ECE3 Final Report
An Implementation of an Autonomous Car

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Develop

In the beginning, we decided to implement one feature of the car at a time until the car accomplishes all goals and does so in the minimum possible time. First, we planned to ensure the proportional control worked correctly on a straight track. When the car moves towards the center from either side of the track, we would know we can move onto the next step. After the proportional control, we wanted to ensure the derivative control worked correctly on a straight track. The derivative control works when, if starting at an angle, the car eases its way onto the track and doesn't overshoot. From there, we planned on tweaking the proportional and derivative weights so that the two control techniques would work together on a straight track. We could only move on from this step when no matter the starting position, the car eventually centers on the track in a reasonable amount of time. Next, we wanted to repeat the above steps except on a track that curves left, then on one that curves right. When the car follows these curves while maintaining an approximately center position, we know we can move on. Then, we prepared to make sure that the car followed a track that went straight and turned both left and right. If the car stays centered on the track during these three conditions no matter the starting position, we could move on to the next developmental stage. Next, we planned on making the car turn 180° at the end of the track. The car needed to be able to detect the end and perform a 180° turn and resume on the track before we could try the next stage. That would be where we planned on ensuring the car would stop when it returned to the start of the track. When the car can consistently detect the second end of the track and stop after doing the last stage successfully, we can finally do optimizations. As a final step, we wanted to optimize the car such that it would perform all of the above as quickly as possible - of course we knew this was done when our car can complete the track in 15 seconds.

Conduct Tests

The parameters we controlled include the weights we initially chose to apply to each of the IR sensor readings, the proportional, derivative, and integral constant multiplier values, the analogWrite values of the motors (effectively changing the driving speed of the car), and our overall approach (either changing the driving speed of the car based on the elapsed time since the beginning of the run to assist on turns and the beginning/end of the run or changing the driving speed based on based on the error such that at times of higher error the driving speed would decrease and vice versa). The variables we measured but did not control include the “Weaving” value, quantitatively describing how well it sticks to the center of the road, “Quality of Run” descriptive value, quantitatively representing the overall performance of the car on a specific run, and general or important characteristics/results of the run recorded as written notes.

To ensure the proportional control works on a straight track, we would first write the initial code that implements basic PID control and makes the wheels turn, making sure to set the integral and derivative constants to 0 so that we isolate the proportional control. Then, we would repeat a similar process for the derivative control, ensuring that the proportional constant was set to 0 to isolate the derivative control. This was followed by testing if the control constants allow the car to correctly follow both a left-turning and a right-turning track and tweaking them (both non-zero) if not**.** Next, we would proceed by testing if the 180° turn functionality works by placing the car towards the end of the track and determining if it successfully turns around at the end; we would also test if the car accomplishes the same task after first completing half the track to be certain the function works. After that, we would then test the car’s ability to stop at the end of the track by allowing the car to first reach the end of the track once, turn around, and then successfully come to a stop the second time (to ensure the car does not stop prematurely). Finally, we would test the optimization/overall speed of the car by performing multiple trial runs and ensuring the car completes the track in under 15 seconds each time.

Analyze

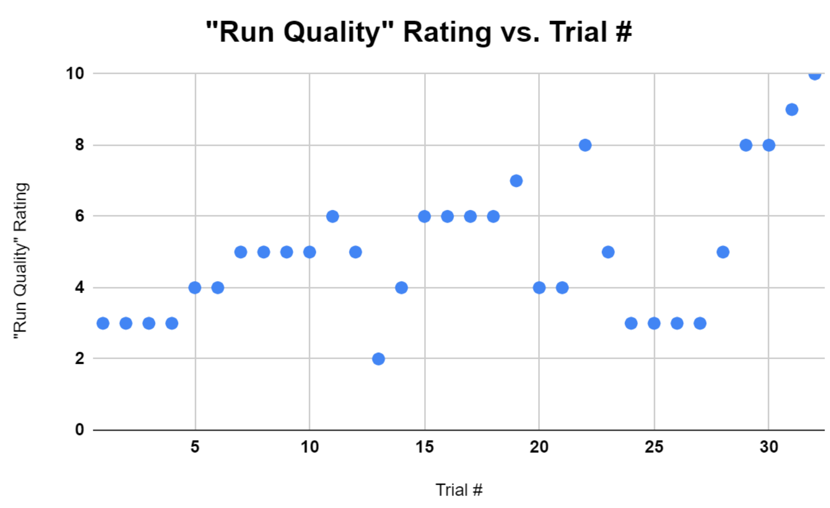

Figure 1. Trajectory of progress over time measured by trial run number and run quality, a value we assigned according to overall run performance.

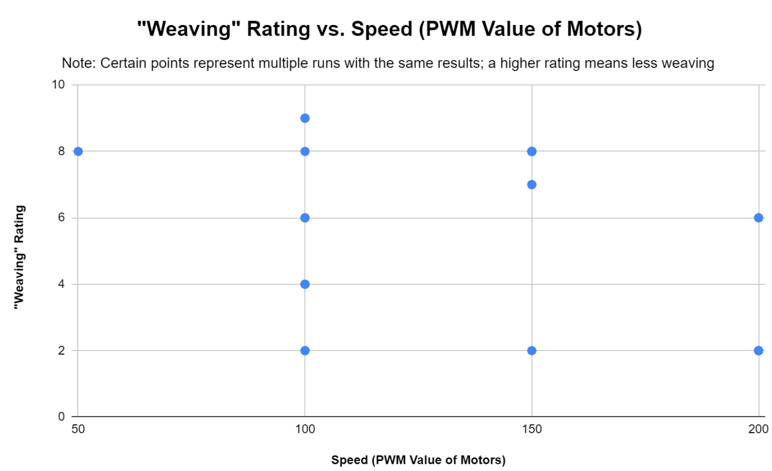

Figure 2. Trajectory of progress over time measured by trial run number and weaving, a value of run quality we assigned according to how well the car stuck to the line.

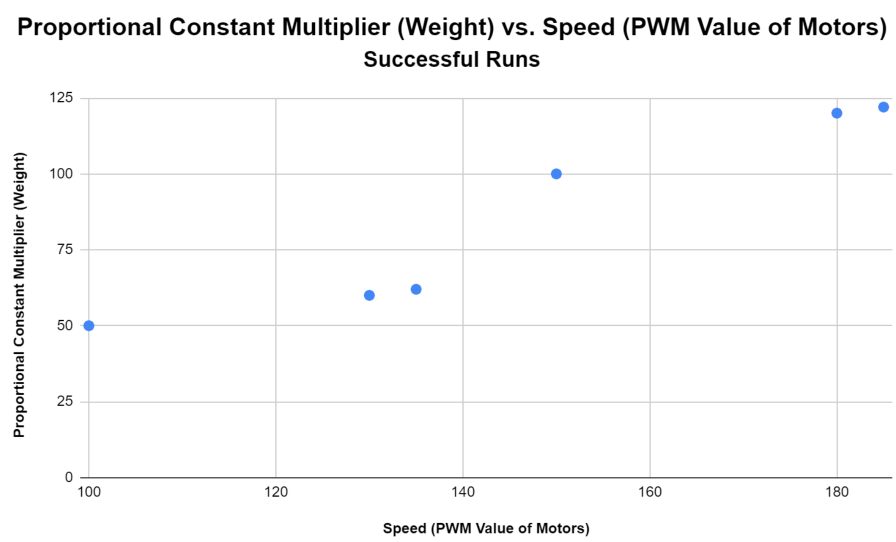

Figure 3. Ratio of Speed (PWM value of motors) and Proportional Constant Multiplier (also referred to as K_P in this paper).

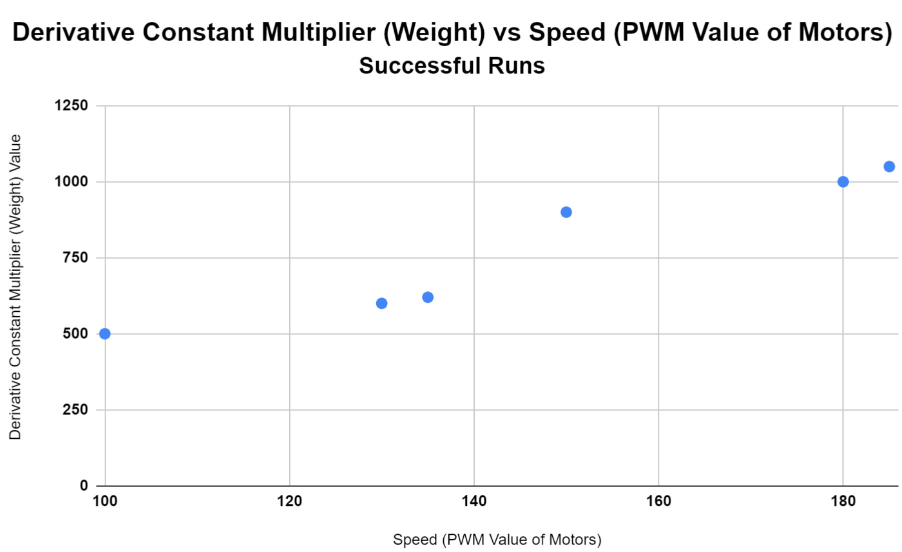

Figure 4. Ratio of Speed and Derivative Constant Multiplier (also referred to as K_D in this paper).

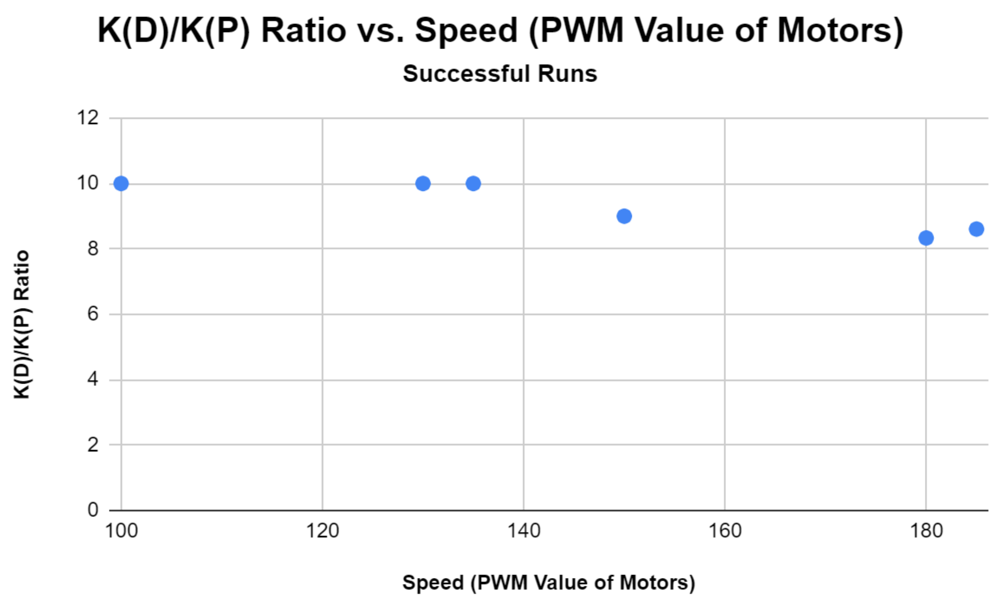

Figure 5. Ratio of Proportional Constant Multiplier and Derivative Constant Multiplier.

Our log kept track of the speed, K_P, K_D, and K_I (we didn't use the integral controller and just ended up putting zeroes throughout the log for that) we set our car to, additional notes on changes we made (such as implementing spin, graded speed based on error), a description on what the car did in the run, a rating of the weaving of the car from 1-10 (with 10 being little weaving) and a quantitative score of that run.

Car Log

In the case of technical difficulties, this log is also present in our submission.

Interpret

Figure 1 refers to the run quality over time as measured by runs completed - this shows the trajectory of our overall performance, which in some cases meant that we had to go backwards in progress (like adding a feature, but it messes up, or trying to adjust for a new speed but using completely incorrect K_p and K_D weights) to increase the potential of performing even better (which is why there is always a drop in rating following a high rating). The next one is the speed vs. weaving (higher number indicates less weaving, which is better), in which we can see that at higher speeds, the car tends to weave more, an idea that we ended up using in our final approach where we only increase the speed when the current error is low. After that, Figure 3 looks at the scaling of speed vs. the scaling of the proportional weight, which seems to increase proportionally to the speed. Figure 4 gives us a similar linear trend for the derivative weight, which combined with Figure 3's analysis means that we can reasonably predict a viable set of weights given a new, untested, speed. This is further clarified by Figure 5, which shows that K_D/K_P remains roughly the same (between a 8.5:1 and 10:1 ratio), further providing evidence that we might be able to predict correct proportional and derivative values for a given speed. Our table containing the raw test data demonstrates our careful testing of various features over time to improve the performance of the car; we followed our plan outlined in the sections above and slowly changed parameters over time to implement a successful, fast car.