Effects of P, I, and D

P – Proportional Term
controls the steering angle of the car in proportion to the cross track error (CTE). This controller alone causes the car to always overshoot the reference trajectory. The higher the value, the sharper the car makes a turn.

I – Integral Term
deals with large CTE which might be caused by systematic bias. The integral term adjusts to this bias and affects more and more as the time goes by. The higher the value, the sharper the car makes a turn.

D – Differential Term
A temporal derivative of the CTE. When applied with P, it allows the car to gracefully approach the target reference trajectory without shooting to the target reference trajectory. The higher the value, the less sharp the car makes a turn.

Hyper-parameters Tuning

P, I and D are chosen manually first to make sure that the car drives without crossing the lane markings. The manual selection is based on the effect of P, I and D as described above. Once they are all chosen, Twiddle is used to fine tune P, I and D.

Twiddle starts when the car starts moving until it reaches the target time step of 2000. Once reached, a single hyper-parameter(either Kp, Ki, Kd) is updated and the car is located at the starting point again to begin the next round of twiddle. These steps repeat until the car moves as smoothly as possible.

Variable "dp" which controls the amount of update to P, I and D in Twiddle.h is initialized differently than the one in Sebastian's video (all 1's in the video) as a single update of P may cause the car to make a sharp turn and roll over the land marking.

Selected Coefficients

Kp: 0.137922
Ki: 0.0028019
Kd: 3.0358

Result

Even though P, I and D are chosen with Twiddle, the car still didn't move very smoothly but it was able to complete the track without popping up onto ledges or rolling over any surfaces. This is because the algorithm is prone to stuck on local minima. So, we might never see the car performs better as more iteration of Twiddle is performed. The log of the coefficient updates below shows that the algorithm stucks around the local minima as they didn't change much.

Log of updated coefficients

Listening to port 4567
Connected!!!
Initialization Kp: 0.182805 Ki: 0.0028019 Kd: 2.9458 Ki: 0.0028019 Error: 0.378968 Sum dpi: 0.146402
Updated Kp: 0.182805 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
New best Kp: 0.228506 Ki: 0.0028019 Kd: 2.9458 Ki: 0.0028019 Error: 0.317703 Sum dpi: 0.150972
Updated Kp: 0.228506 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.00350237 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.00210142 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.0028019 Kd: 3.0458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.0028019 Kd: 2.8458
Reset Simulator
Connected!!!
Updated Kp: 0.228506 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.278778 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
New best Kp: 0.178235 Ki: 0.0028019 Kd: 2.9458 Ki: 0.0028019 Error: 0.304026 Sum dpi: 0.145929
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.00343233 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.00217147 Kd: 2.9458
Reset Simulator
Connected!!!

Updated Kp: 0.178235 Ki: 0.0028019 Kd: 2.9458
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
New best Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358 Ki: 0.0028019 Error: 0.292453 Sum dpi: 0.154866
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.233533 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.122936 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.00336928 Kd: 3.0358
Reset Simulator
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Updated Kp: 0.178235 Ki: 0.00223452 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.1348
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 2.9368
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
^[eUpdated Kp: 0.228004 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.128466 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
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Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
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Updated Kp: 0.178235 Ki: 0.00331255 Kd: 3.0358
Reset Simulator
Connected!!!

Updated Kp: 0.178235 Ki: 0.00229125 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.1249
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 2.9467
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.223027 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.133443 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.00326148 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.00234232 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.11599
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 2.95561
Reset Simulator
Connected!!!
Updated Kp: 0.178235 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.218547 Ki: 0.0028019 Kd: 3.0358
Reset Simulator
Connected!!!
Updated Kp: 0.137922 Ki: 0.0028019 Kd: 3.0358