MEEN 432 –Automotive Engineering

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Lecture : Vehicle Controls

Smoothening Desired Quantities

- Desired Speed:
- The desired speed command can be determined based on a logic that looks at the current location and a knowledge of the race track: $v_{d,c}(X, Y)$
- This command is filtered through a 1st order filter so that we can (i) smoothen the desired speed profile, and (ii) calculate the rate of change of desired speed:
  - $v_d(t+1) = v_d(t) + \Delta t \lambda \left(v_{d,c}(t) - v_d(t)\right)$
  - and $\dot{v}_d(t+1) = \frac{\left(v_d(t+1) - v_d(t)\right)}{\Delta t}$

Feed forward Control – 1

- While feedback is a good way to fix any deviation between desired and actual, it is also useful to consider a "feed forward" term that anticipates the desired quantity
- Consider that we are given $\dot{v}_d(t)$ and $v_d(t)$ at any time instant t
- The tractive force at the vehicle required to achieve this is:
  - $F_{xd} = m\,\dot{v}_d + \left(c_0 + c_1 v_d + c_2 v_d^2\right) + mg\sin\theta$
- This tractive force can be cascaded through the powertrain to arrive at the desired final drive input (or transmission output) torque:
  - $\tau_{fd,d} = F_{xd} r_w / G_{FD}$
- Corresponding to this tractive force, there is also the desired angular speed and net power desired:
  - $\omega_{fd,d} = \frac{v_d}{r_w} G_{FD}$
  - $p_{fd,d} = F_{xd} v_d$
    - (Note that for this cascade of torque and power, we assume no inertia effects and no losses)

Feed Forward Control – 2

- Assume a gear with gear ratio G is chosen
- Then the motor torque and speed requirement is given by:
  - $\tau_{md} = \frac{\tau_{FD,d}}{G} = \frac{F_{xd} r_w}{G_{FD} G}$ and $\omega_{md} = \omega_{FD,d} G = \frac{v_d}{r_w} G_{FD} G$
- Then the driver control will have two components:
  - Feed Forward:
    - $\alpha_{FF} = \frac{\tau_{md}}{\tau_{m,max}}$
  - Feed Back:
    - $\alpha_{FB} = PID(v_d - v)$
  - $\alpha = \alpha_{FF} + \alpha_{FB}$

Gear Selection

- Let there be n Gear choices available, with the gear ratios defined as $G_i \;\; 1 \leq i \leq n$
- The (feed forward) motor operating point is defined for each gear G_i:
  - $\tau_{md,i} = \frac{F_{xd} r_w}{G_{FD} G_i}$ and $\omega_{md,i} = \frac{v_d}{r_w} G_{FD} G_i$
- Corresponding to the operating point, there is an efficiency $\eta_i(\tau_{md,i}, \omega_{md,i})$
- The choice of the gear G^* is then done through a simple optimization:
  - $G^* = argmax_{1 \leq i \leq n} \eta_i(\tau_{md,i}, \omega_{md,i})$ such that
  - $\omega_{min} \leq \omega_{md,i} \leq \omega_{max}; \tau_{min} \leq \tau_{md,i} \leq \tau_{max}$
- Additionally, some practical constraints are added: (examples)
  - Shift Business: Do not shift within x seconds of a shift
  - Shift magnitude: Do not shift by more than x gears when in gear y

Desired psi_d: 1/2

- Find Look Ahead Point (x_l, y_l), vehicle at (x, y) with look ahead l
  - Vehicle on Straightaways:
    - Bottom:
      - if $x + l < 900$: $x_l = x + l; y_l = 0$
      - Else $x_l = 900 + R\sin(\frac{l_1}{R})\,; y_l = R\cos(\frac{l_1}{R})$, with $l_1 = x + l\ - 900$
    - Top
      - if $x - l > 0$: $x_l = x - l; y_l = 400$
      - Else $x_l = -R\sin\left(\frac{l_1}{R}\right); y_l = 400\ -\ R\cos(\frac{l_1}{R})$, with $l_1 = l - x$
  - Vehicle on Curves:
    - Right Curve:
      - $x_l = 900 + R\sin(\frac{l+l_2}{R})\,; y_l = R\cos(\frac{l+l_2}{R})$, with $l_2 = R\tan^{-1}(\frac{200-y}{x-900})$
    - Left Curve
    - $x_l = -R\sin\left(\frac{l+l_2}{R}\right); y_l = 400 -\ R\cos(\frac{l+l_2}{R})$, with $l_2 = R\tan^{-1}(\frac{200-y}{x})$

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Desired psi_d: 2/2

- Once you find the look ahead point, the desired heading angle can be calculated as below:
- $\psi_d = \tan^{-1} \frac{y_l - y}{x_l - x}$