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1. Objective

The objective of this project is to run a car in Udacity's simulator using a PID Controller and identify optimal coefficients for PID components and throttle.

2. Summary

The project primarily implements PID Controller to derive steering angle and throttle of the car. This project also identifies tuning coefficients for each PID value in order to calculate a steering angle that keeps the car on the track.

3. Reflection

3.1. Approach

This section explains PID Controller components and how each component and coefficients influences the behavior car in Simaultor.

In the PID Controller,

- The "P" refers to proportional. It will determine how fast the car will turn. The car will steer in proportion to the cross-track error, or CTE. CTE basically represents how far is the car from the middle line of the road. If the car is to the left of the line then PID Controller will need to steer the car to the right.

Coefficient for P (kp) is passed to PID Controller. If the coefficient is set too high for P, the car will oscillate a lot, as the car will constantly overcorrect and overshoot the middle. If the coefficient is too low, the car may react too slowly to curves.

- The "I" refers to integral sums up of all CTEs up to that point.

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Coefficient for I (ki) is passed to PID Controller. ki is used to fix a bias. If the coefficient is too high for I, the car tends to have quicker oscillations, and does not tend to get up to a quick speed. A low coefficient for I will cause the car to tend to drift to one side of the lane or the other for longer periods of time.

- The "D" refers to derivate of CTE – meaning change in CTE from one value to the next.

If the car is moving outward from the middle, "D" component will cause the steering to get but if the car is moving toward the center, the "D" component will cause the car's steering angle to get smoothed out leading to a more smoother driving experience. If the derivative is quickly changing, the car will correct itself faster, such as in the case of a curve

Coefficient for D (kd) is passed to PID Controller. kd is used to dampen the behavior because it will otherwise overshoot and oscillate. Too high of a coefficient leads to almost constant steering angle changes of large degrees, where although the car will be well-centered it can hardly move. Too low of a D coefficient will lead to the oscillations being too high with more overshooting.

3.2. Identifying optimal coefficient values for PID

```
PID program command lineUsage ./pid kp ki kd speed_goal throttle_kp throttle_ki
throttle_kd twiddleFlag"
```

1) First, I tried PD controller without Twiddle logic. One can enable or disable Twiddle in the command line.

To understand the influence of I in simulated environment, we can set ki = 0 with the assumption that the simulator has either no or only a very small steering bias. Setting ki=0 will enable the code to behave as PD controller.

Setting ki=0 resulted in car not running smoothly and after several cycles, the car went out of the lane. Which means PD controller did not complete the run properly.

2) Next, I tried adjusting kp, kd , tp and td with twiddle disabled. This also did not help much. After many cycles, car comes to stop by moving out of the lane.

3) Finally, I enabled Twiddle logic and tried various coefficients. I concluded that following coefficients made the car run smoothly and completed several laps successfully. As you see below, the bias in the Simulator is not a big deal as ki=0.004 is sufficient to run the car smoothly.

```
kp=0.27
ki=0.004
kd=3

tp=0.1
ti=0.002
td=12


.
```