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CarND - PID Control Project
Reflection Paper

Describe the effect each of the P, I, D components had in your implementation:

- P is proportional to cross track error (CTE) of the vehicle's position. P is used to define how hard the vehicle tries to steer back to desired position.
- D term is the differential of cross track error. It is used to compensate for steering by the 'P' part once the CTE starts reducing and avoids overshooting the steering.
- I term is integral of the cross track error over the time the robot is in motion. It accumulates the error over time and compensates for robots position to be as close to it's reference position as possible.

Describe how the final hyperparameters were chosen:

Manual Tuning

- Hyper parameters were chosen by manual tuning. I started with a set of values for PID as 1, 1, 1 and depending on how the vehicle reacts, I used a different combination of values until the vehicle drove safely on the track.
- I also tuned the throttle and speed of the vehicle to ensure it stays on track. I tried with the initial throttle value of 0.3 and for several values of PID, at higher speeds, the oscillations became violent and car would eventually go off track.
- I hard coded value of the throttle to 0.1 and started testing PID values. Some of my tested values and their observations are:

Throttle	P	I	D	Observations
0.1	-0.1	0	-0.1	Vehicle goes off-track
0.1	-0.15	0	-0.1	Drives well but too slow
0.2	-0.15	0	-0.1	Off-track and violent oscillations
0.15	-0.2	0	-0.1	Drives well but oscillates
0.2	-0.2	0	-0.2	Fails. Goes off-track
0.18	-0.18	0	-0.2	Slight off track

When the throttle is 0.2 and params are -0.2, 0, -0.2, the vehicles goes off-track because at high speeds the oscillations become violent and car seems to be out of control, but initial drive is fine. The car steers back in fine but due to high speed, tends to go off-track.

So to control the speed, I put a cap on throttle and speed. To do so, I set initial throttle to 0.2 and checked CTE and speed on each event. If CTE and speed are above 0.5 and 20 mph respectively, I reduce the throttle to about 0.05. But I noticed that the vehicle is too slow to pick up initial speed and when in straight line.

I tried out some combinations of values of these parameters to have the vehicle drive at a reasonable speed and not go off-track.

Finally, I set the initial throttle to 0.6 and started capping only if the speed is above 10. At higher speeds, if the CTE is above 0.4 or speed goes above a cap of 18, then the throttle is set to 0.01. This way the car slows down on complex turns and during unstable conditions (just like in the real world) A max speed of 20 also works. 18 seemed to work better.

How to improve manual tuning:
Since manual tuning is cumbersome and time consuming, the Twiddle algorithm may help us automate the above manual process.