

# **\*\*PID Controller Project\*\***

4 videos in the folder named(video)

## **P Control:**

**Formula:**

$$\text{steering angle} = K_p \cdot e(t)$$

CTE (Cross Track Error) means the distance from the line of reference,

$e(t)$  is the CTE when time is  $t$ .

When **K<sub>p</sub>** is large, it is fast to come back to line of reference. However, it often happens to be oscillates faster. **Seen in the video p\_control\_0.5.mp4**. we can find the car runs out of road when the **K<sub>p</sub>** is 0.5. But when I set the **K<sub>p</sub>** is 0.05(**Seen in the video p\_control\_0.05.mp4**), the car come back to the center of road very slowly. As a result, the car also runs out of road when the road is curve.

## **PD Control:**

**Formula:**

$$\text{steering angle} = K_p \cdot e(t) + K_d \frac{de(t)}{dt}$$

**K<sub>d</sub>  $\frac{de(t)}{dt}$**  can void the oscilates. But when the **K<sub>p</sub>** is large and the **K<sub>d</sub>** is small (**seen video pd\_control\_d\_1.mp4**), we can find that it also has obvious oscillates. So I change the **K<sub>d</sub>** from 1 to 5, the effect is better than before.

## PID Control

Formula:

$$\text{steering angle} = K_p * e + K_d \frac{de(t)}{dt} + K_i \int_0^t e(t) dt$$

$K_i \int_0^t e(t) dt$  can void steady state error that is caused by D. it terms to compensate for biases. But in the simulate, it has no bias. So I set **Ki** is 0.

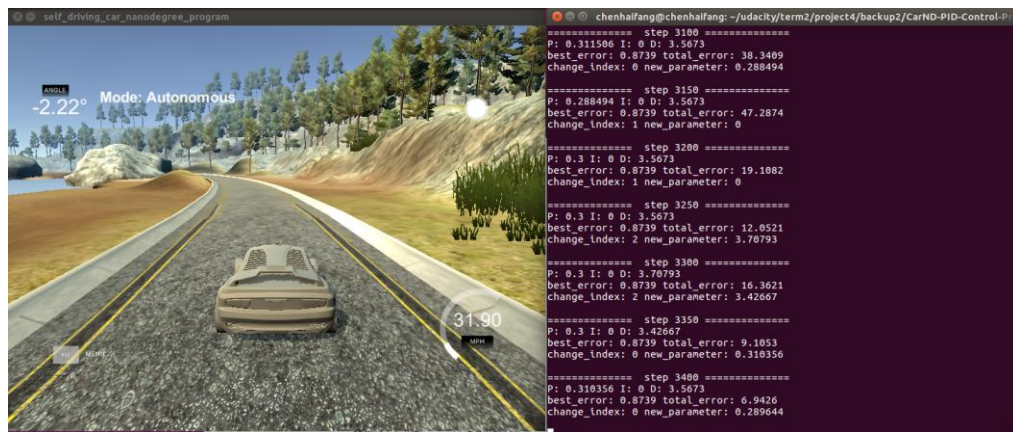
## PID Control parameter Optimization

My final hyperparameters is (P:0.222, I:0, D:6.20593) and it is handle with a combination between manual tuning and twiddle method.

Firstly, I set init parameter (P:0.3, I:0, D:3) through manual tuning. Because too large **Kp** and the too small **Kd** leads to be obvious oscillates. At the mean time, too small **Kp** and too large **Kd** leads to cost too much time to reduce the CTE. When **Ki** is 0.1, the car run start to run out of road. So through a huge number of manual tuning, I set init parameter (P:0.3, I:0, D:3).

Secondly, I used twiddle method to search relatively accurate parameter. As I set every 50 step to change one parameter, it seems that parameters (P:0.222, I:0, D:6.20593) is final hyperparameters(seen the picture1) after step 12900; However, after step 37400(means  $37400/50 = 748$  times), the truly final hyperparameters(P:0.324696,I:0, D:3.3) shows in the picture 2.

Picture 1



Picture 2

