School

of

Electronics and Communication Engineering

Mini Project Report

on

MOTION CONTROL FOR AUTONOMOUS VEHICLES

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SCHOOL OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

This is to certify that project entitled **" MOTION CONTROL FOR AUTONOMOUS VEHICLES "** is a bonafide work carried out by the student team of" **Rajendra G Kanbargi-01FE19BEC246,Prajwal Vakkund-01FE19BEC250,Tejaswini N-01FE19BEC256 and Vishwas Raju Banagar-01FE19BEC258 "**. The project report has been approved as it satisfies the requirements with respect to the mini project work prescribed by the university curriculum for BE (V Semester) in School of Electronics and Communication Engineering of KLE Technological University for the academic year 2021-2022.

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ABSTRACT

Self-driving vehicles require a high level of precision and consistency to operate. It is based on a wide range of factors, many of which are impossible to forecast and control. The efficiency of control algorithms is commonly impaired as a result of bad parameter selection.

Controlling self-driving vehicles necessitates a high level of precision and consistency. It is dependent on a huge number of characteristics, many of which are difficult to predict and regulate. Control algorithm efficiency is frequently harmed as a result of poor parameter selection. We presented a simplified control system for autonomous vehicles based on a small number of easily modifiable parameters in this paper. This control system is made up of longitudinal and lateral controls. The longitudinal controller is in charge of controlling the vehicle's speed, while the lateral controller is in charge of controlling the vehicle's steering. The longitudinal controller controls the vehicle's speed, while the rear controller directs the car's wheels to follow the path. The placement and speed of the vehicle are two of the most important aspects of the road.

We employed a pure puesuit model for lateral control of autonomous cars in our implementation while keeping the longitudinal parameters constant. We used a Raspberry Pi-3 board for our project, in which we simulate a pure pursuit model in the pigames window and provide a waypoint for our prototype, which is relayed to our prototype over wifi. We used an RC car chassis, one servo motor for steering control, and a DC motor for speed control that is controlled by an LN298 motor driver, a 12V DC voltage battery to power the DC and servo motors, and a power bank to power the Raspberry-pi-3 board that manages and controls the prototype in our prototype.

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Chapter 1

Introduction

As information and communication technology and vehicle techniques evolve, the competition to develop and commercialise intelligent and autonomous vehicles has heated up. The purpose of these vehicles is to increase traffic efficiency while also assuring vehicle stability and comfort for the driver.

The intelligent Advanced Driver Assistance System (ADAS) supports drivers by following the lane departure warning system, Lane Keeping Assistance System (LKAS), Forward Collision Warning System, and Smart Parking Assistant System through a human–machine interface (SPAS). When the system senses the vehicle straying from its lane, LKAS assists it in staying on track by supplying a modest amount of counter-steering force on a constant basis. SPAS simplifies parking by providing automatic steering assistance along a specified path, guiding a driver to the ideal starting position for backing into a parking place. A self-driving car is one that can go to a destination without the need for the driver to be present.

An autonomous vehicle is one that can drive itself. It is capable of moving from a starting point to a predetermined destination in "autopilot" mode. It uses various in-vehicle technologies and sensors, including adaptive cruise control, active steering (steer by wire), anti-lock braking systems (brake by wire), GPS navigation technology, lasers and radar.
2.1

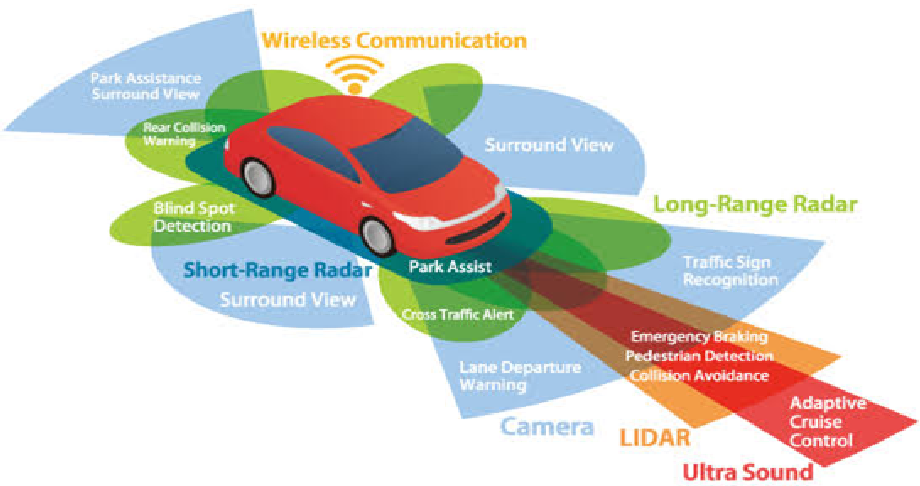

Figure 1.1: Autonomous vehicles

1.1 Five levels of automation:

The classification of the development stages up to the self-driving vehicle comes from the Society of Automotive Engineers (SAE). The development stages up to the autonomous vehicle are divided into five levels.It describes the extent to which the vehicle can and may take over the tasks of the driver.

Level 0 - No Automation:
This is how your typical automobile looks. There are no bells and whistles. Simple cruise control to aid long-distance driving and reduce the possibility of receiving a speeding ticket from a lead foot. Almost every automobile on the road today will have Level 0 autonomy..

Level 1 - Driver Assistance:
To help with driving weariness, we can find your adaptive cruise control and lane keep assist here. Adaptive cruise control uses radars and/or cameras to maintain a safe distance between you and the car ahead of you, automatically applying braking when traffic slows and resuming speed when traffic clears. If you stray from the lane, Lane Keep Assist will gently guide you back into it. These systems will aid drivers, but the driver must remain in command. Almost all cars today have Level 1 autonomy, including the 2018 Toyota Corolla (Toyota Safety Sense1) and the 2018 Nissan Sentra (Intelligent Cruise Control).

Level 2 - Partial Automation:
Level 2 automation can help with speed and steering control. It will assist you in stop-and-go traffic by maintaining a safe distance between you and the vehicle in front of you, as well as steering assistance by keeping the car centred within the lane. For commuters, these features are a godsend! Level 2 autonomous capabilities include Tesla Autopilot, Volvo Pilot Assist, and Audi Traffic Jam Assist, to name a few..

Level 3 - Conditional Automation:
Level 3 autonomous vehicles are capable of driving themselves, but only under ideal conditions and with limitations, such as limited-access divided highways at a certain speed. Although hands are off the wheel, drivers are still required behind the wheel. A human driver is still required to take over should road conditions fall below ideal. The next generation 2019 Audi A8 is expected to be the first to market a level 3 autonomous driving system3.

Level 4 - High Automation:
Level 4 autonomous cars will be limited to known use cases and will not be able to drive themselves (apart from entering your destination). We're not far from seeing self-driving cars on public roads. Despite the fact that restrictions limit its availability, Waymo has developed and is testing Level 4 vehicles capable of driving autonomously in a wide range of environments and road conditions..

Level 5 - Full Automation:
Super Pursuit Mode is now available! We arrive at real autonomous autos when we reach Level 5 autonomy. Vehicles with Level 5 capability should be able to monitor and manoeuvre through all types of road conditions with no human interaction, obviating the need for a steering wheel and pedals. Despite the fact that many of the technological components for an artificially intelligent car exist today, Level 5 vehicles are likely still many years away due to laws and legal disputes. We'll have to make do with limited automation till then. 1.2

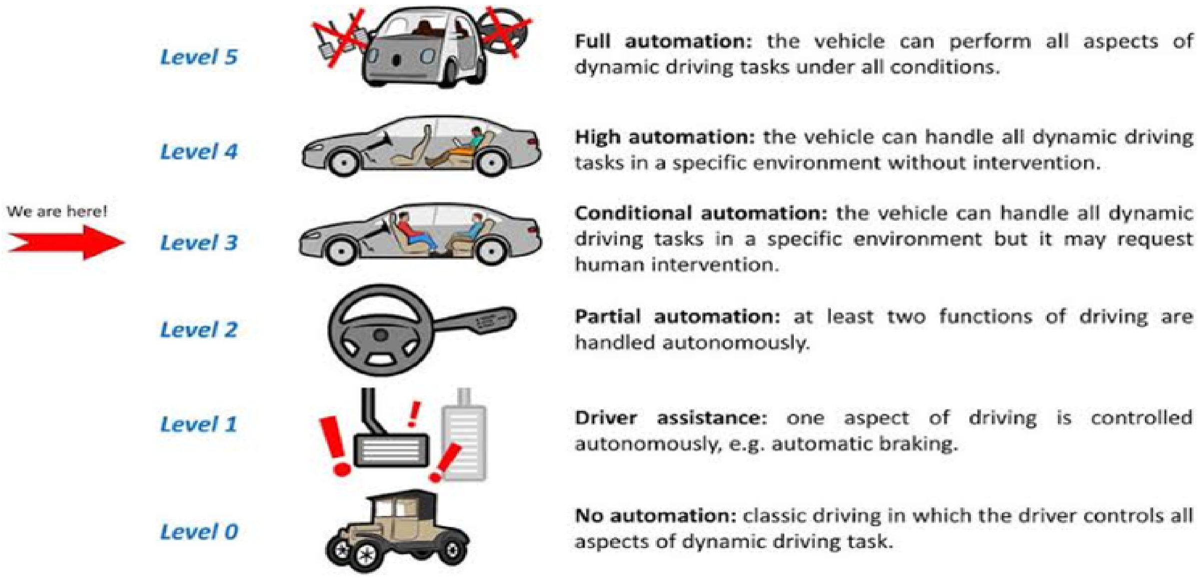

Figure 1.2: Five levels of automation

1.2 Motivation

In order to control the autonomous vehicle's speed and steering system. Longitudinal and lateral controllers make up the control system. The longitudinal controller is in charge of controlling the vehicle's cruise speed, while the lateral controller is in charge of steering the wheels for route tracking.

The Motivation Behind Self-Driving Cars:
We are a long way away from having a true self-driving car. By a true self-driving car we mean a car that can be essentially driven in any manner as a human driving a car. This is an incredibly hard thing to achieve.

Major automobile companies have been trying to achieve true autonomous driving The main motivations behind the idea are:

1.Safer Roads.
2.Increase in productivity.
3.More economical.
4.The movement will be more efficient.
5.More environment friendly.

1.3 Objectives

Our objective is to: 1. The purpose of lateral control is to move in a specific direction.
2. To transport the self-driving vehicle from one location to another.
3. The lateral control system uses an output-feedback controller to track a planned trajectory for the vehicle's lateral motion.
4. For better safety and fewer accidents.

1.4 Literature survey

1."An introduction of autonomous vehicles and a brief survey", Raviteja Tirumalapudi,I.s , Rajay Vedaraj, VIT University Vol 7, Issue 13, 2020
Humans are currently addicted to automation and robotics technology in areas such as agriculture, medicine, transportation, automobile and manufacturing industries, information technology, and so on. Every day, researchers working on autonomous car technology face new obstacles. Autonomous vehicles require constant data and updates, therefore IoT and artificial intelligence can assist in sharing information from one device to another. Literature evaluations were performed to determine what technology and methods are used in autonomous vehicles, as well as the gap between them.

2."Longitudinal and Lateral Coordinated Motion Control of Four-Wheel-Independent Drive Electric Vehicles ", , EVS27 Barcelona, Spain, November 17-20, 2013
The longitudinal and lateral motions of a car on the road can be distinguished. To increase vehicle handling stability and energy efficiency, a coordinated longitudinal and lateral motion control system for four-wheel-independent drive electric cars (4WID EV) is presented. The state estimator is used to estimate longitudinal velocity and vehicle sideslip angle using data from GPS and INS. Tire force distribution is controlled by the top controller, which optimises tyre workload and energy dissipation. The lower controller for tyre force control is constructed using an inverse tyre model. The longitudinal and lateral coordinated motion control system may effectively increase vehicle handling stability and energy efficiency, according to simulation and field test results.

3.Longitudinal and Lateral Control for Autonomous Ground Vehicles June 8-11, 2014. Dearborn, Michigan, USA
Navigation of self-driving cars necessitates robust and steady control. Some of the existing approaches rely on a large number of parameters that are often difficult to estimate. The efficiency of control algorithms is frequently reduced due to inadequate parameter selection. We propose a simplified control system for autonomous cars in this study that is based on a small number of easily adjustable parameters. Longitudinal and lateral controllers make up this control system. The longitudinal controller is in charge of controlling the vehicle's cruise speed, while the lateral controller is in charge of steering the wheels for route tracking. Simulated and experimental tests with the CaRINA II platform have yielded positive results on the university campus.

4.A Review of some Pure-Pursuit based Path Tracking Techniques for Control of Autonomous Vehicle. International Journal of Computer Applications (0975 – 8887) Volume 135 – No.1, February 2016. Moveh Samuel,Mohamed Hussein,Maziah Binti Mohamad

An autonomous vehicle is a self-driven vehicle that drive itself with necessary sensors, such as GPS, IMU, cameras,sensors etc. The basic operational process is such that the vehicle first detects the environment and positions itself according to these sensors, and then navigates itself with global and local planner; finally, the vehicle drives its self autonomously by executing the necessary control command along the given path.Pure-pursuit can be dated back in history to the pursuit of missile to a target [10]. In this process, the missile velocity vector is always directed toward the instantaneous target position.Another geometric path tracking technique used in tracking the path of a non-holonomic autonomous ground vehicle is vector pursuit. They introduced a path-tracking technique known as vector pursuit, which is based on the theory of screws, by Sir Robert Ball in 1900. It generates a desired vehicle turning radius based on the vehicle's immediate location relative to the position of a point ahead on the planned path and the desired orientation along the path at that point.

Integrated Longitudinal and Lateral Control System Design for Autonomous Vehicles Jin ZHAO, Abdelkader EL KAMEL
Transport systems all over the world are suffering from the spreading problems such as traffic congestion, safety, pollution and fuel consumption, etc. Regarding the design of longitudinal control system, it needs to handle several challenges, such as nonlinear vehicle dynamics, spacing policy and its associated control law design, string stability and traffic flow stability, operation at all speed from a complete stop to high-speed, and the execution of longitudinal split and join maneuvers with the application of communication system.The Longitudinal control system architecture is typically designed to be hierarchical, with an upper level controller and a lower level controller. The upper level controller determines the desired acceleration for the controlled vehicle, and the lower level controller determines the throttle and/or brake commands required to track the desired acceleration.

1.5 Problem statement

To design and implement control algorithm for lateral motion control of an autonomous vehicle.

1.6 Application in social context

1. The likelihood of widespread usage of self-driving cars has a number of advantages, including a reduction in traffic accidents and the associated economic costs of property damage, injury, and death.
2. These autonomous vehicles will save energy by maximising driving efficiency and reducing traffic congestion.
3. Automation of vehicles in several sectors.
4. GPS data collection and analysis.
5. Acquisition and processing of local positioning system data.
6. Local positioning with the help of landmarks.

1.7 Project Planning

Our project objective is to design and implement controlled model for steering control keeping the speed constant. In order to accomplish our goal, we have done literature survey based on the objective which helped us by providing clear idea and a right path to proceed further. We identified different possible models relevant to our project and did a comparative study and created a successful pure pursuit model which we prototyped and tested then implemented our project successfully.

1.8 Bill of materials

Sl.No	Components	Specification	Cost	Quantity
1	Raspberry pi kit	Raspberry pi 3	6000/-	01
2	Servo Motor	SG 90	195/-	01
3	DC Motor	60rpm	150/-	02
4	DC Motor Drivers	Robocraze L298	250/-	01
5	Battery	12V,1200 maH	600/-	01
6	Wires	-	-	-

Table 1.1: Bill of materials

1.9 Organization of the report

- Chapter 1 Covers the introduction.
- Chapter 2 Briefs about functional block diagrams , design alternatives and final design.
- Chapter 3 Gives implementation details.
- Chapter 4 Discusses the mathematical models.
- Chapter 5 Discusses the results and discussions.
- Chapter 6 Gives the conclusion.

Chapter 2

System design

2.0.1 Functional block diagram

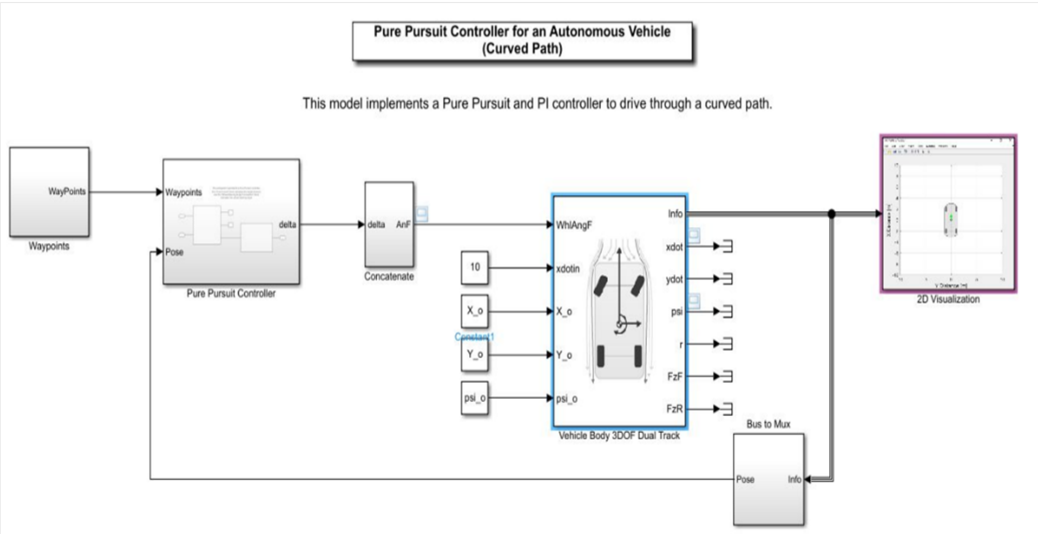

Figure 2.1: Pure pursuit block diagram

2.0.2 Design specification:

INPUTS:
A goal point is a spot on the path that is a certain distance ahead of where the vehicle is now. A group of discrete points is used to represent a path. (It needs to be kept in memory.) A path point is usually of some PATH-TYPE, which means it has the following information:
1. x location in global coordinates
2. y location in global coordinates
3. Using global coordinates as a guide.
4. The path's curvature at this point.
5. The distance between this point and the start of the path (in a straight line).
OUTPUTS:
The position of the vehicles should be updated.

Transfer the vehicle to the new location point.

2.1 Design alternatives

Our main aim is to accomplish steering control model for autonomous vehicle which is able to control the steering of autonomous car. This can be done in multiple ways using different model like PID , Stanley ,MPC and Pure pursuit model. Out of these we choosed pure pursuit model to work on.

2.1.1 Stanley Method:

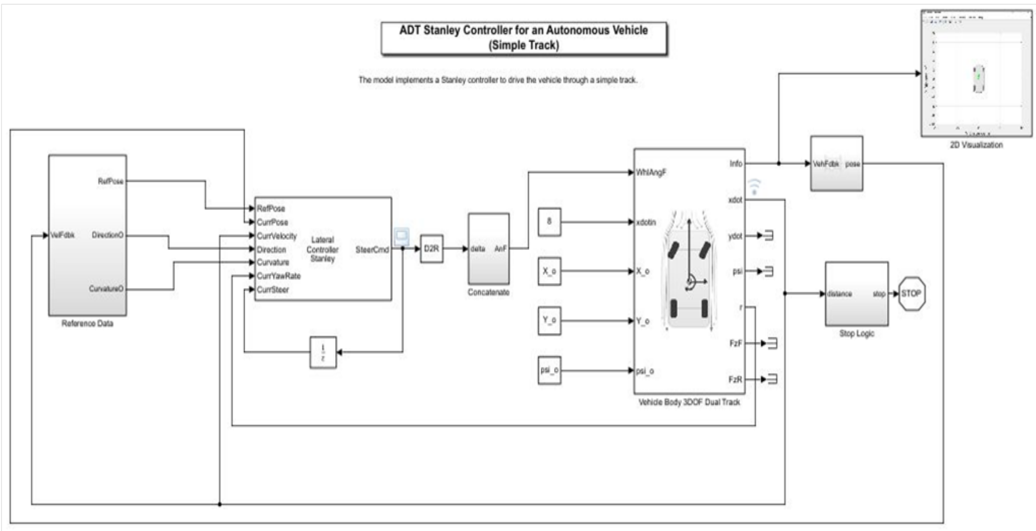

Figure 2.2: Stanley block diagram

2.1.2 Design specification:

INPUTS:
The Driving Scenario Designer is used to create the waypoint.
2. Use the Driving Scenario Designer to create the waypoints and save the mt file if you want the vehicle to take a different path.
WORKING:
1.The reference velocity is generated by the live script "velocityProfile.mlx" using the following ways.
2.Trapezoidal profile in its most basic form.
3.A trapezoidal profile based on the radius of curvature and friction.
4.Trapezoidal profile based on maximum velocity and acceleration.
5.Various tuning parameters of the Longitudinal Controller Stanley and Lateral Controller Stanley blocks influence the performance of the Stanley controller.
OUTPUT:
1. To follow the reference trajectory, the Stanley controller sends out steering, acceleration, and

deceleration orders.

2.2 Final Design

After going through detailed research on pure pursuit model and optimization i.e Hardware optimization : By exploring and checking availability of components we selected LN298, DC motor, servo motor, raspberry pi3. We switched from Arduino to raspberry pi 3. The Raspberry Pi 3 is faster than the Arduino (1.2 GHz compared to 16 MHz), which gives it the ability to complete everyday tasks that computers do – playing videos, surfing the web, listening to music, etc. This makes the Raspberry Pi 3 an easy choice if you want to use it for media-centered applications Software optimization: Using python library functions like math, pygame, numpy. Using various code optimization like using loops, conditional statements. Hence we found that pure pursuit is good model.

Chapter 3

Optimization

3.1 Introduction

Optimization is a technique in which an optimal solution is found by comparing various solution till the most optimized solution is found.

3.2 Types of optimizations

1.Hardware optimization
2.Software optimization

3.3 Selection and justification of optimization method

1.Using python library functions like math, pygame, numpy.
2.Using various code optimization like using loops, conditional statements.
3.By exploring and checking availability of components we selected LN298, DC motor, servo motor, raspberry pi3.
4.We went from Arduino to a Raspberry Pi 3 for this project. The Raspberry Pi 3 is also much quicker than the Arduino (1.2 GHz vs. 16 MHz), allowing it to perform common computer functions such as watching videos, accessing the web, and listening to music. If you want to use the Raspberry Pi 3 for media-related applications, this makes it an easy choice..
5.Simulation with Matlab Simulink. Matlab Simulink is a visual tool for performing computational simulations that we employ. It employs a drag-and-drop mechanism for simulation components, which are subsequently linked using lines. You can configure the components you utilise, and you have components that support mathematical operations.
6.As follows, the lateral distance between the heading vector and the target point is defined as the cross-track error. If the cross-track error is reduced, our car is following the course more closely. Pure Pursuit control acts as a proportional steering angle controller based on cross-track error. Controlling the steering angle reduces cross-track error, hence Pure Pursuit Controller is good in controlling lateral motion.

Chapter 4

Implementation details

4.1 Specifications and final system architecture

A path tracking algorithm is known as pure pursuit. It determines the angular velocity command that will advance the robot from its current position to a look-ahead point in front of it. The programme then updates the look-ahead point on the path based on the robot's current position until it reaches the path's end. Another extensively utilised control technique in ground vehicles is the Pure Pursuit controller. The controller was first introduced as a way for ground robots to track their paths.

4.2 Algorithm

The pure pursuit algorithm is quite simple to build on its own. The following is a description of the pure pursuit algorithm:

1.Find the vehicle's approximate position.

2.Select the path point that is closest to the vehicle.

3.Locate the goal point.

4.Convert the goal point's coordinates to vehicle coordinates.

5.Calculate the curvature and request that the vehicle's steering be adjusted to that curvature.

6.Refresh the vehicle's location.

Explanation:

1) Determine the vehicle's current position. The position is given in relation to the vehicle's position at the moment of initiation. This initial position serves as the run's global reference frame.

2) Locate the nearest path point to the vehicle. The destination point would be within one look ahead distance of the vehicle, according to the geometric derivation. There may be

many points within one look ahead distance of the vehicle's current location. One look forward distance from its current location, the vehicle should steer toward the closest point. As a result, the closest path point to the vehicle will be discovered first, and the search for a point 1 look ahead distance away from the vehicle will begin at this point and proceed up the path.

3) Locate the objective spot. Moving up the path and calculating the distance between that path point and the vehicle's present location yields the objective point. Path point locations are recorded in the global frame; this calculation is done in global coordinates.

4) Convert the goal point's coordinates to vehicle coordinates. After locating the destination point, it must be converted to the vehicle's local coordinates. Vehicle coordinates were used for the geometric derivation of the curvature, and curvature commands to the vehicle made sense in vehicle coordinates.

Chapter 5

Mathematical modelling

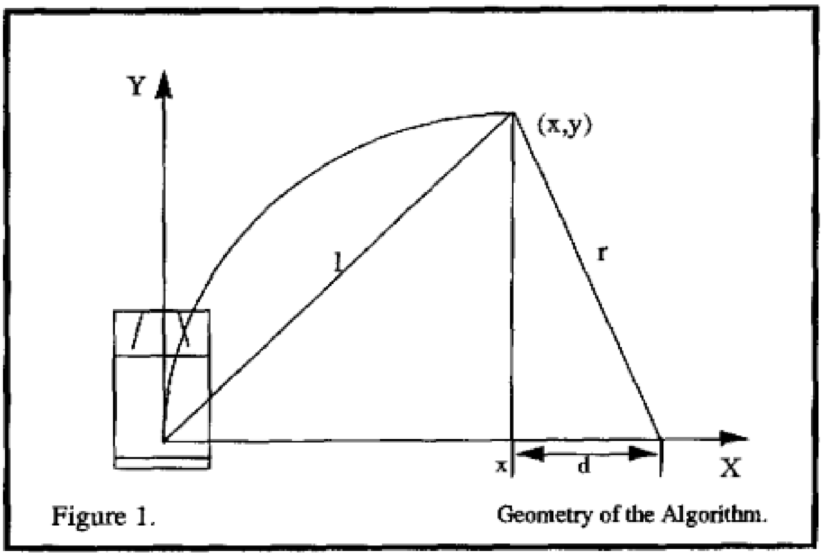

Figure 5.1: Mathematical Model

The point (x, y), which is one look forward distance 1 from the origin, is also indicated. On the path, the point (x, y) must be located. The purpose is to determine the curvature of an arc with a chord length of one that connects the origin to (x, y).

Both of the equations below are correct. The first is based on the geometry of the smaller right triangle in Figure. The second is derived from the summing of line segments on the x-axis.

x+y = I (2.1)
x+d = r (2.2)

Equation 1 describes the circle of radius 1 around the origin (2.1). This is where the vehicle's possible goal points are located.

Equation 2 describes the radius of the arc between the origin and the goal point, as well as the x offset of the goal point from the vehicle (2.2).
The arc's radius and the x offset

$d = r - x$

$(r-x)^2+y^2 = r^2$

$r^2 - 2rx + x^2 + y^2 = r^2$

$2rx = l^2$

$r = l^2 / 2x$

$Y = 2x / l^2$

The inverse square of the look ahead distance 1 has been used to relate the curvature to the goal point's x offset from the origin. In terms of form, it resembles a proportional controller with a gain of 2 times the inverse square of 1. In this case, the "error" is the x offset of a point ahead of the vehicle.

Chapter 6

Results and Discussion

6.1 Discussion

Autonomous Car with Raspberry Pi- In this project, we'll build a miniature autonomous car that can follow a waypoint on its own and is controlled by a Raspberry Pi. So, this is really a waypoint-following car; you simply draw waypoints, and the autonomous car follows them; you do not have to send directions to manage this car, which qualifies it as a self-driving vehicle. The cheapest version of the same project can be made with an Arduino Uno or Arduino Nano. Making a completely effective autonomous or self-driving automobile is not easy; you'll need to use cameras, lidars, GPS trackers, and other sensors. In a real traffic environment, an autonomous automobile or self-driving car should be able to recognise individuals, animals, small and large cars, position, distance, and other factors.

6.2 Results

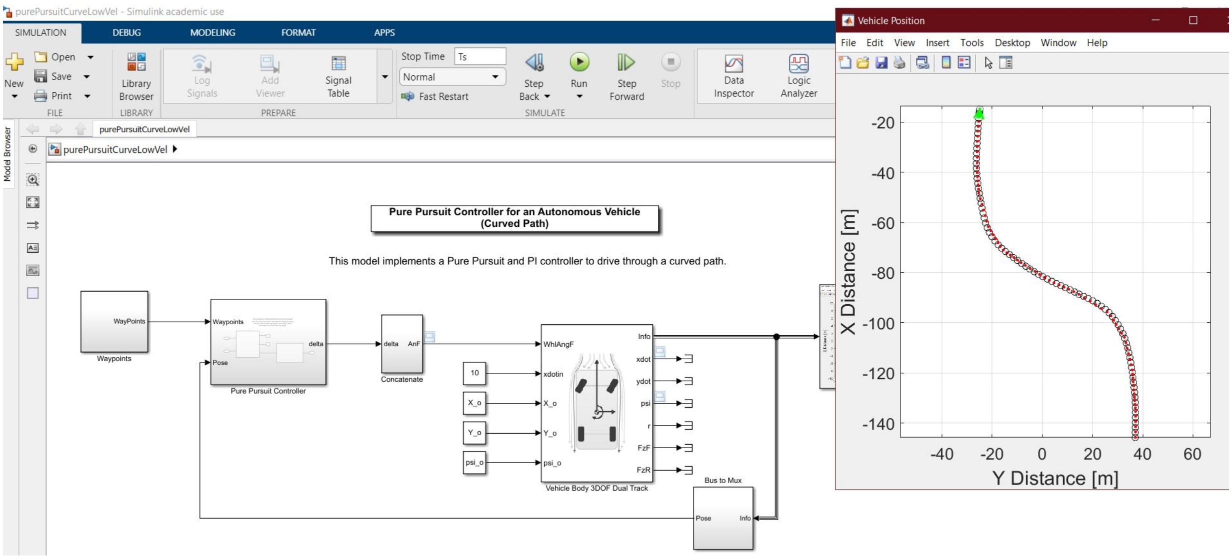

Figure 6.1: Simulation Result:the simulation of the Pure Persuit algorithm in matlab simulink

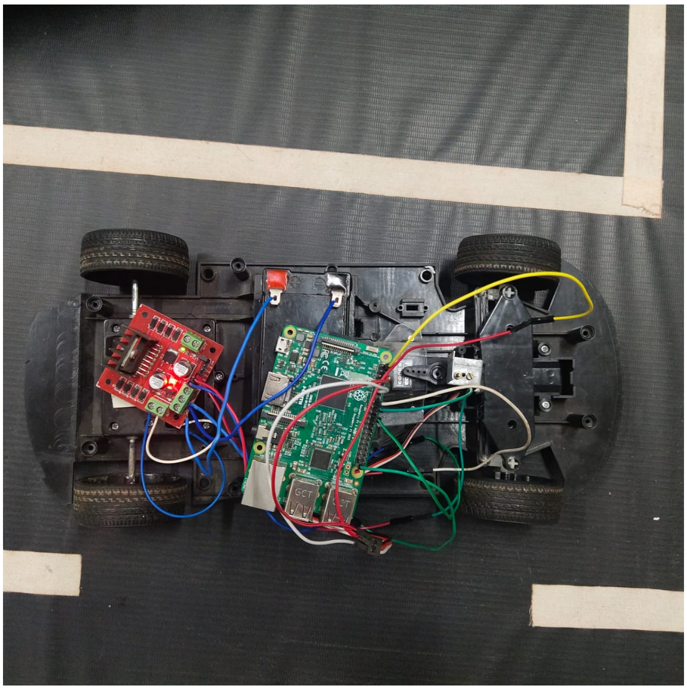

Figure 6.2: Final assembled prototype

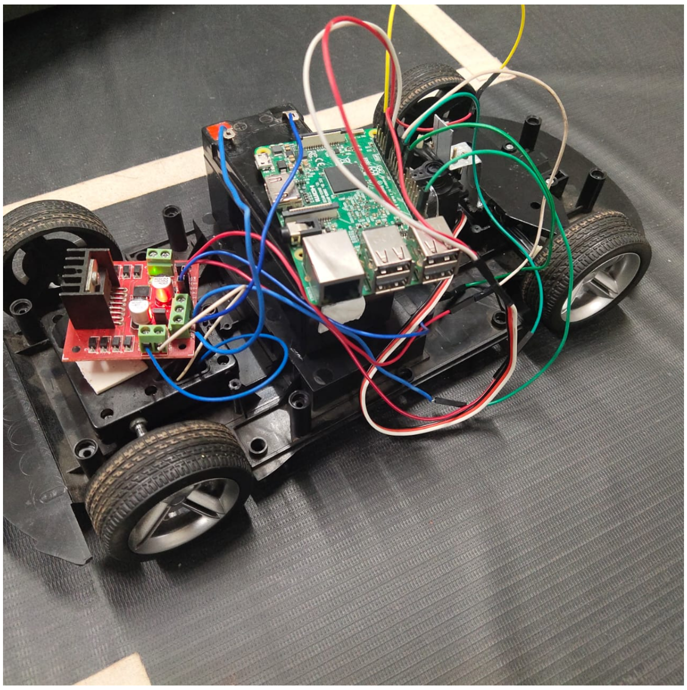

Figure 6.3: Final assembled prototype

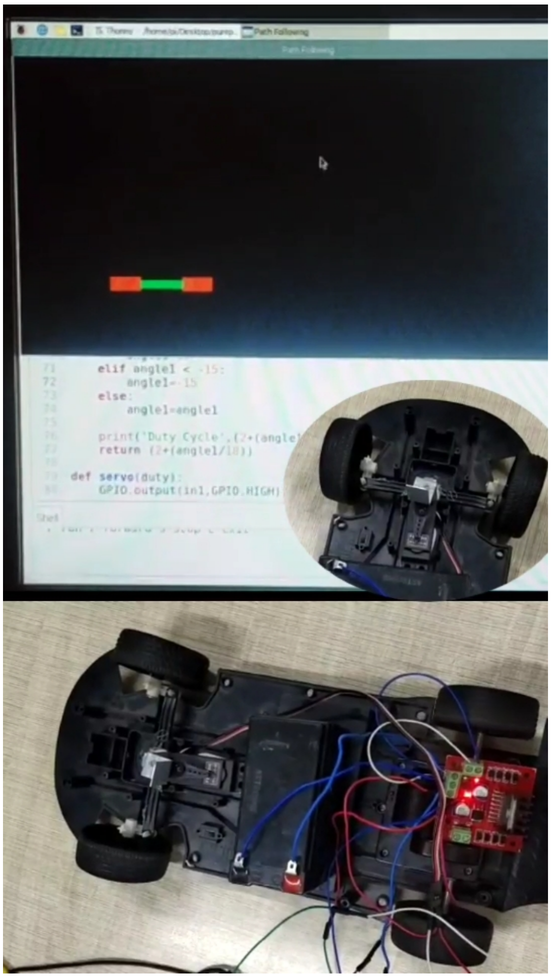

Figure 6.4: Implementation image1:Pure Pursuit model is simulated in pygame window and the prototype is connected with system and powered up.

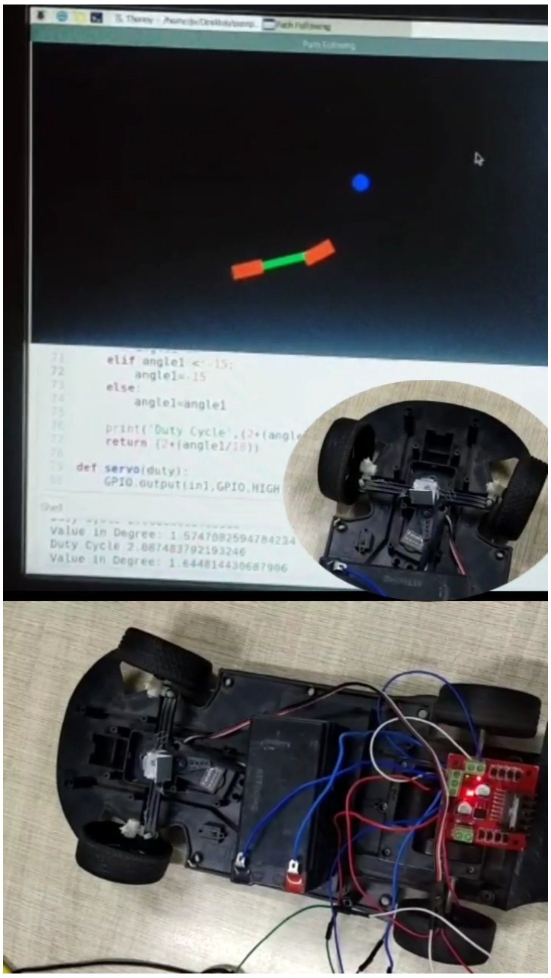

Figure 6.5: Implementation image2:A waypoint is marked in pygame window and the prototype steering is also turned to that marked point.

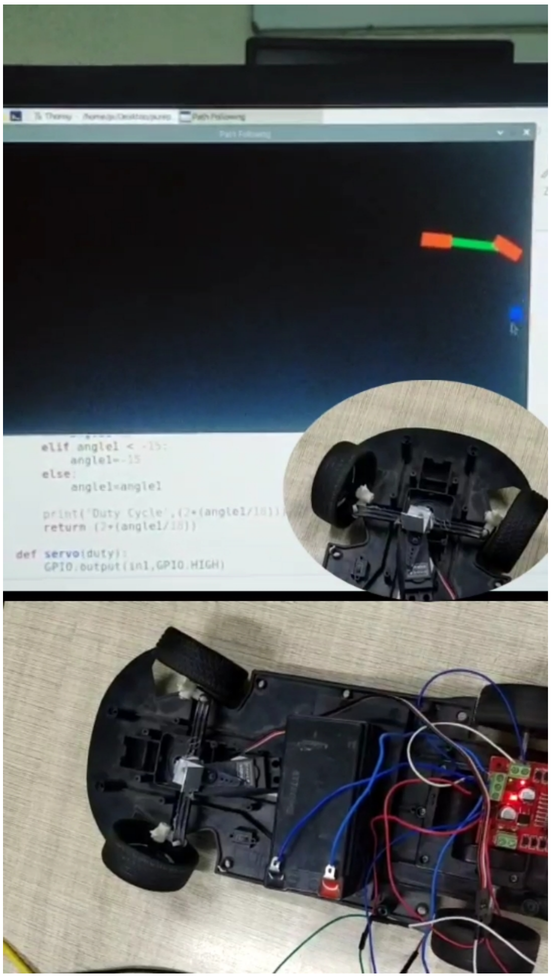

Figure 6.6: Implementation image3:the next waypoint is marked in pygame window and the prototype steering is also turned to that marked point.

Chapter 7

Conclusion

The solution can be combined with back-stepping and feed-forward ideas to create a lateral controller for autonomous cars. The steering mechanism of an autonomous car was controlled by a pure pursuit algorithm. We used a servo motor for steering angle control and a Ln298 motor driver for vehicle motion control in the hardware implementation.

Despite the fact that the control design is centred on lane-keeping, it may be adapted to lane-changing and other situations by utilising correct path planning methods to establish a "feasible" reference trajectory that the car follows. In the future, we'll focus on developing a robust control scheme for the vehicle's lateral dynamics in the presence of disturbances and uncertainty.

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