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# Development of Steering Control System for Autonomous Vehicle

**Abhishek Pushpakanth, Mangesh N. Dhavalikar**

***Abstract:** Automation can help us to reduce the number of crashes on our roads. Through research it is identified that 94 percent of the accidents that occur are because of driver behavior or error as a factor and self-driving vehicles can help reduce driver error. High levels of automation have the potential to reduce risky and dangerous driver behavior and prevent accidents. The main aim is to convert the manual operated steering of the vehicle into fully autonomous steering. The objective of Steering Control System is to control the vehicle's steering while the vehicle is in motion and also to take accurate decisions while making a turn from the given inputs. The main purpose to develop a steering system for the autonomous vehicle is to replace the manual steering of the vehicle into driverless steering. The steering control is responsible for the vehicle's steering i.e., at what desired angle the vehicle need to turn. A PID (Proportional Integral Derivative) controller and an encoder is basically used to control the system based on the necessary conditions and requirement's. For the vehicle's steering the encoder is used to generate pulses when the steering wheel is turned so that those pulse values can be sent to the DC Motor which is attached to the front axle which is responsible for the vehicle to turn. This autonomous vehicle is a Level-4 automation system and the benefit of this automation is that the vehicle can be even operated in manual mode whenever it's necessary.*

***Keywords:** Autonomous vehicle, Encoder, PID, Steering Control.*

## I. INTRODUCTION

Today almost all vehicles are operated manually that it needs a driver to operate it. It has many disadvantages – dependency on human being populated areas or long-distance travel, chances of accident because of driver error and behavior resulting in fatality. An autonomous vehicle is a driverless vehicle which is able to operate without any human intervention [1]-[2], through the ability to sense it's surrounding and take the input data from the surrounding through sensors mounted on the vehicle. The steering control operates in such a way that considering all the factors a human would consider while driving a vehicle, the steering control system implements the same conditions and factors to operate the autonomous vehicle in an efficient way.

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***** Correspondence Author
**Abhishek Pushpakanth***, Department of Mechanical Engineering, MIT ADT University, Pune (Maharashtra), India. Email: abhishekpushpakanth10@gmail.com
**Mangesh N. Dhavalikar**, Department of Mechanical Engineering, MIT ADT University, Pune, (Maharashtra), India. Email: mangesh.dhavalikar@mituniversity.edu.in



The steering control system for an autonomous is controlled through PID (Proportional Integral Derivation) controller, Encoder and DC Motor. A PID controller and an encoder is basically used to control the system based on the necessary conditions and requirement's. For the vehicle's steering the encoder is used to generate pulses when the steering wheel is turned [3] so that those pulse values are sent to the DC Motor which is attached to the front axle which is responsible for the vehicle to turn. Two PID controllers are used for angle generation, the first PID generates the desired angle considering the encoder readings and the second PID calibrates the set point value with the first PID readings so that an accurate steering angle is generated [4]. If the vehicle is moving in an speed of 5km/hr in an straight path or road it continues to moves in an same speed, if it detects a turn or during an turn the speed reduces to 2-3km/hr until the vehicle begins to move in an straight path [5].

## II. METHADOLOGY

First, a research on autonomous vehicle was dispensed and therefore the basic information needed to implement in the system was obtained. The steering is controlled through embedded systems, software codes and the trajectory points plotted through the AI (Artificial Intelligence) module. After these studies, detailed information has been obtained about variety of sensors, camera, radars, etc., which obtains raw data and information from the surrounding environment. These data would then serve as input for software which would recommend the appropriate courses of action, such as vehicle turning and to generate the steering angle [6]-[7].

### A. Proposed Methodology

A self-driving car, also known as an autonomous vehicle is a vehicle that is capable of sensing its environment and moving safely with little or no human input. The vehicle's steering is calculated based on the desired angle which has will be generated with the help of PID and encoders and also the trajectory points (Tx1-Tx5) which are plotted for the vehicle to follow the path to reach its destination as shown in Fig 1. These trajectory points are mainly responsible for the vehicle's steering because based on these points the path will be generated.

For the angle generation two PID's will be used because the job of first PID is to generate an desired steering angle and the second PID will calibrate that value comparing it with the trajectory points which have been plotted and also the vehicle's acceleration is been controlled with help of PID and the trajectory points . The overall tuning of the PID is done based on Kp (proportional gain), Ki (integral gain) and Kd (derivative gain) values [8]-[9].


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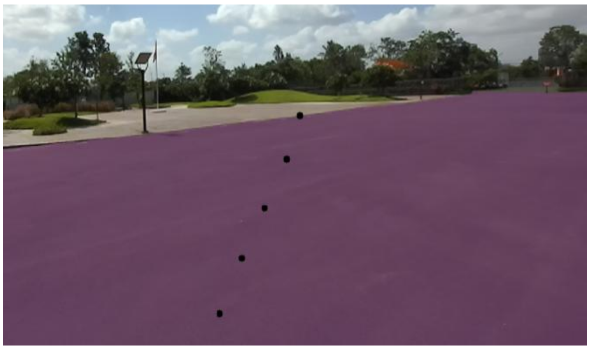

**Fig. Plotted Trajectory Points**

### B. Structure of Steering System

To the steering wheel an servo motor is attached which is responsible for the movement of the steering wheel, after the servomotor an Multiturn Absolute Encoder is attached to the DC Motor, this DC Motor is attached to the front axle which is responsible for the turning of the wheels. An Multiturn Absolute Encoder is used because we need an precise turning angle and position of the steering wheel as well as the data which we are giving is not in format for the motor to read, understand and process it, so the encoder does the job by converting the data into readable format so that the DC Motor can process it.

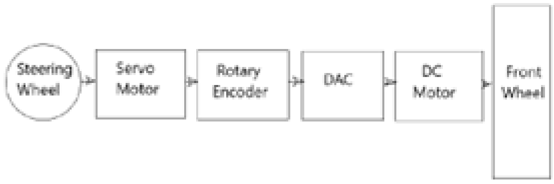


**Fig. Block Diagram of Steering System**

**Fig. Assembled Steering System**

## III. STEERING ANGLE CALCULATION

For the steering angle generation we are using two PID's. The first PID is usually used to generate the desired angle and the second PID is used to calibrate or check whether the angle is achieved or not. In the PID program for the steering we use the equation of the straight line i.e., $y = mx + c$ [10], with the help of this equation as we have calculated the value of slope and put the encoder pulses value in "x" and the angle which is generated in degrees in "y" we can get the exact steering angle. The steering wheel turning is set between the range -17 to +26, negative sign indicates the wheel turning to the left side and positive sign indicates the wheel turning to the right side [11].

Theoretically we have calculated the steering angle based on the wheel rotation by taking the first point (reference point) of the wheel when it's in straight position i.e., at 0 deg and after it reaches final set point it. By subtracting the reference point value with the final point value we get the steering angle for the suitable encoder value. The two main functions which are considered during steering wheel rotation is that the velocity at which it turns or rotates and the achieved steering angle.

**Table-I: Reference for the encoder value in pulses and the steering angle**

| Encoder Pulses | Angle (deg) |
|---|---|
| 5578 | -17 |
| 5310 | -15 |
| 3619 | 0 |
| 1577 | +18 |
| 1028 | +26 |

### A. Equation for Angle Generation

To get the value of an accurate steering angle we have used the equation of straight line i.e. $y = mx + c$. With the help of this equation which is implemented in the code which is used and as we have calculated the values of slope, we only need to put the encoder pulse value in "x" and the angle which is generated in degrees in "y" to get the steering angle. In the code we have defined the equation as:

y=(-0.037362x)+3.840879.

Where, m= -0.037362= slope or gradient

c= 3.840879= vertical intercept of line

y= generated steering angle

x= encoder pulses

After putting the respective encoder values (x), slope value (m=-0.037368) and value of vertical intercept of line (c=3.840879) in the straight line equation which is defined in the code, we get the final generated steering angle, refer Table 2.

**Table-II: Generated Steering Angle Using Straight Line Equation**

| | Encoder Value "x" | Steering Angle "y" |
|---|---|---|
| **Point 1** | 5578 | -17 deg |
| **Point 2** | 1028 | +26 deg |

### B. PID Algorithm

P controller: If we set the controller gain value (Kp) higher than the control loop will begin to oscillate and become unstable or if we set the value too low it will not respond to the changes which are made to get the set point. Proportional gain value (Kp) is used to generate the desired angle. I Controller: The Integral gain value (Ki) is responsible to solve the error which is present, it will continuously increment or decrement the output value depending on the type of error, if the error is large the process will be fast and if the error is less the changes will take place slowly. Main aim of I controller is to reduce the error to zero [13]. D controller: The D controller is used to make the control loop operation faster than PI alone, the changes in error will be faster. If there is no error or the error value is zero then the derivative action is zero. The derivative gain value (Kd) is mostly used to solve the overshoot value which is achieved by the proportional gain (Kd).

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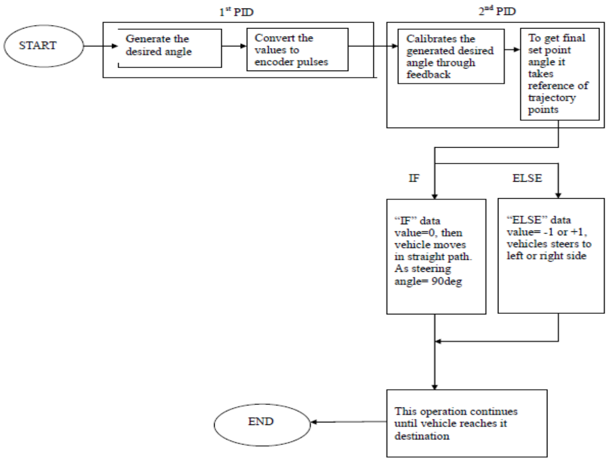



**Fig. Basic Working Flow Chart of PID**

### C. Steering Control

The system uses a path tracking system which controls the vehicle steering based on the current vehicle position [14]. Here we are using five trajectory (Tx1-Tx5) path tracking system, where with the reference of point three i.e, Tx3 the turning angle is generated. During the turning if the data value changes to -1 the vehicle is supposed to take an left turn and if the value changes to +1 the vehicle takes right turn and if the data value remains or changes to 0 the vehicle is supposed to move in an straight path, refer Fig (a) & (b).

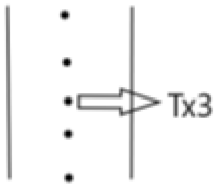
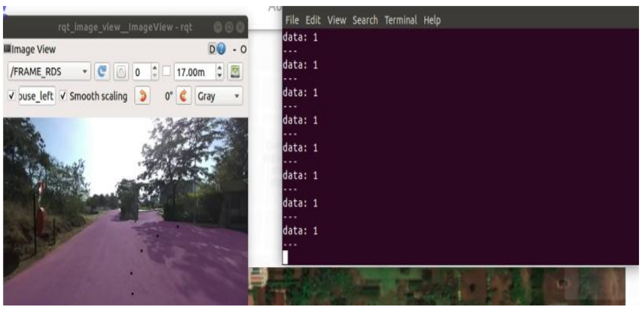
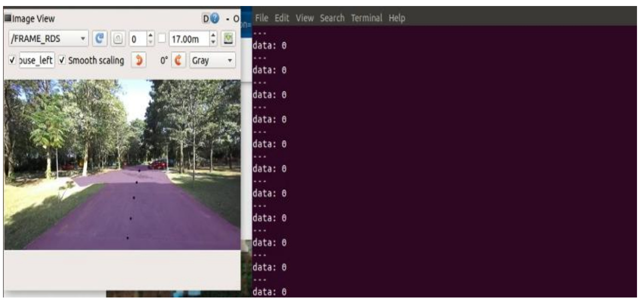



**Fig. Turning Angle w.r.t point Tx3**



**Fig(a). Data Value w.r.t Plotted Trajectory Points during Right Turn**



**Fig(b). Data Value w.r.t Plotted Trajectory Points while Vehicle is Moving Straight**

### D. Implementation of New Trajectory Points

But after considering the Trajectory 3 point (Tx3) for angle generation for the vehicle steering, during the turn w.r.t Tx3 point we were getting an sharp turn so the vehicle wasn't able to keep up with it or we can say that the vehicle was responding a bit slower because of which the vehicle was taking an long turn instead of taking an short sharp turn. So this issue was solved by instead of taking Tx3 point as reference an average of the points Tx1 to Tx4 was taken, i.e., (Tx1+Tx2+Tx3+Tx4/4). After considering the average of 4 points the vehicle was able to take an smooth turn during turning [15].

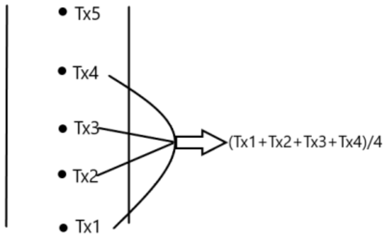



**Fig (a). Turning Angle w.r.t 4 Points**

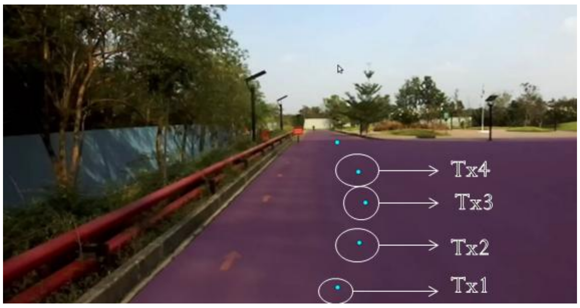



**Fig (b). Plotted 4 Trajectory Points**

## IV. RESULTS & DISCUSSION

The performance of the steering control system is tested on an autonomous vehicle with different trajectories. The Fig (a) shows the screenshot of the User Interface which includes the waypoints which are generated through GPS and shows the different trajectories that consists straight path, curve roads and different turns.

**Fig(a). Plotted Waypoints through GPS**

The vehicle follows a 5 trajectory path (Tx1-Tx5), (Tx1+Tx2+Tx3+Tx4)/4 are used for determination of the angle for vehicle to make a turn or move in a straight line based on the path detected from the road.



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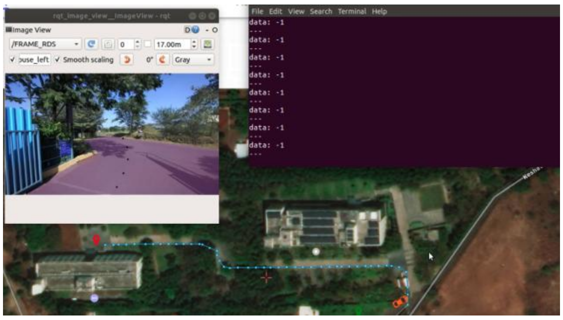
The vehicle was highly responsive after taking the average of 4 points i.e., (Tx1+Tx2+Tx3+Tx4)/4 which were taken as reference for generating the steering angle and to make a turn. The vehicle could take a smooth turn instead of taking sharp or long turn. The reason for not considering trajectory point 5 (Tx5) is because it is the first point which is plotted and this point would vary even based on minute change in path, it doesn't give us the accurate reference data to make the necessary decisions, as shown in Fig. The GPS gets updated as the vehicle moves and while the vehicle makes a turn.



**Fig(b). Data Value during Turn**

Tuning of PID was done by changing the gain value of Kp, Ki & Kd to 0.1, 0.01 & 0 respectively. During tuning of PID for values of kp, ki and kd, its was observed that value of kp cannot be equal to zero because we were getting an huge deviation in graph and also the curve had an greater deviation from point zero. Kp, ki & kd usually determine;- kp- desired angle, ki- resolves steady state error and kd- resolves overshoot. After of tuning of the gain value the steering could rotate smoothly without any jerkiness and vehicle could make a smooth turn. Steering angle is generated through the generated encoder pulses as the steering wheel rotates and the pulse data is sent to the DAC (Digital to Analog Converter), this process data is sent to the DC Motor which rotates the wheel to make a turn

## V. CONCLUSION

The vehicle steering operates with the help of servomotors, encoders, PID microcontroller and data which it receives through the software. The vehicle takes the reference of the trajectory points to make a turn and the steering angle is generated using plotted trajectoy points and generated encoder pulses. With the implementation of steering control system manual intervention will not be necessary to operate the vehicle's steering.

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## AUTHORS PROFILE

**Abhishek Pushpakanth,** is an M-Tech student, Dept. of Mechanical Engineering from MIT ADT University, Pune. He has done his M-Tech specialization in Mechatronics & Automation. He has done various institute level projects relating to his background and completed his 1 year internship in Artificial Intelligence, where he developed vehicle control system for the Autonomous Vehicle.

**Mangesh N. Dhavalikar**, is currently working as an Assistant Professor in Dept. of Mechanical Engineering in MIT ADT University. He has completed his M-tech in Mechatronics from Sinhgad College of Engineering, Pune and has a 2 year work experience with industry followed by 5 years teaching experience. His area of interest is Artificial Machines, Mechatronics and Control Systems. He is also currently pursuing his Ph.D.