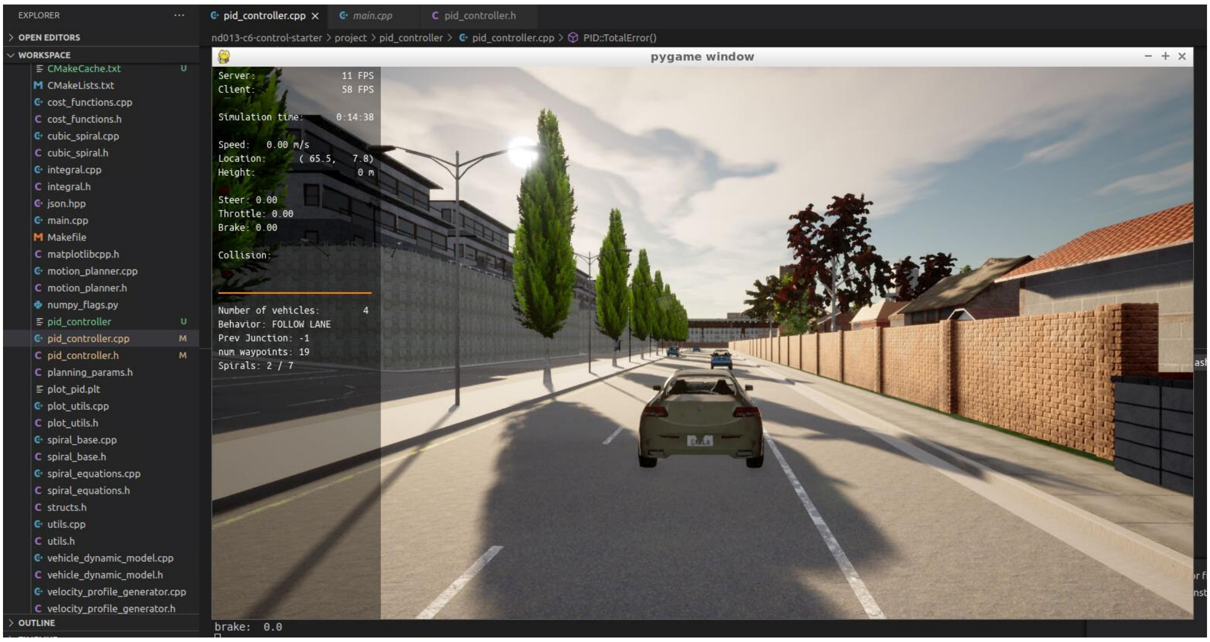
# Control and Trajectory Tracking for Autonomous Vehicle

## Step 1: Building the PID controller object

- Complete the TODO in the pid_controller.h and pid_controller.cpp.
- Running the simulator and see in the desktop mode the car in the CARLA simulator. The car is found not to move.



```
Server:              11 FPS
Client:              58 FPS

Simulation time:    0:14:38

Speed:    0.00 m/s
Location:       ( 65.5,   7.8)
Height:                   0 m

Steer: 0.00
Throttle: 0.00
Brake: 0.00

Collision:

Number of vehicles:        4
Behavior: FOLLOW LANE
Prev Junction: -1
num waypoints: 19
Spirals: 2 / 7
```

```
brake:  0.0
```

## Step 2: PID controller for throttle:

- In main.cpp, completing the TODO (step 2) to compute the error for the throttle pid.

## Step 3: PID controller for steer

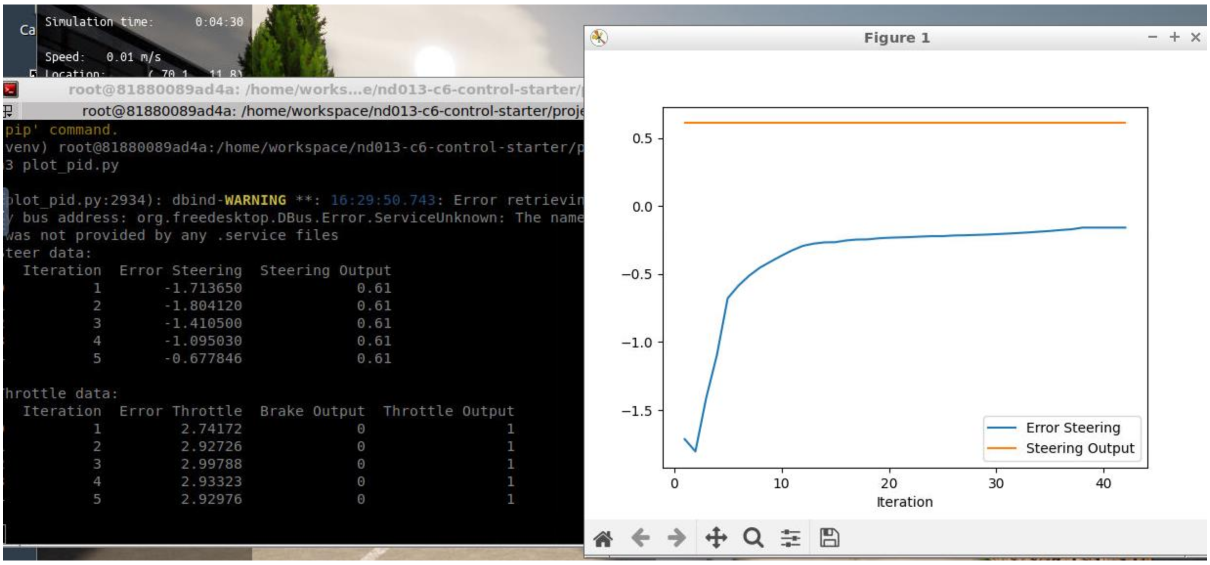
Different parameters for tried for gain factors. Following parameters lead to collision with wall.

| | Kp | Kd | Ki | Maximum output | Minimum output |
|---|---|---|---|---|---|
| Throttle | 0.21 | 0.0009 | 0.1 | 1.0 | -1.0 |
| Steer | 0.4 | 0.01 | 0.8 | 0.61 | -0.61 |

In the simulation, the car is found to be colliding with the wall.

## Step 4: Evaluating the PID efficiency

Q1. Add the plots to your report and explain them (describe what you see).

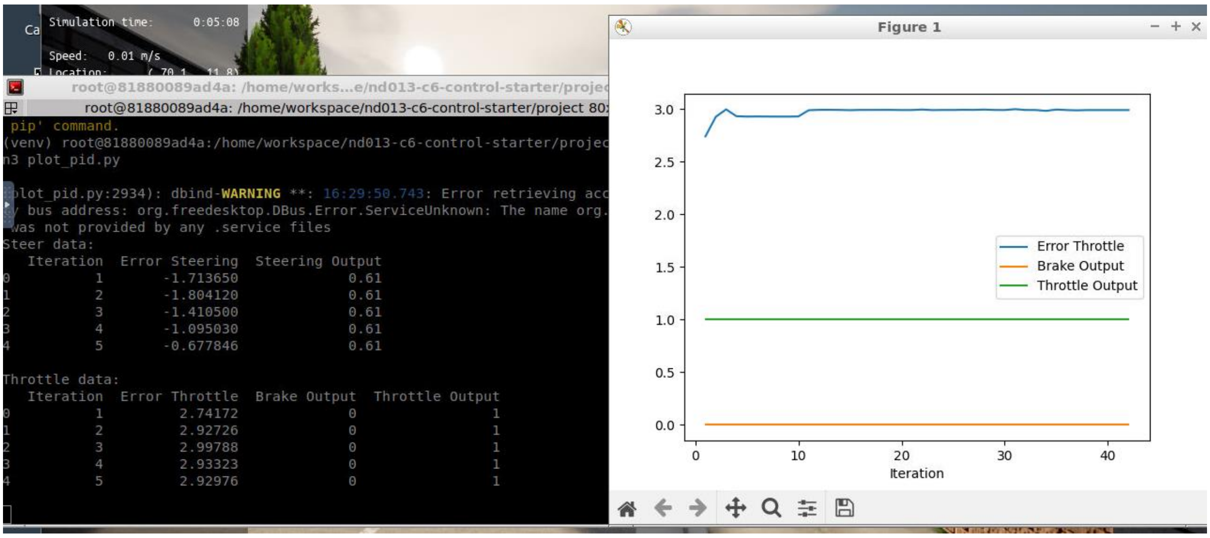


```
root@81880089ad4a: /home/works...e/nd013-c6-control-starter/
root@81880089ad4a: /home/workspace/nd013-c6-control-starter/proje
pip' command.
venv) root@81880089ad4a:/home/workspace/nd013-c6-control-starter/p
3 plot_pid.py

plot_pid.py:2934): dbind-WARNING **: 16:29:50.743: Error retrievin
/ bus address: org.freedesktop.DBus.Error.ServiceUnknown: The name
was not provided by any .service files
teer data:
  Iteration  Error Steering  Steering Output
          1       -1.713650             0.61
          2       -1.804120             0.61
          3       -1.410500             0.61
          4       -1.095030             0.61
          5       -0.677846             0.61

hrottle data:
  Iteration  Error Throttle  Brake Output  Throttle Output
          1         2.74172             0                1
          2         2.92726             0                1
          3         2.99788             0                1
          4         2.93323             0                1
          5         2.92976             0                1
```

Error steering and steering output

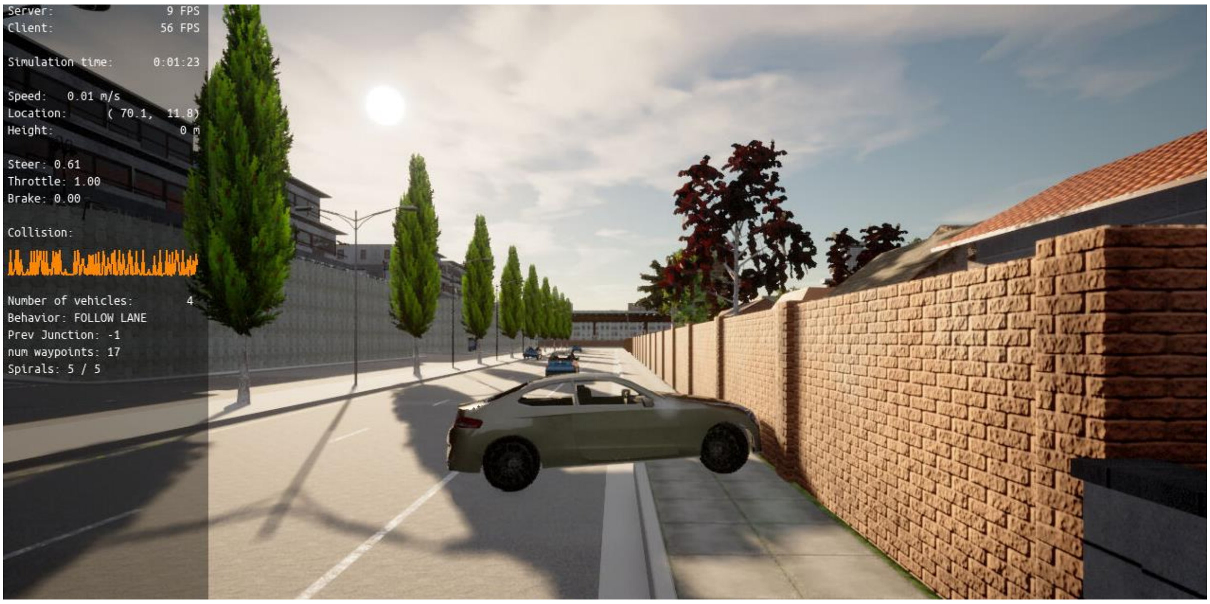


```
root@81880089ad4a: /home/works...e/nd013-c6-control-starter/projec
root@81880089ad4a: /home/workspace/nd013-c6-control-starter/project 80:
 pip' command.
(venv) root@81880089ad4a:/home/workspace/nd013-c6-control-starter/projec
n3 plot_pid.py

plot_pid.py:2934): dbind-WARNING **: 16:29:50.743: Error retrieving acc
/ bus address: org.freedesktop.DBus.Error.ServiceUnknown: The name org.
was not provided by any .service files
Steer data:
   Iteration  Error Steering  Steering Output
0          1       -1.713650             0.61
1          2       -1.804120             0.61
2          3       -1.410500             0.61
3          4       -1.095030             0.61
4          5       -0.677846             0.61

Throttle data:
   Iteration  Error Throttle  Brake Output  Throttle Output
0          1         2.74172             0                1
1          2         2.92726             0                1
2          3         2.99788             0                1
3          4         2.93323             0                1
4          5         2.92976             0                1
```

Error throttle, brake output and throttle output



```
Server:                9 FPS
Client:               56 FPS

Simulation time:     0:01:23

Speed:   0.01 m/s
Location:      ( 70.1,  11.8)
Height:                  0 m

Steer: 0.61
Throttle: 1.00
Brake: 0.00

Collision:

Number of vehicles:        4
Behavior: FOLLOW LANE
Prev Junction: -1
num waypoints: 17
Spirals: 5 / 5
```

***Q2. What is the effect of the PID according to the plots? How does each part of the PID effect the control command?***

- The values of proportional gain, if it is low lead to haphazard steering, if the values are high it will lead to overshoot and oscillations.
- This is one of the limitations of PID controller
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***Q3. How would you design a way to automatically tune the PID parameters?***

- As discussed in the lesson, one of the ways is to use Twiddle algorithm.
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***Q4. PID controller is a model-free controller, i.e. it does not use a model of the car. Could you explain the pros and cons of this type of controller?***

Pros:

a. It is widely used, tested and trial theory
b. It is easy to understand

Cons:

a. Parameter optimization/ tuning is more of hit and trial technique
b. This controller cannot deal with complex scenarios like sharp turns, turns in intersections etc.
c. There is limitation in handling high-dimensional nonlinear equations.