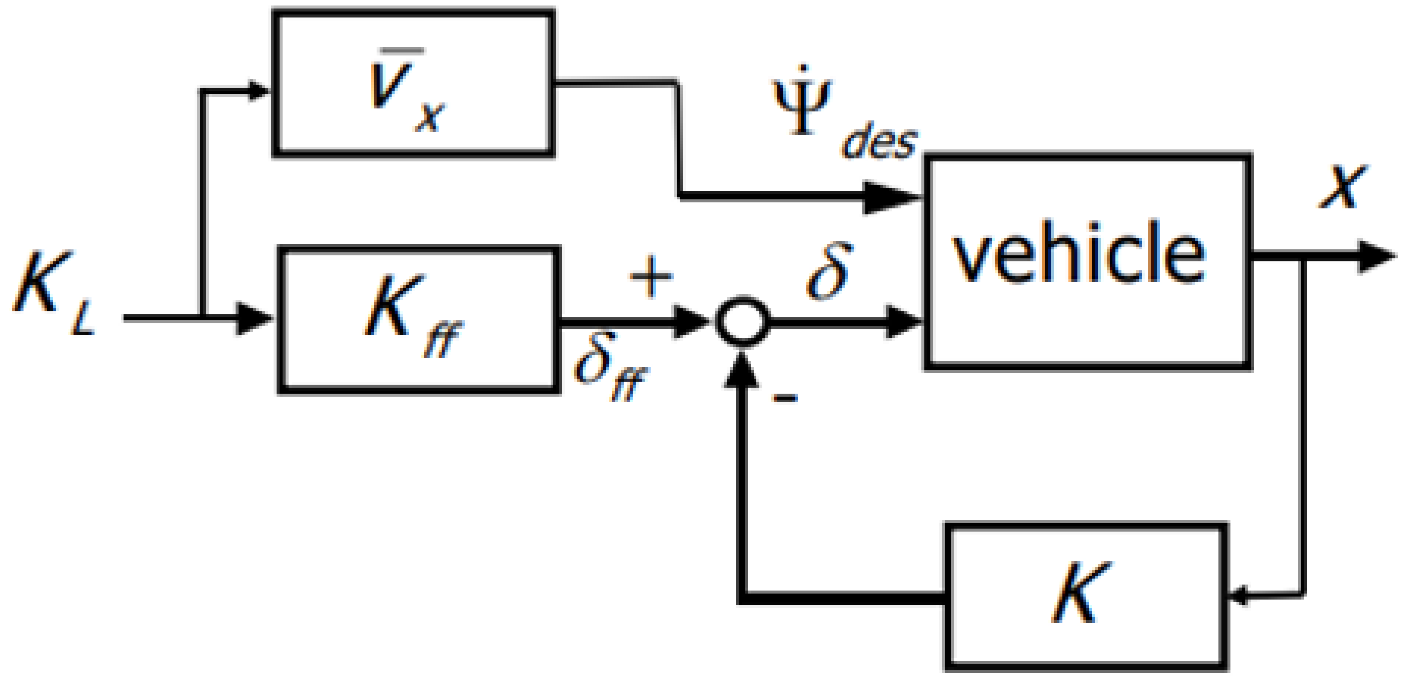
$$
\underbrace{\begin{bmatrix} \dot{e}_1(t) \\ \ddot{e}_1(t) \\ \dot{e}_2(t) \\ \ddot{e}_2(t) \end{bmatrix}}_{\dot{x}(t)} = \underbrace{\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & -\frac{C_f+C_r}{m_v \bar{V}_x} & \frac{C_f+C_r}{m_v} & \frac{C_r l_r - C_f l_f}{m_v \bar{V}_x} \\ 0 & 0 & 0 & 1 \\ 0 & \frac{C_r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

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

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

State feedback lane keeping control simulation

State feedback control architecture



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
- 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?
- 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

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State feedback lane keeping control simulation

- 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
- Assess the significance of the feedforward and feedback steering angle contributions
- 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
- Consider the effect of the presence of a pure time delay of 0.01 s for the generation of the feedforward control input

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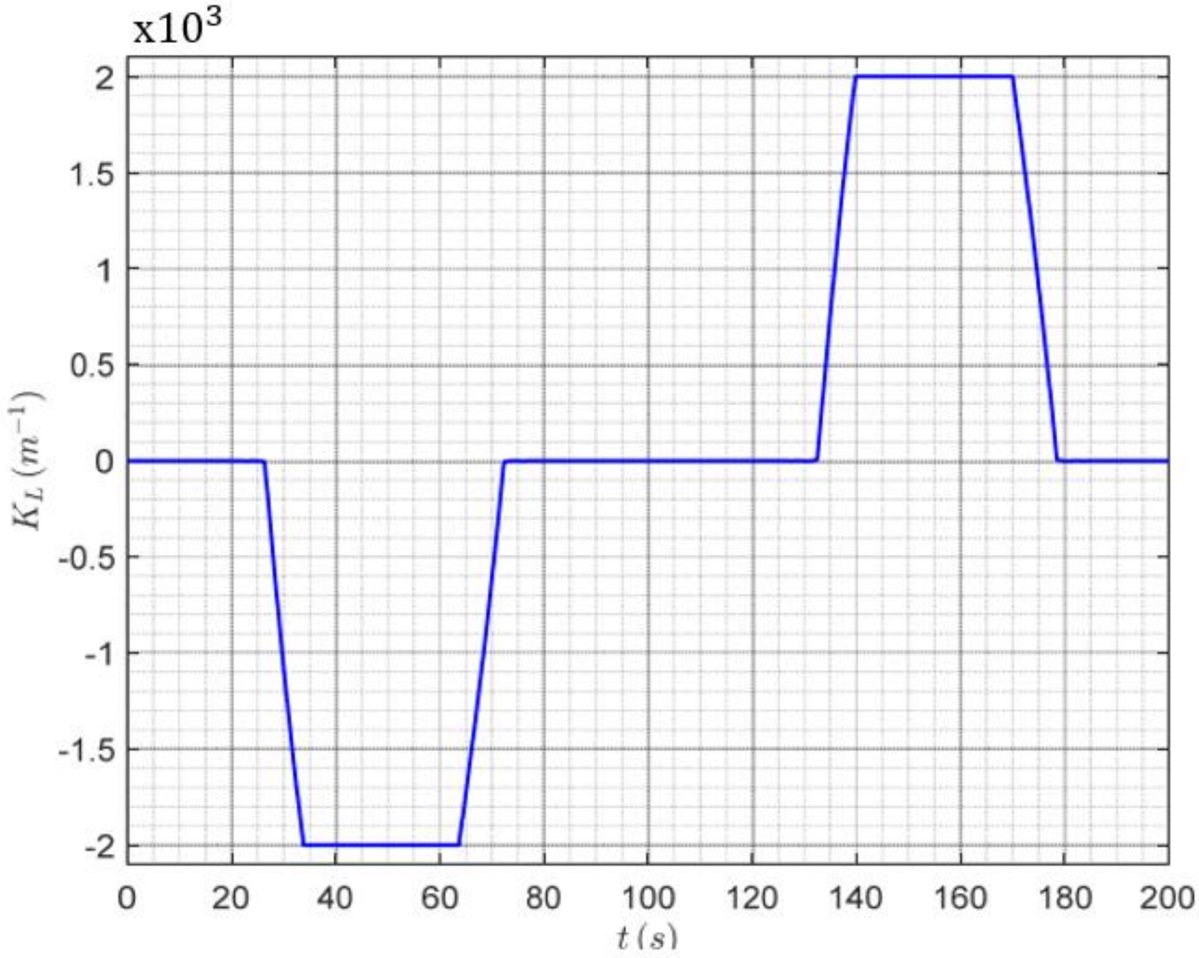
Example of relevant curvature profile



State feedback lane keeping control simulation

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
- The submission deadline is 16 June 2024

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