Project Plan

Adaptive racer

Group 5

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1 Solution

1.1 Iterative learning Control (ILC)

The ILC algorithm that will be implemented in our project is a current iteration PD-type algorithm, which will be implemented in parallel with the existing PI controller. The algorithm that will be implemented is defined in the following formulae:

\[ u_{j+1} = Q(q) \left[ u_j + k_p u_e (k + 1) + k_d \left( e_{j+1} - e_j \right) \right], \]

where \( k_p \) is the proportional gain, \( k_d \) is the derivative gain and \( Q(q) \) is the Q-filter. The Q-filter is used to improve the transient learning behavior and robustness of the system. A Q-filter will be implemented as a second order low pass filter to disable learning at high frequencies.

Current iteration ILC is a method to incorporate feedback with ILC. The motivation for choosing this algorithm is that the learning function relies on tuning and do not require an accurate model. With this algorithm monotonic convergence can be achieved if the iteration is sufficiently short. If it turns out that the error doesn’t converge, we will start to experiment with spatial ILC rather than temporal ILC.

1.2 Traction Control (TC)

We are only concerned with the longitudinal traction control. In most solutions implemented in the industry, TC is achieved by detecting slip and then controlling the amount of slip to maintain traction. The control is done by regulating the torque applied to the wheel. Most of these methods require sensing of chassis velocity, which is a bit problematic in our case. Therefore we require a method independent of vehicle chassis velocity. One such method is Maximum Transmissible Torque Estimation (MTTE) [1]. MTTE can be summed up in the following block diagram.
The basic idea is that if we subtract the amount of torque required to accelerate the wheel from the torque applied to the wheel, the remaining torque exactly balances the friction. Once the frictional force $\hat{F}_d$ is estimated, it is possible to estimate the maximum torque $T_{\text{max}}$ that could be applied to the wheel without causing slip. The value of $T_{\text{max}}$ is used to adapt the saturation limit applied to the torque command $T$. This will prevent slip from occurring.

The design shown in the figure has to be modified to include the viscous and coulombic friction of the motor-gear system to make it suitable for our application. The relevant equations become:

$$\hat{F}_d = \frac{T}{r} - \frac{J_w \dot{\omega}}{r} - \frac{B \omega}{r} - \frac{\tau_s}{r}$$

$$T_{\text{max}} = \left(\frac{J_w}{\alpha M r^2} + 1\right) \hat{F}_d r + B \omega + \tau_s$$

$\hat{F}_d$: Estimated frictional force, or driving force.
$T$: Torque applied to the wheel.
$r$: Radius of the wheel.
$J_w$: Moment of inertia of the motor-gear-wheel.
$B$: Coefficient of viscous friction of the motor-gear.
$\omega$: Angular velocity of the wheel.
$\tau_s$: Coulombic friction of motor-gear.
$T_{\text{max}}$: Maximum transmissible torque.
$M$: Mass of the vehicle.
$\alpha$: A relaxation factor close to 1 to smoothen the control.
Torque is estimated according to the following equation:

\[ T = \frac{N K_t}{R} (V - K_b \omega N) \]

Where \( N, K_t, K_b, R, V \) are gear ratio, motor torque constant, motor BEMF constant, motor resistance and applied voltage to the motor respectively.

2 Completed work

2.1 ILC

- Developed basic code for a line follower including a PI controller: C. Klarin, S. Abdul Khader.
- Developed and implemented a current iteration PD-type learning algorithm of first order: G. Baguma, C. Klarin.
- Implemented a second order low pass filter (Q-filter) and tuned the corner frequency: Y. Zhuo, C. Klarin, S.
- Developed a wireless, real-time data logging functionality in MATLAB to record and plot system variables: C. Klarin, Y. Zhuo.
- Carried out theoretical analysis for convergence and found that the implementation is convergent: G. Baguma, S. Abdul Khader.
- Tuned the ILC gains for best performance but no satisfactory convergence behavior. So to target spatial ILC: G. Baguma, C. Klarin, S. Abdul Khader.
- Designed a new track for spatial ILC: C. Klarin, S. Abdul Khader.
- Started to develop the code for ILC with spatial sampling: G. Baguma, C. Klarin.

2.2 TC

- Developed theoretical model to be implemented for MTTE: S. Abdul Khader.
- Completed system identification to determine parameters of the model: Y. Zhuo, S. Abdul Khader.
- Completed implementation of MTTE in code: Y. Zhuo.

3 Remaining work

3.1 ILC

- Complete the code for spatial ILC and test it: Week 50, G. Baguma, C. Klarin.
- Try ILC on track with varying traction conditions: Week 51, G. Baguma, C. Klarin.

3.2 TC

- Test basic operation of MTTE on straight motion: Week 50, S. Abdul Khader, Y. Zhuo.
• Add varying traction surface to the track. Try MTTE while line following: Week 51, S. Abdul Khader, Y. Zhuo.

3.3 Conclusion and report writing

• Compare and draw conclusion about performance of ILC and TC: Week 1, All members.
• Report for ILC part: Week2, G. Baguma, C. Klarin.
• Report for TC part: Week2, S. Abdul Khader, Y. Zhuo.

4 Reference