MODEL PREDICTIVE CONTROL PROJECT

In this project, a few design decisions were made to achieve good reference trajectory tracking by our simulated vehicle. These decisions include:

1) Kinematic model used for vehicle dynamics
2) Number of timesteps (N) as well as the size of each timestep (dt) used by the controller
3) Accounting for delay in our system

NUMBER OF TIME STEPS (N) AND TIME STEP SIZE (DT)

The product N*dt determines the prediction horizon (T) for the MPC. If the prediction horizon is too large, then control may fail because we are predicting too far into the future when the real world may be changing much more rapidly. On the other hand, if the prediction horizon is too small, then we'll use too few points from the reference trajectory and we'll produce controls that are very sensitive and reactive to short-term deviations in the reference trajectory. Furthermore, a choice for dt that is too large, will render our Kinematic model obsolete since it is most accurate for short timesteps.

When I tried N=20 and dt=0.1 which is equivalent to a prediction horizon of 2 seconds, the car was unable to complete a lap around the track because the prediction horizon was too long. In contrast, when I tried N=5 and dt=0.1 the car also failed to complete a lap around the track since the prediction horizon was too small. A choice for N and dt that worked well was N=10 and dt=0.1 which corresponds to a prediction horizon of 1 second.

KINEMATIC MODEL AND ACCOUNTING FOR SYSTEM DELAYS

Our system has 100 ms delay which corresponds to one MPC timestamp (since dt = 0.1 sec). The consequence of this delay is that the actuator inputs at timestep t-1 affect the state at time t+1 (not the usual time t). This is captured directly in our kinematic model detailed next.

The kinematic model maintains the vehicle position, velocity, and yaw (x, y, v, and psi) as well as the error in position (cross track error denoted "cte") and pose (denoted "epsi") with respect to the reference trajectory. The vehicle is moved by the two actuation signals corresponding to throttle (a) and steering (delta).

The throttle actuator updates the vehicle position (x,y) and velocity (v) as shown below. Note how the throttle actuation (term in red) from timestep t-1 updates the velocity at timestep t+1 which is how we account for delay.

$$x(t+1) = x(t) + v(t) * cos(psi) * dt$$

$$y(t+1) = y(t) + v(t) * sin(psi) * dt$$

$$v(t+1) = v(t) + a(t-1) * dt$$

The steering actuator updates the vehicle yaw (psi) as shown below. Note again how the steering actuation (term in red) from timestep t-1 updates the yaw at timestep t+1 which is how we account for delay.

$$psi(t+1) = psi(t) + v(t)/L * delta(t-1) * dt$$

Finally, the vehicle position and pose error are updated as illustrated below and once again we see that an actuation signal (steering signal in red) is taken from step t-1 to account for system delay. Note also that cte(t) is simply the difference in vehicle position and where the vehicle would be on the reference trajectory, while epsi(t) is the difference between vehicle pose (yaw angle) and its yaw angle on the reference trajectory.

$$cte(t+1) = cte(t) + v(t) * \sin(epsi) * dt$$

$$epsi(t+1) = epsi(t) + v(t)/L * delta(t-1) * dt$$