

Tuning of PID Parameters

The performance of a PID controller is totally depends on the three parameters: proportional coefficient (K_p), integral coefficient (K_i), and the differential coefficients (K_d). I tried a P controller at first, that is, I set K_d and K_i to zero. Then, I tried a PD controller followed by a PID controller. After tuning these parameters, I got the following results:

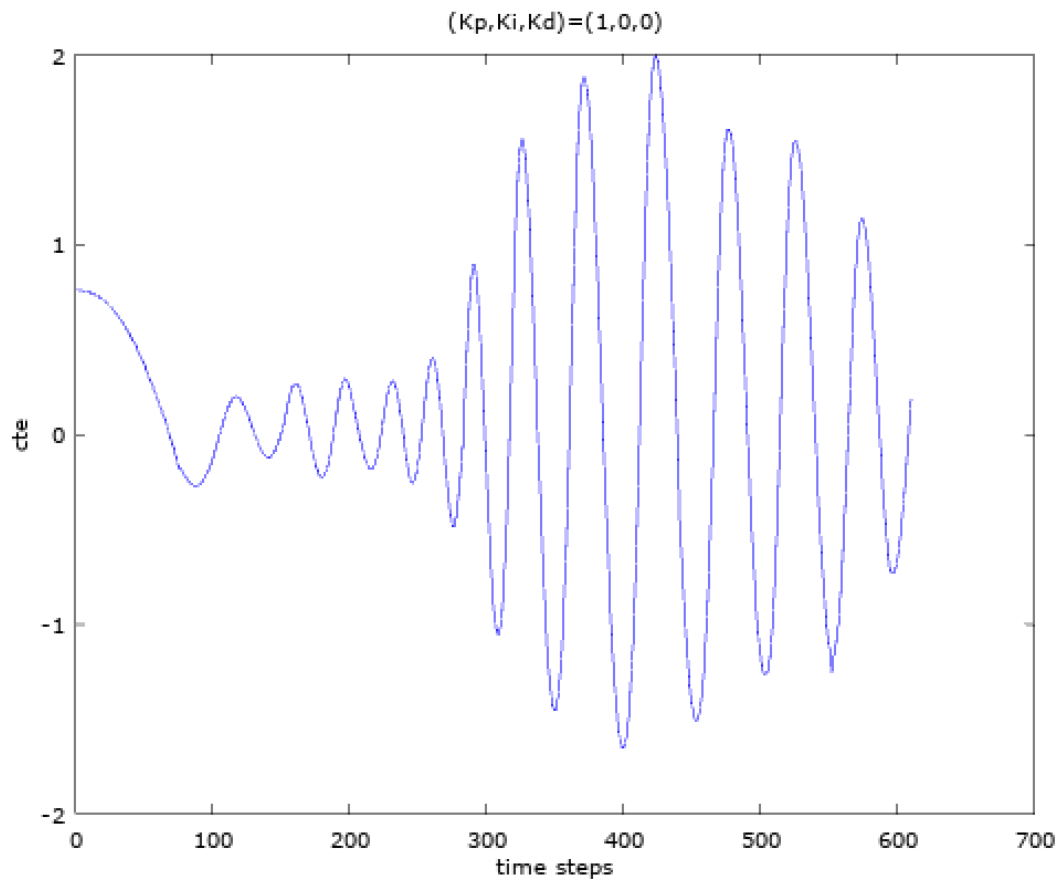
- A P controller is not stable. It always oscillates. Larger parameter K_p can lead to quicker response. However, the oscillation is also heavier. Smaller gain lead to slower response. Because the response is too slow, the vehicle also oscillates heavily.
- A PD controller can be stable. Generally, more the differential coefficient K_d , more stable the vehicle has. However, we cannot set too large K_d because of at least two reasons: one is the response will be too slow, the other is the actuator will saturate very quickly.
- A PID controller is useful in our case because there is a bias between the actual steering angle and the setting. When I set the steering angle to 0, the actual steering angle was not 0; it was 0.44. A PID controller can eliminate steady state errors. I know the parameter K_i cannot be too high. If the parameter K_i is too high, the controller will become very unstable. I tried K_i from 0.1, then 0.01, then 0.001.

I tried parameter combinations as below:

No.	1	2	3	4	5	6	7	8	9	10	11
K_p	1	2	0.5	0.5	0.5	0.25	0.25	0.25	0.25	0.25	0.20
K_i	0	0	0	0	0	0	0.1	0.01	0.001	0.001	0.001
K_d	0	0	0	1	2	2	2	2	2	3	3

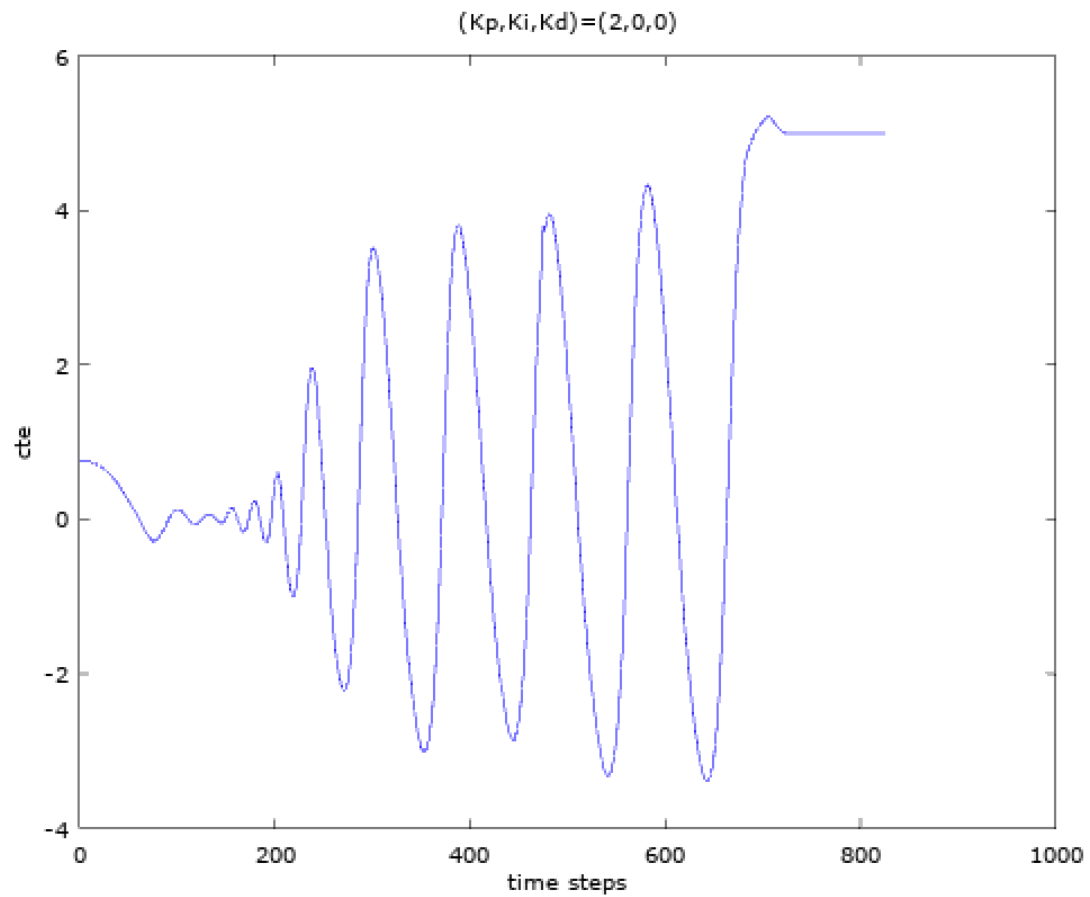
The simulations results are listed as following figures.

The first parameters are $(K_p, K_i, K_d) = (1, 0, 0)$



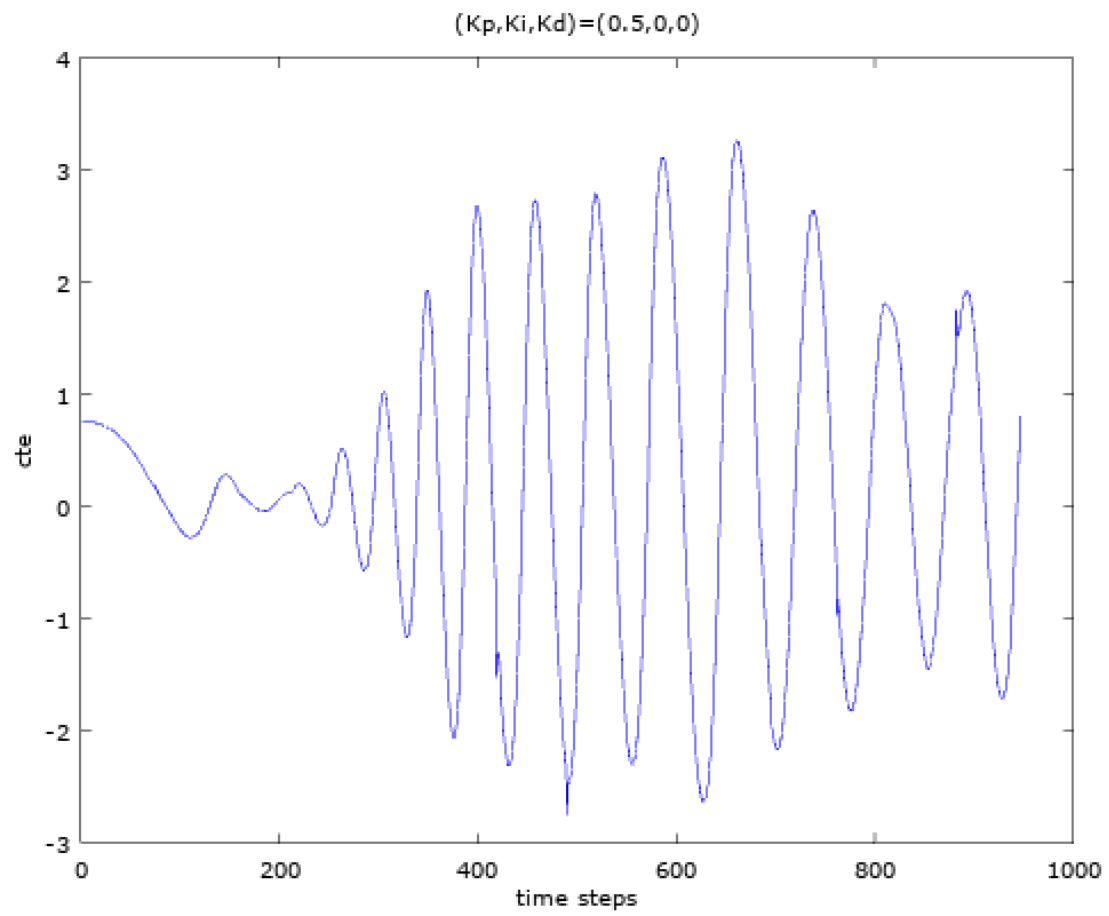
The vehicle oscillates. Especially, after time step 300, the vehicle enters its first turn, and the vehicle oscillates heavier.

The next parameter combination is $(K_p, K_i, K_d) = (2, 0, 0)$

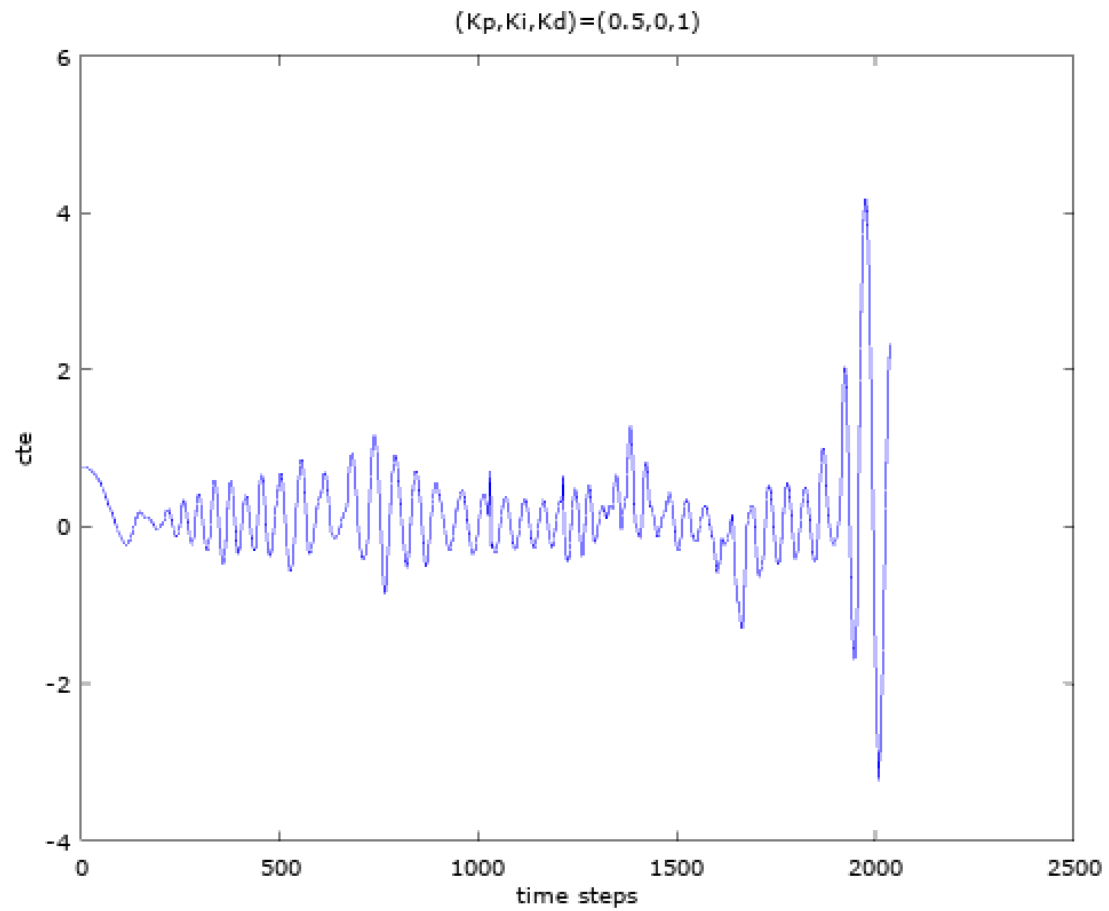


We can find that more gain got heavier oscillation.

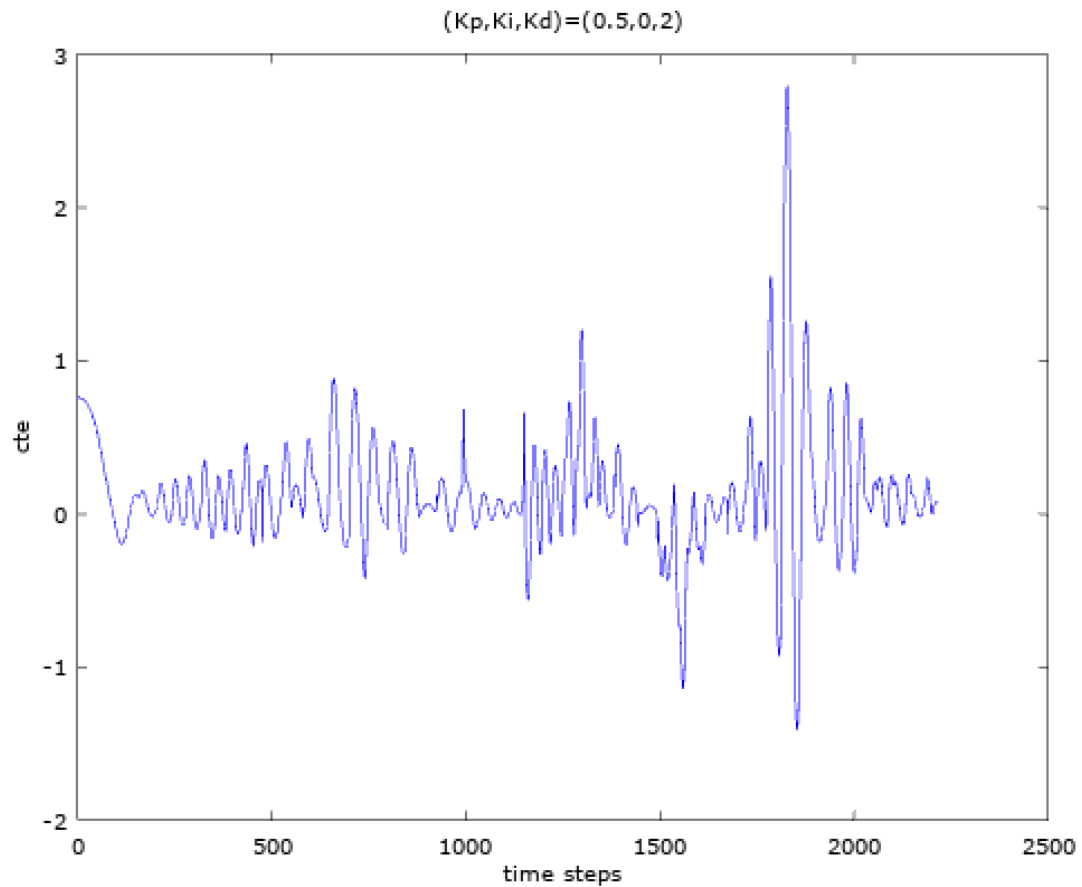
The next parameter combination is $(K_p, K_i, K_d) = (0.5, 0, 0)$



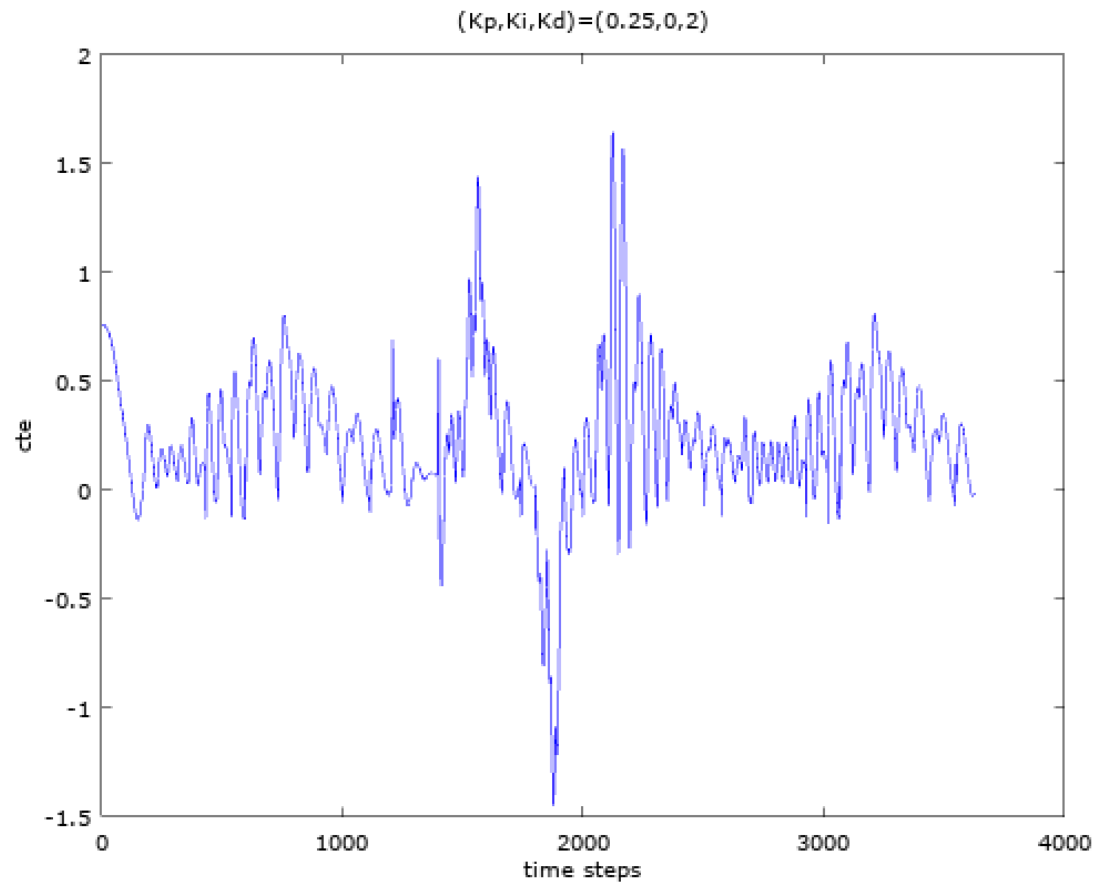
The vehicle still oscillates.



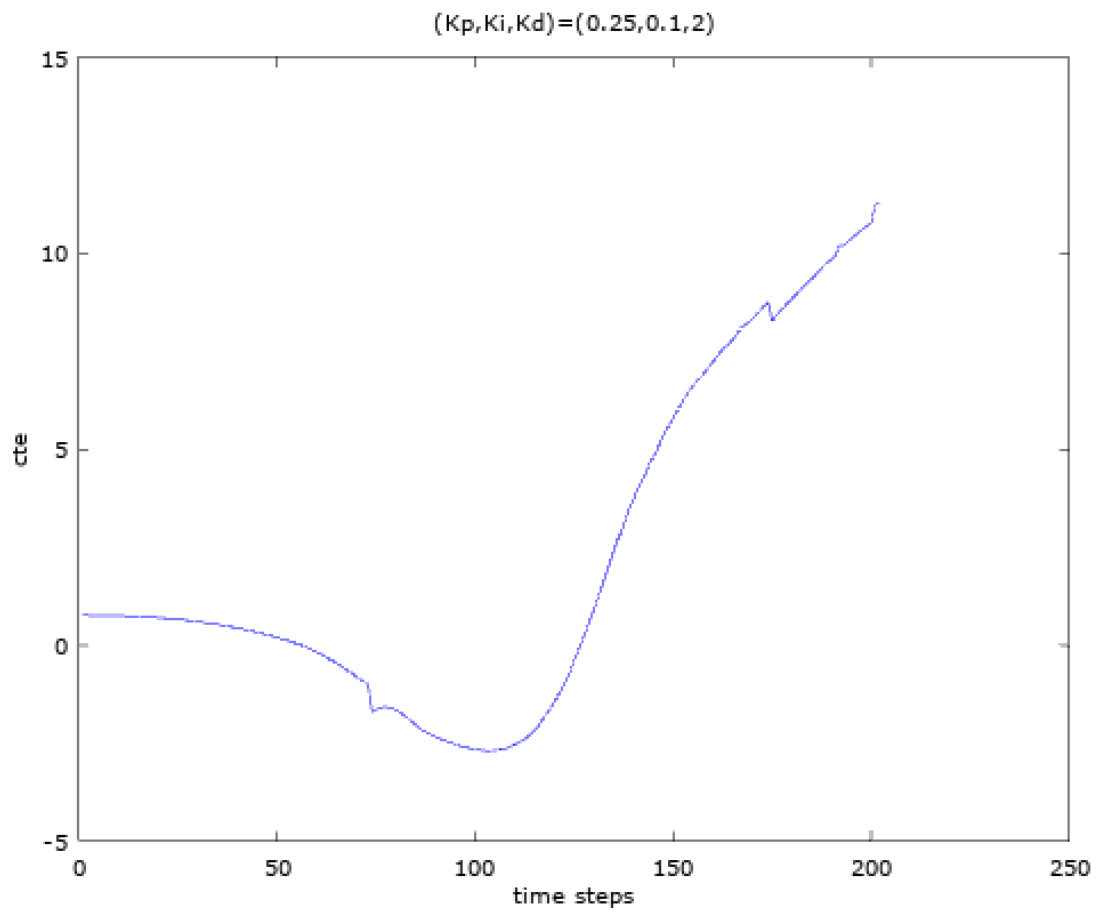
Add differential coefficient is effective. However, about time step 1800, the vehicle began oscillated. So, I want to add more K_d next time.



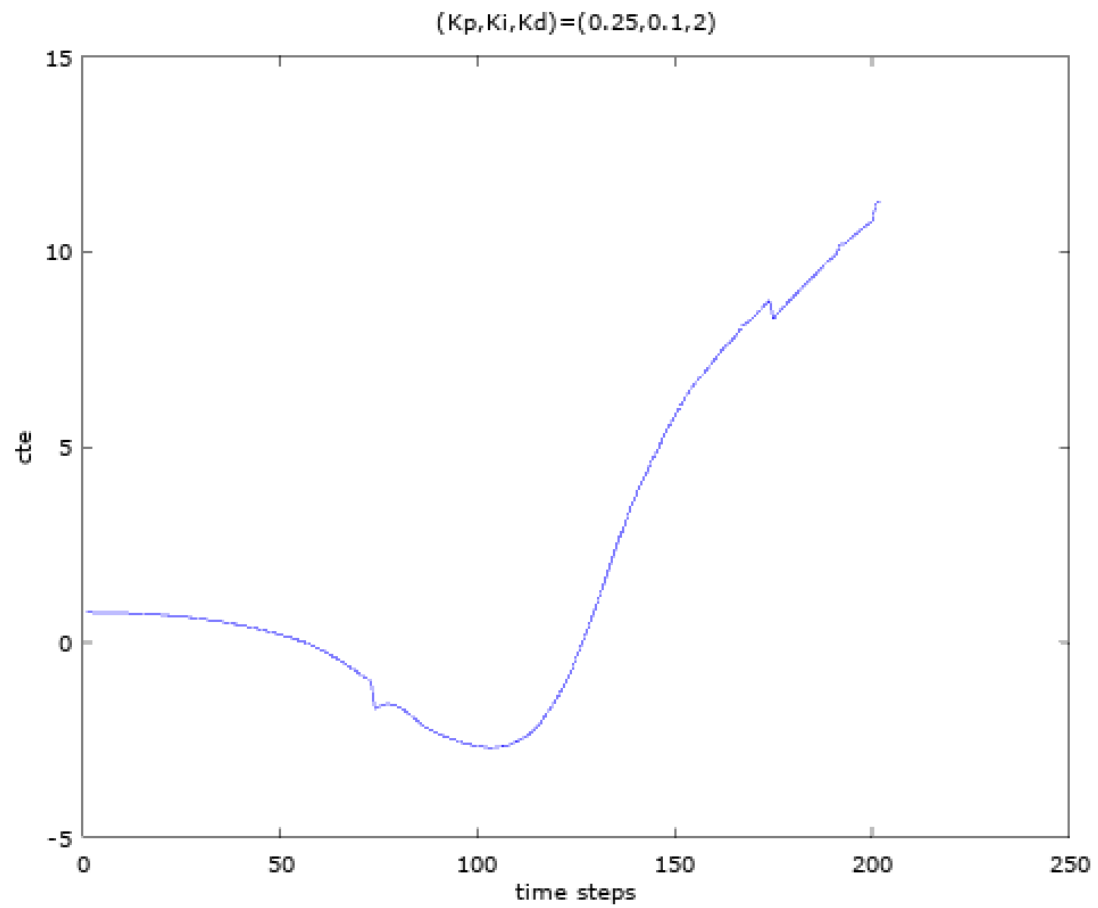
Although I added the Kd gain, the vehicle is still unstable around time step 1800. So, I guess maybe the proportional gain is too large. Next time, I will reduce the Kp gain.



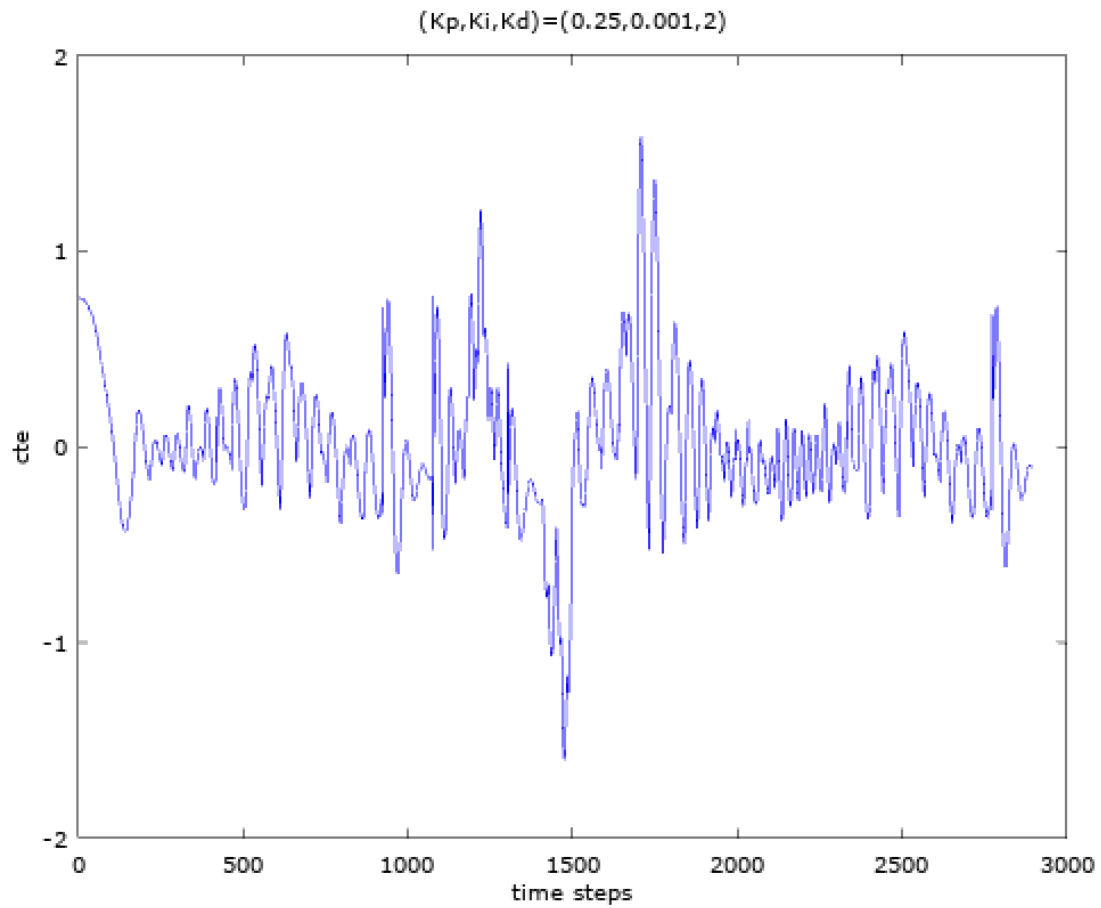
This time, the vehicle can drives itself within the lane. Next time, I will try a PID controller.



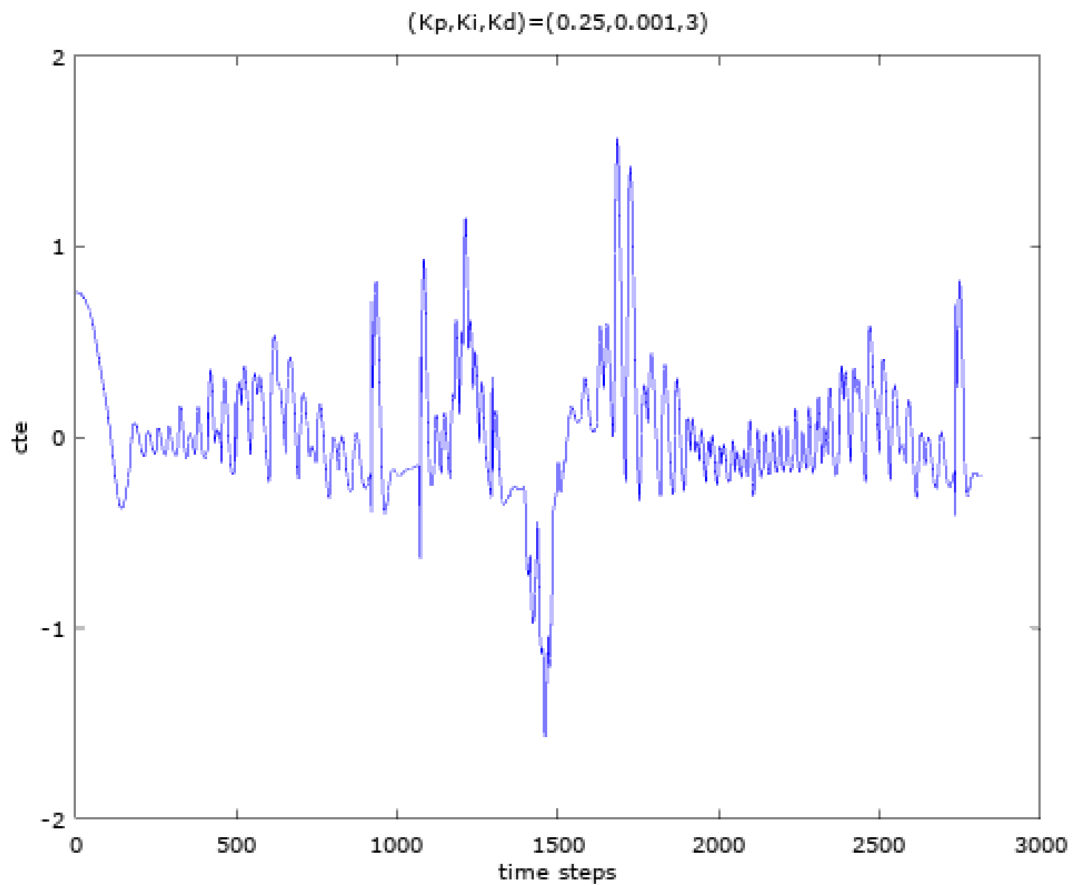
It is obvious that K_i is not a good one. I will reduce K_i next time.



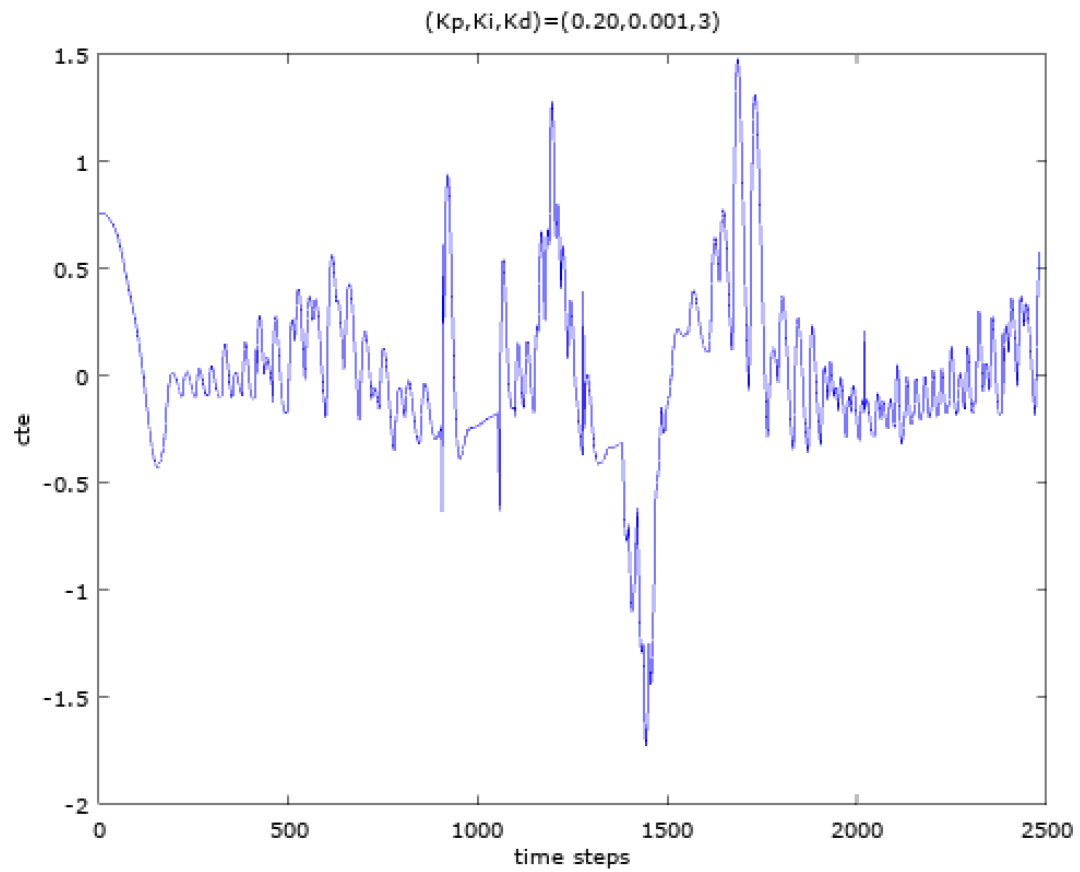
It is still unstable. I will keep reduce K_i next time.



Now, the parameter combination $(K_p, K_i, K_d) = (0.25, 0.001, 2)$ looks pretty good. Next time, I would like to know whether adding a little K_d can let the vehicle more stable.



The result is very similar to the previous one. Since I have added a little K_d , I also have to reduce a little K_p . So, next time, I will reduce a little K_p .



This time, it seems everything is good, I accept this parameter combination:
 $(K_p, K_i, K_d) = (0.2, 0.001, 3)$.