Project: Model Predictive Control

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Simulator video **here**.

The Model

State at timestep t

- x_t - x position of vehicle in global coordinates
- y_t - y position of vehicle in global coordinates
- ψ_t - heading angle of vehicle
- v_t - velocity of vehicle
- cte_t - cross-track error of vehicle off trajectory
- $e\psi_t$ - heading angle error of vehicle off trajectory

Actuators at timestep t

- δ_t - turning rate (steering wheel)
- a_t - acceleration (accelerator)

Timestep update

$$\begin{aligned} x_{t+1} &= x_t + v_t \cos \psi_t dt \\ y_{t+1} &= y_t + v_t \sin \psi_t dt \\ \psi_{t+1} &= \psi_t + \frac{v_t}{L_f} \delta_t dt \\ v_{t+1} &= v_t + a_t dt \\ cte_{t+1} &= f(x_t) - y_t + v_t \sin e\psi_t dt \\ e\psi_{t+1} &= \psi_t - \psi des_t + \frac{v_t}{L_f} \delta_t dt \end{aligned}$$

Cost function

$$J = \sum_{t=1}^{N} 10cte_t^2 + 10e\psi_t^2 + (v_t - v_{ref})^2 + \sum_{t=1}^{N-1} 200\delta_t^2 + 0.5a_t^2 + \sum_{t=2}^{N-1} 25000(\delta_t - \delta_{t-1})^2 + (a_t - a_{t-1})^2$$

Hyperparameters

The time step Δt was chosen to exactly equal the latency time of 100ms. This was to ensure that the actuator optimization took into account latency time along the trajectory. For determining N, we want to have the value as high as possible to have a longer time horizon to optimize over, while keeping compute time into account. After trial and error, $N = 7$ was chosen.

Trajectory Waypoints

Because the actuator values are in the vehicle coordinate system rather than global, the waypoints at every time step needed to be converted into the vehicle coordinate system by the transformation (given waypoint w/ global coordinates (p_x, p_y))

$$\begin{aligned} x = &\quad (p_x - x_{vehicle}) \cos\psi - (p_y - y_{vehicle}) \sin\psi \\ y = &\quad (p_x - x_{vehicle}) \sin\psi + (p_y - y_{vehicle}) \cos\psi \end{aligned}$$

These transformed coordinates were then fed into the polynomial fitting algorithm.

Latency

To deal with the latency of the controls, prior to running MPC, the current vehicle state was simulated forward in time for the latency amount (100 ms), and the result was passed in as the initial vehicle state in MPC. This simulation was done in vehicle coordinates.