Driver assistance system design A

Cruise control

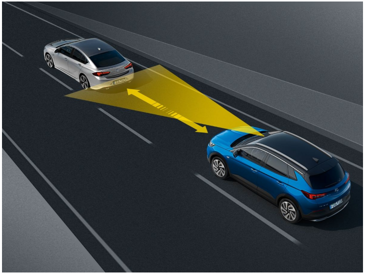
Carlo Novara

Politecnico di Torino
Dip. Elettronica e Telecomunicazioni

Outline

Introduction

- A cruise control system automatically regulates the throttle of a vehicle to maintain a desired speed.
- It is the driver's responsibility to ensure that the vehicle can safely travel at the desired speed on the road.
- If a preceding vehicle travels at a slower speed or is too close to the vehicle, the driver must take action and if necessary apply brakes.
  - Application of the brakes automatically disengages the cruise control system and returns control of the throttle to the driver.



Cruise control

- The architecture of a cruise control system is hierarchical:
  - Upper level controller: imposes the desired vehicle acceleration.
  - Lower level controller: provides the throttle/brake inputs required to have the desired acceleration.
- We focus on the upper controller design (more interesting), supposing that the vehicle is equipped with an effective lower controller.
  - The effect of the lower controller is simply modeled as a delay given by a first-order dynamics.

Cruise control

- The vehicle is represented by the DSTP model

$$
\begin{aligned}
\dot{X} &= v_x \cos\psi - v_y \sin\psi \\
\dot{Y} &= v_x \sin\psi + v_y \cos\psi \\
\dot{\psi} &= \omega_\psi \\
\dot{v}_x &= v_y \omega_\psi + a_x \\
\dot{v}_y &= -v_x \omega_\psi + \frac{2}{m}\left(F_{yf} + F_{yr}\right) \\
\dot{\omega}_\psi &= \frac{2}{J}\left(l_f F_{yf} - l_r F_{yr}\right).
\end{aligned}
$$

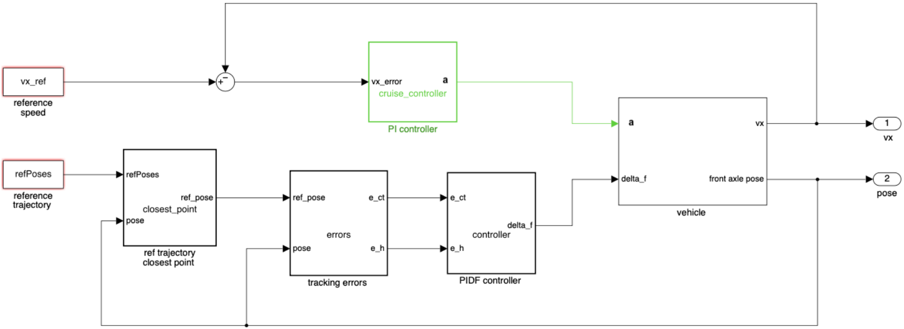
- State: $\zeta = (X, Y, \psi, v_x, v_y, \omega_\psi)$, input: $u = (a_x, \delta_f)$.

Cruise control

- Vehicle command inputs:
  - δ_f: controlled by a PIDF controller previously designed.
  - a_x: controlled by a PI controller (see the next point).
- **PI upper level controller** (discrete-time):
  - Uses the vehicle longitudinal speed v_x as the feedback variable.
  - Designed by means of manual trial-and-error. Only two parameters to choose, no complicated procedures are needed.
- A PI controller is enough to provide a satisfactory performance. No relevant motivations for more complex controllers.

Cruise control

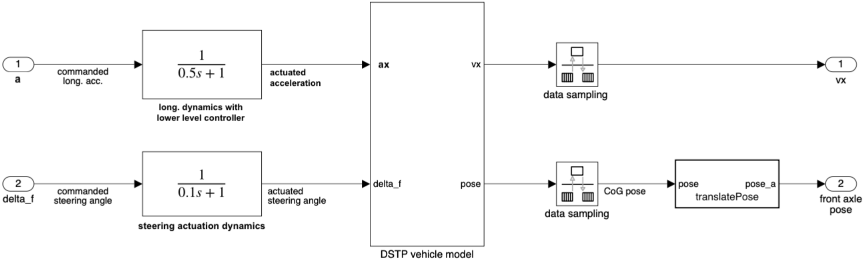
Closed-loop scheme



Cruise control

Vehicle model

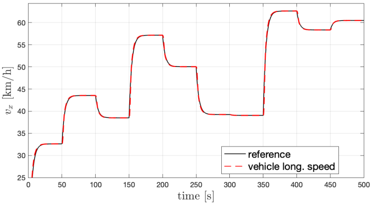
- DSTP: dynamic single-track vehicle model with Pacejka's tire formula.
- Other blocks:
  - pose translation from CoG to front axel
  - data sampling blocks
  - steering actuation dynamics
  - lower level long. control dynamics.

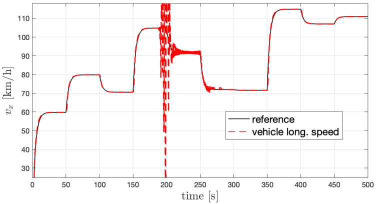


Cruise control

Simulation results

- Reference trajectory: $Y_r^c = 2\sin(0.01 X_r^c)$ (small curvatures).
- Reference speed: generated as a filtered piecewise constant signal with random values. The filter is used to avoid abrupt variations.



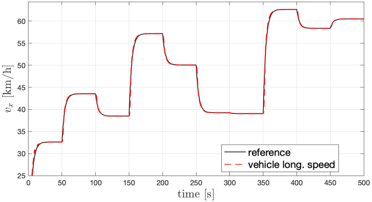


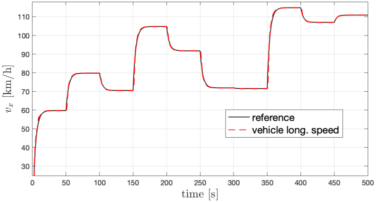
- Problems occur at high speed due to the fact that the lane keeping controller was designed assuming $v_x = 40\,\mathrm{km/h}$.

Application: cruise control

Simulation results

- A new lane keeping controller was designed, assuming $v_x = 65\,\mathrm{km/h}$. **PIDF3 controller** (discrete-time):
  - Uses the cross-track error as the feedback variable.
  - Designed using the Simulink PID tuner.
- The same PI cruise controller was used.





- The combined PIDF3 (lane keeping) and PI (cruise control) work well. They may fail in roads with higher curvatures.