Model Predictive Control

Model

A Kinematic model is used to control the car neglecting the dynamic forces. The following equations are being used:

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x[t] = x[t-1] + v[t-1] * cos(psi[t-1]) * dt
y[t] = y[t-1] + v[t-1] * sin(psi[t-1]) * dt
psi[t] = psi[t-1] + v[t-1] / Lf * delta[t-1] * dt
v[t] = v[t-1] + a[t-1] * dt
cte[t] = f(x[t-1]) - y[t-1] + v[t-1] * sin(epsi[t-1]) * dt
epsi[t] = psi[t] - psides[t-1] + v[t-1] * delta[t-1] / Lf * dt
```

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Where
X,y = Position coordinates of the car
Psi = Orientation of the car/ heading angle
v = Velocity of the car
cte = Crosstrack error- error between vehicles lateral position and the
desired trajectory
epsi = error between heading angle and desired heading angle of the car
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These 5 values are the states of the models. There are two actuator
values: steering angle and throttle
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Delta = steering angle
a= acceleration of the car, determines the throttle value
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Lf = this is the distance between centre of gravity and front wheels.
dt= timestep
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The idea is to pass the states, model and the way track through an optimisation algorithm to find out the optimum (steer, throttle) that would make the car follow the path as closely as possible.

The following constraints are placed on the actuator values

- a—acceleration is in the range [-1, 1] = [full brake, full throttle]
- delta—steering angle is in the range [-25°, 25°]

The cost function for the optimisation problem took into consideration following
- the states - cte, epsi and velocity
- The actuator values - a, delta
- the rate of change in actuator values to penalise the sharp changes.

Finally the weights on these cost considerations are chosen to minimise the cost in this optimisation problem.

Timestep Length and Elapsed Duration (N & dt)

The preview time is is the duration over which future predictions are made. It is the product of two other variables, N and dt.
Where:

N is the number of timesteps in the horizon.

dt is how much time elapses between actuations.

The value I started with for N and dt is 10 and 0.1 respectively which would mean 1 second of preview time. That was causing problems in higher speeds on hard turns where the things are changing faster than that can be managed by controller. After trying various values for T like 1, 0.9, 0.8 I had to reduce the preview time to 0.68 so that the vehicle can make the turn.

Next I have to increase the number of actuations from 10 to 17 to make it smoother.

Polynomial Fitting and MPC Preprocessing

A third degree polynomial is used to fit the waypoints. However before fitting, the polynomials are transformed to the vehicle coordinates as This simplifies the process to fit a polynomial to the waypoint. The vehicle is now at origin x, y = 0 and also orientation is zero.

Model Predictive Control with Latency

There is a latency of 100ms in the simulation to mimic real life situations. It is countered by running a simulation using the vehicle model starting from the current state for the duration of the latency. The resulting state from the simulation is the new initial state for MPC. The state values are calculated using the model and the delay interval. These values are used instead of the initial one.