DESIGN AND FABRICATION OF A MINI AUTONOMOUS VEHICLE

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CERTIFICATION

This is to certify that the project work titled "**DESIGN AND FABRICATION OF A MINI AUTONOMOUS VEHICLE"** was carried out by

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DEDICATION

This project is dedicated to God almighty who has given us the grace, strength and wisdom to successfully complete this project.

It is also dedicated to all those who have inspired, supported, and believed in us throughout this journey. We extend our deepest gratitude to our family for their unwavering encouragement and understanding, which provided the foundation for every success. We are also profoundly thankful to our lecturers especially our supervisor Prof S. A . Aliu, whose guidance and insights have been invaluable in shaping our academic and professional endeavours.

Lastly, we dedicate this project to our friends and colleagues whose collaboration and constructive feedback enriched this work. This report stands as a testament to our shared commitment to learning, innovation, and perseverance.

ACKNOWLEDGEMENT

First and foremost we will like to thank God almighty for his grace, mercy and provision from the start to the completion of this project. He gave us the strength and wisdom we needed to be able to successfully complete this project.

We also wish to acknowledge the support of our family and friends for their continuous encouragement and understanding. Their belief in our abilities provided us with the motivation to persevere, even during the most challenging moments.

We would also like to extend our appreciation to our project supervisor Prof S. A. Aliu whose guidance, expertise, and unwavering encouragement helped us through out the project. His insightful suggestions and constructive feedback significantly enriched the quality of this work.

Also we would like to acknowledge the HOD of Mechanical Engineering Department, Prof E. G. Sadjere for the support he has given to us during this project.

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ABSTRACT

The transportation and logistics sector could become much safer and more efficient with the use of autonomous vehicle (AV) technology. This project presents the design, development, and evaluation of a mini autonomous vehicle aimed at demonstrating the feasibility of low-cost, compact automation for indoor and controlled outdoor environments. The vehicle uses an ultrasonic sensor for real-time obstacle detection, with a microcontroller(ESP32)-based control system to execute navigation and collision avoidance maneuvers. A modular architecture was implemented, incorporating sensor data processing, path planning, and control algorithms to ensure responsive and adaptive vehicle behaviour. Both simulation and field tests were conducted to validate system performance, with results indicating reliable obstacle detection, effective trajectory tracking, and robust control response under various operating conditions.

The successful realization of this mini autonomous vehicle project not only underscores the potential of accessible, cost-effective autonomous systems but also provides a solid foundation for future enhancements and applications in small-scale robotics.

CHAPTER 1

INTRODUCTION

1.1 Background of study

Autonomous vehicles also known as self-driving cars are equipped with technologies that make them capable of sensing their environment, making decisions, and navigating without human intervention. This is a transformative technology with the potential to revolutionize transportation and improve road safety. The idea of self-driving cars or autonomous cars originates from witnessing many accidents caused due to careless driving of people which could sometimes become extremely harmful. The development of self-driving cars has significantly reduced the need for manual driving (Armaghan, n.d.).

The idea of an autonomous vehicle originated with General Motors' Futurama exhibit at the 1939 New York World's Fair, which showed their vision of the world in 20 years, which included an automated highway system that would direct self-driving cars (TitleMax, 2017). In 1958, General Motors turned Norman Bel Geddes's concept of the first self-driving car—an electric vehicle guided by radio-controlled electromagnetic fields created with magnetized metal spikes embedded in the road—into a reality by equipping the front end of the car with sensors known as pick-up coils, which could sense the current flowing through a wire embedded in the road and manipulate the current to direct the steering wheel to the left or right (TitleMax, 2017).

Presently tech companies like Google, Tesla and others have made a lot of progress into autonomous technology, making advances in machine learning and sensor technology. While a world filled with autonomous robotic vehicles isn't yet a reality, it surely would be in the near future.

1.2 Statement of the Problem

Road injuries accounted for more than 67 million disability-adjusted life years in 2015, representing a 4.6 percent increase since 1990 (GBD, 2016). Each year, more than 1.3 million people are killed on roadways and another 50 million are injured. Recognizing this serious global public health problem, the World Health Organization (WHO) declared 2011–2020 as the decade of action on road safety. A lot of these road accidents are caused by human errors and negligence, especially those caused by drunk drivers.

The invention of autonomous vehicles comes with several benefits, but the most important one is likely to be the improved safety on roads. The number of accidents caused by impaired driving is likely to drop significantly, as cars can't get drunk or high like human drivers can. Self-driving cars also don't get drowsy, and they don't have to worry about being distracted by text messages or by passengers in the vehicle. And a computer isn't likely to get into an accident due to road rage. A 2015 National Highway Traffic Safety Administration report found that 94 percent of traffic accidents happen because of human error: By taking humans out of the equation, self-driving vehicles are expected to make the roads much safer for all.

1.3 Aim and objectives

The aim of this project is to design and build a mini autonomous vehicle (self driving car) capable of moving with minimal to no human intervention.

The key objectives of this project are to:

1) design a sensing unit
2) develop an effective decision making algorithm
3) design the mobility system of the vehicle
4) improve real time data processing and response of the system

Design a sensing unit:

A sensing unit will be designed to detect the distance to objects by making use of an ultrasonic sensors. This sensor is key to the development of the mini autonomous vehicle.

Develop an effective decision making algorithm:

This will be achieved by programming the microcontrollers to combine and process the inputs generated by the sensor from the environment in order to develop an autonomous system that will be able to make efficient and accurate decisions when trying to avoid obstacles on the road.

Design the mobility system of the vehicle:

The vehicle will be designed to have 4 wheels, motors will be used to aid the rotation of the wheels, thereby making it possible for the vehicle to be able to practically move from one place to another.

Improve real-time data processing and response:

Implement techniques for quick processing of the inputs gotten from the sensors. The computational efficiency of the system is optimized to improve the response of the system, ensuring that the system can make fast and accurate decisions based on environmental data.

1.4 Scope

In this project, in order to design the mini autonomous vehicle system, the components used are: 4 wheel chassis, rubber tyres, motors, battery, ESP32, arduino uno R3, ultrasonic sensor and others. The project (autonomous vehicle) was designed taking some factors into consideration such as budget, availability of components, portability, efficiency and durability. The performance of the system met with the design specifications after testing. The general operation of the system is to detect the range or distance of objects in its immediate environment and to properly navigate around them. The operation depends on how well and quickly the ultrasonic sensor detects an obstacle and how the system efficiently responds to this input by changing the direction of the car.

1.5 Relevance of Study

The relevance of study for autonomous vehicle lies in its potential to enhance road safety. Many road accidents are caused by human errors. Autonomous vehicles rely on a combination of sensors, cameras, and advanced algorithms to navigate and react to their surroundings. They do not get distracted, fatigued, or impaired, which greatly reduces the likelihood of accidents. It can also provide increased mobility and independence to individuals who are unable to drive due to age, disabilities, or other factors.

This project can provide valuable insights that can shape technology, policies, and infrastructure, enabling a safer, more efficient, and inclusive future in transportation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The creation of self-driving cars marks a significant shift in the way we think about transportation. These autonomous vehicles are built on an advanced combination of technologies that allows these vehicles to safely and efficiently navigate the roads without human intervention.

This literature review covers existing research on autonomous vehicles, the implementation of lane detection algorithm, economic impact, measuring and proving safety, sustainability, and the analysis of publications on autonomous vehicles over time.

When it comes to moving people and products across the road network, the road transport system is important. The availability of transportation services, collectively referred to as transportation systems, satisfies the demand for travel within an area. In transportation studies, it is essential to examine the relationship between road capacity and traffic volume (Olayode et al., 2023). But in a connected and automated driving environment, there have been serious problems with road transportation systems, including traffic jams, accidents, and poor road infrastructure (Alex et al., 2023; Barberi et al., 2022; Pappalardo et al., 2022). Urban planners in metropolitan cities base their transportation planning and decision-making on the movement of people from one place to another, with a primary focus on public transportation, walking, and cycling (Zhang et al., 2023), which are increasingly relying on electric vehicles and other intelligent shared mobility. In addition to reducing global warming and air quality issues, these intelligent shared mobility help hasten the transition from fuel-powered to electric vehicles (Olayode et al., 2023).

In order to support connected multimodal transportation systems, metropolitan cities have recently made financial investments in road infrastructure and intelligent transportation systems, which include shared autonomous electric vehicles to replace less efficient bus lines (Raposo et al., 2019). Additionally, prior research conducted by transportation and logistics researchers on autonomous vehicles stated that the goal is to reduce the risks of vehicular collisions (Glaser et al.., 2010), and Gelbal et al. (2020) proposed a novel method for preventing collisions involving pedestrians on low-speed autonomous shuttles in a real-world traffic scenario, as opposed to existing methods (Olayode et al., 2023). Their aim was to focus on the immediate environment and safety of their driving environment, like steering or braking, without any human intervention. Some of the potential benefits of self driving cars are increased mobility for people with disabilities and the elderly (Zhang et al., 2019), a substantial reduction in the number and severity of accidents (Xu et al., 2018), reduced congestion, emissions, and efficient use of the infrastructure (Fagnant and Kockelman, 2015).

According to earlier research (Fagnant and Kockelman, 2015; Kockelman et al., 2016; Litman, 2017; Olayode et al., 2020a, 2020b), autonomous cars are expected to decrease traffic accidents, shorten travel times, prevent accidents, reduce excessive road maintenance (Bösch et al., 2018), make travel more ergonomically comfortable and feasible (Anderson et al., 2014; Brown et al., 2014; Fagnant and Kockelman, 2014; Wadud et al., 2016), and lower travel expenses. Depending on the actual traffic situation (Bösch et al., 2018; Chen et al., 2016; Zachariah et al., 2014; Zhang et al., 2015) and the substantial urban road capability (Brownell, 2013; Fernanda's and Nunes, 2010; Friedrich, 2015), autonomous vehicles may result in a progressive decrease in the total number of vehicles on the road (Olayode et al., 2023).

Autonomously navigating and avoiding obstacles while accurately interpreting the highly complex semantic meaning of the scene and dynamic activities (Daily et al., 2017) is the idea behind self-driving cars, which are vehicles that can move partially or completely without human assistance (Hussain and Zeadally, 2019). For effective operation and safety, an AV must not only understand the current state of the traffic and its surroundings, but also proactively anticipate their future behavior (Caleffi et al., 2024). Thus, it is crucial to comprehend and accurately forecast how cars and pedestrians will behave. The problem is made more complex by the practical constraints of observing the surrounding environment and the computational resources needed to run prediction algorithms (Mozaffari et al., 2022).

We use the perception-planning-control pipeline (Pendleton et al., 2017), which is shown in Fig 2.1, to map and classify the research papers because we want to show both software and hardware efforts in the field of self-driving cars. By presenting vehicle setups (i.e., sensors, computation hardware, and experimental environment), we give a clear overview of the hardware/software used for research. The ability of an autonomous system to gather data and derive pertinent knowledge from its surroundings is referred to as perception. Planning is the software process of making deliberate decisions to move the vehicle from a start location to a goal location while avoiding obstacles and optimizing designed heuristics; control is the vehicle's capacity to carry out the planned actions produced by the higher-level processes; and, to put it another way, it encompasses all algorithms that offer solutions for mapping, localization, or object detection (Caleffi et al., 2024).

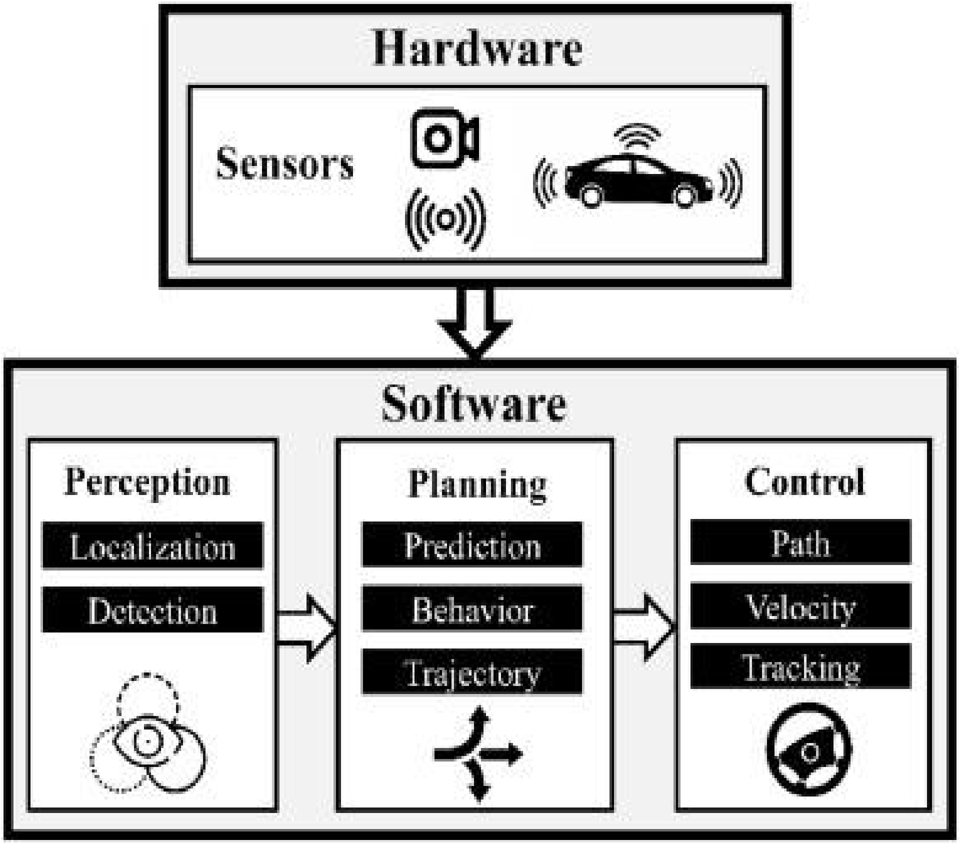

FIG 2.1. Autonomous Vehicle System Overview

(Caleffi et al., 2024)

2.2 Implementation of Lane Detection Algorithm for an Autonomous vehicle

In addition to having a solid understanding of CNN and machine learning, creating a self-driving car necessitates a deeper understanding of a number of other subjects, including deep learning, computer vision, fusion sensors, localization, control, and path planning (Hasan et al., 2019).

In autonomous vehicles, computer vision is crucial. It is a machine learning technique applied to image processing that uses machine learning to find patterns for image analysis, similar to how human vision helps to distinguish between objects, classify them, and arrange them based on their size. In autonomous vehicles, computer vision is used to locate lane lines on the track.

From an engineering perspective, computer vision is a subfield of image processing that focuses on making computers comprehend digital images or videos. One of the key functions of self-driving cars is the ability to accurately sense their environment, which is made possible by the multiple sensors or cameras that these vehicles are outfitted with. Sensor fusion is the process of combining data from various sensors or sources so that the resulting information has less ambiguity than would be possible when these sources were used to collect data individually. This is similar to how humans use all five senses to make sense of their surroundings. If these sensors are producing the same outputs with some pluses and minuses, then combining all the outputs will ultimately produce better output. Generally speaking, it is not possible to directly program a computer to perform specific tasks like driving a car; speech recognition and object detection are far too complex to just program, whereas machine learning algorithms can learn and improve based on experience. Deep learning is a subset of machine learning, which uses specialized algorithms to describe and analyse data, learn from it, improve, and predict useful outcomes. Path-planning is a crucial primitive for self-driving cars that allows the car to find the optimal path between two points; alternatively, optimal paths could be paths that minimize the amount of turning, the amount of braking, or whatever a particular application requires. It also interacts with the environment to learn, to detect and predict meaningful patterns to achieve desired results. To navigate in its environment, a robot or other mobility device needs representation, i.e., a map of the environment and the ability to interpret that representation. Localization in a self-driving car refers to the car's ability to determine its own position in its frame of reference and then plan a path towards some goal location (Hasan et al., 2019).

2.3 ECONOMICAL IMPACT

1. Transportation Costs and Efficiency

Reduced Costs: AVs can lower transportation costs by eliminating the need for human drivers, optimizing fuel efficiency, and reducing maintenance expenses through smoother driving patterns.

Improved Efficiency: Optimized routes and reduced congestion can save billions in fuel and time, enhancing productivity.

2. Automotive Industry Transformation

Increased R&D and Investment: Massive investments in AI, sensors, and vehicle-to-everything (V2X) technologies are driving economic growth in the tech and automotive sectors.

Shift in Car Ownership: A transition from individual ownership to shared autonomous fleets (Mobility-as-a-Service) could reshape vehicle demand and production trends.

New Revenue Streams: Data generated by AVs could open opportunities for monetization in advertising, navigation, and traffic analytics.

3. Job Market Disruption

Job Losses: Millions of driving-related jobs in trucking, taxis, and delivery services are at risk of automation, potentially creating unemployment challenges.

New Opportunities: Demand for software developers, system engineers, and maintenance technicians for AVs will increase, requiring workforce reskilling.

4. Logistics and Freight

Cost Reduction: Autonomous trucking can significantly cut labour and operational costs in logistics, improving supply chain efficiency.

24/7 Operation: AVs can operate continuously without fatigue, reducing delivery times and increasing supply chain reliability.

5. Urban Planning and Real Estate

Infrastructure Changes: Reduced need for parking spaces in urban areas could free up valuable land for other developments, boosting urban real estate markets.

Commuting Patterns: Autonomous ridesharing might encourage suburban expansion as commuting becomes less stressful and more productive.

6. Public Safety and Healthcare Costs

Fewer Accidents: AVs are expected to reduce road accidents caused by human error, potentially saving lives and cutting healthcare costs.

Insurance Adjustments: The focus of liability might shift from individuals to manufacturers, affecting insurance models and premiums.

7. Environmental Impact

Emission Reductions: Enhanced traffic flow and adoption of electric autonomous vehicles could decrease greenhouse gas emissions.

Energy Usage: Reduced reliance on fossil fuels (with electric AVs) may alter energy markets.

8. Government Revenue and Regulation

Loss of Revenue: Reduced fuel consumption and ownership might decrease fuel tax revenues and vehicle registration fees.

Infrastructure Investment: Governments may need to invest in AV-compatible infrastructure like smart roads and communication systems.

9. Broader Economic Impact

Economic Productivity: AVs could boost productivity by enabling individuals to work or relax during commutes.

Global Competitiveness: Countries leading in AV technology development and deployment may gain a competitive edge in the global economy.

2.4 Measuring and Proving Safety

Allowing AVs to operate in cities requires measuring and proving their safety, particularly when compared to human drivers. Crash rates, particularly fatal crashes, are so low per mile driven that it is difficult to gather enough driving data to test AVs on the path to proving safety. Kalra and Paddock (2016) calculated that AVs would need to travel 275 million miles without experiencing a single fatal crash in order to show with 95% confidence that they cause fewer deaths than human drivers. Given the rapid evolution of software, it is unlikely that any build will be tested enough to meet this statistical standard. Failures have already occurred, so it would take decades of testing and 11 billion miles of driving to show with 95% confidence and 80% power that AVs are 20% safer than human drivers at avoiding fatal crashes (Kaufman et al., 2022).

Waymo has been putting in billions of miles in simulation to supplement its road testing and trial service provision in Arizona, and it simulates recent actual human-driven crashes to test how a Waymo car would have fared. However, other methods are required because driving alone cannot demonstrate safety sufficiently to provide statistical significance ("The Future of Autonomous Vehicles," 2021) . In a different approach, Tesla is running the autonomous system in the background while the human is driving in order to compare the decisions made by the system (which is not controlling the car) with the decisions made by the human driver. This methodology enables testing of specific crash scenarios that would not be covered by looking only at disengagements (Lundgren, 2020).

Although McBridge (2016) recommends a driver's test for autonomous vehicles, he warns that there would need to be enough variation in the tests for businesses to be unable to create custom software for the test, as Volkswagen did for diesel emissions. Lundgren (2020) warns that for any simulation-based testing procedure, the results are only as good as the assumptions on which the scenarios are based, and there is no clear procedure of objectively evaluating the completeness and accuracy of these simulations. Other approaches include accelerated testing, virtual testing and simulations, mathematical modeling and analysis, scenario and behaviour testing, and pilot studies (Kalra and Paddock, 2016). Regulators must create guidelines and protocols for handling this uncertainty, though, as it is evident that the issue of whether autonomous vehicles are safer than human drivers is more complex than a pass/fail test (Kaufman et al., 2022).

The rate of disengagements (the point at which the human driver must take over from the autonomous system) has been the most frequently used milestone for companies testing AVs. However, this measure is insufficient on its own because it does not take into account variations in driving conditions and scenarios (Simpson, 2021). The second consideration is what metrics to use to measure safety. Three criteria were proposed by the Transport Research Laboratory to evaluate proposed safety metrics: whether they are reliable, repeatable, and measurable; whether they have a known association with adverse safety events; and whether they do not promote unsafe driving or behaviours (Kaufman et al., 2022).

Metrics that extend beyond disengagements could include driving infractions, safety envelope violations, the vehicle's driving style as determined by the vehicle kinematic systems, a measure of unfinished missions, the capacity to perceive driving risk accurately and recognize hazards, and qualitative user feedback.

Proponents point to the widely used statistic from NHTSA (2015) that 94 percent of motor vehicle crashes are caused by human error, suggesting that autonomous driving systems would be able to avoid all or most of these. The third part of evaluating safety is figuring out how safe is "safe enough" to support full operation on city streets. Others, however, believe that this statistic is misleading (Shetty et al., 2021) because it does not only include crashes caused by driving while intoxicated or distracted, or by breaking traffic laws; it also includes crashes caused by "false assumption of other's actions," "decision error," "recognition error," and “inadequate surveillance.” For example, it is unclear whether autonomous vehicles are more accurate than humans at correctly assuming the actions of other road users. Additionally, according to the National Safety Council, AVs might be better suited to handle particular driving conditions, like night-time, when 50 percent of traffic fatalities occur. The Safe Driving Initiative of the World Economic Forum suggests that regulators establish localized scenarios to be tested at each milestone (Dawkins, 2020).

In the coming decades during the AV transition, policies other than vehicle driving autonomy (e.g., street design) could make human driving safer, indicating that AVs should be benchmarked against future human-driven vehicles and their safety systems rather than the current ones. With enough data or estimation, it may still be possible to measure whether crash and fatality rates are lower for autonomous systems than for human drivers, but this is a shifting baseline (Lundgren, 2020). While new technologies may make driving more dangerous by enabling new forms of distraction while driving (Boudette, 2021) and owner-hacked vehicles for breaking the law, alcohol locks, speed governors, and focus improvements could reduce human error due to intoxication, speeding, and distracted driving, respectively, making human driving safer and setting a higher standard for AVs to be safer than human drivers. AVs would be able to claim greater safety than human driving by meeting a lower standard, but this does not mean that politicians and human drivers will embrace its implementation if human driving (and coexisting with human drivers on the road) becomes less safe in the future (Kaufman et al., 2022).

Shetty et al. (2021) identified two methods to ensure vehicle safety, the first of which is the Responsibility-Sensitive Safety (RSS) framework, which was put forth by researchers from Mobileye, one of the companies currently testing in New York City. The fourth consideration is the amount of risk that should be permitted for autonomous vehicles (AVs) operating in uncertain conditions in densely populated cities. The second strategy would be to use vehicle-to-vehicle and vehicle-to-infrastructure connectivity to bridge information gaps. This strategy involves restricting an AV’s maneuvers so that it is safe under all reasonable future outcomes from its partial observations, but it is constrained by the information that it can gather and necessitates significant trade-offs between safety and throughput. A communication-based strategy will always exclude a sizable percentage of road users in a congested urban setting like New York

City, where crucial interactions occur not only with other cars but also with a large number of pedestrians and cyclists.

In the short term, different trolley problem scenarios are unlikely to be relevant to autonomous vehicle policy. According to Lundgren (2020), autonomous vehicles (AVs) will not have all the information needed to make decisions about trolley problems in the instant before a collision; in order to make a decision, an AV would need to determine whether a person in front of it is there, estimate their chances of surviving, and retrieve personal information about them (such as age and life status) (Kaufman et al., 2022). But when it comes to choosing between pedestrians and passengers, the owner of the vehicle will probably win out.

2.5 Sustainability

Autonomous vehicle (AV) adoption is expected to have a significant impact on urban sprawl, pollution, and congestion; the impact on pollution will depend on government regulation and the electrification of AV fleets; a shift in the ownership model of AVs in conjunction with the efficiency of urban development can reduce congestion, but may have a long-term positive correlation with sprawl (Kaufman et al., 2022).

The transportation sector, which is responsible for 28.5% of greenhouse gas emissions in the United States, with passenger cars accounting for 60% of these emissions (Jones, Leibowicz, 2019), has the opportunity to drastically reduce its emissions if AVs are widely adopted. California has already taken a step to combine AVs with environmental progress by mandating that all new light-duty autonomous vehicles be zero emissions beginning in 2030 (Bonifacic).

If AVs are widely used by rideshare networks, fewer people will likely own cars and choose to use shared vehicles, which could reduce urban congestion. However, if individual ownership is still common in the near future or if cars are designed to cruise when not in use, this trend could actually make congestion worse. In any event, a greater number of AVs will be used, bringing with them a new form of transportation that will eventually allow people to live farther from the center of cities, which could prolong urban sprawl (Jones and Leibowicz, 2019).

In the event that a shared mobility system is widely implemented, cities can repurpose roads and spaces to support sustainability, such as converting parking curbs into pickup/drop-off zones or narrowing and tightening city lanes to prioritize bicycle and bus lanes and pedestrian pathways (Kaufman et al., 2022). To support and encourage shared AV use, major roads and highways can implement dedicated AV lanes, which would enable platooning, maximize travel speed, and reduce traffic and pollution (Litman).

Regulation, financial incentives, and improvements to public transportation are the main ways that policies pertaining to AV sustainability are proposed in the area of lowering vehicle miles traveled (Greenwald and Kornhauser, 2019).

CHAPTER 3

METHODOLOGY

This chapter contains the methodology of this project. We will go through the steps we used in creating a self-driving car equipped with GPS navigation, using an ESP32 microcontroller, a L293D motor driver, and various other components.

3.1 Materials Required

3.2 Hardware Implementation

- Microcontroller:
- Motor Driver (L293D)
- Motors: DC motors
- GPS Module: NEO-6M
- Ultrasonic Sensor: HC-SR04 (for obstacle detection)
- Power Source: Rechargeable battery
- Chassis: 4-wheel drive chassis with caster wheel
- Wires and Connectors (jumper wires and breadboard)
- Other Components

3.2.1 Microcontroller:

The ESP32 and the arduino uno R3 microcontrollers was used for this project, the ESP32 is a low-cost, low-power microcontroller with built-in Wi-Fi and bluetooth capabilities, giving it internet connectivity capabilities, which is essential for this project. Because of it's internet connectivity capabilities the ESP32 is able to receive and process the location data gotten from the app and GPS module. The main purpose of the ESP32 in this project is that it enables us to set the destination of the car. The arduino uno receives and processes the data gotten from the ultrasonic sensor, it also receives data from the ESP32 microcontroller. It processes this data in real time to detect obstacles. It is used to run control loops to adjust steering, throttle, and braking based on sensor inputs, it also executes decision making algorithms such as obstacle avoidance.

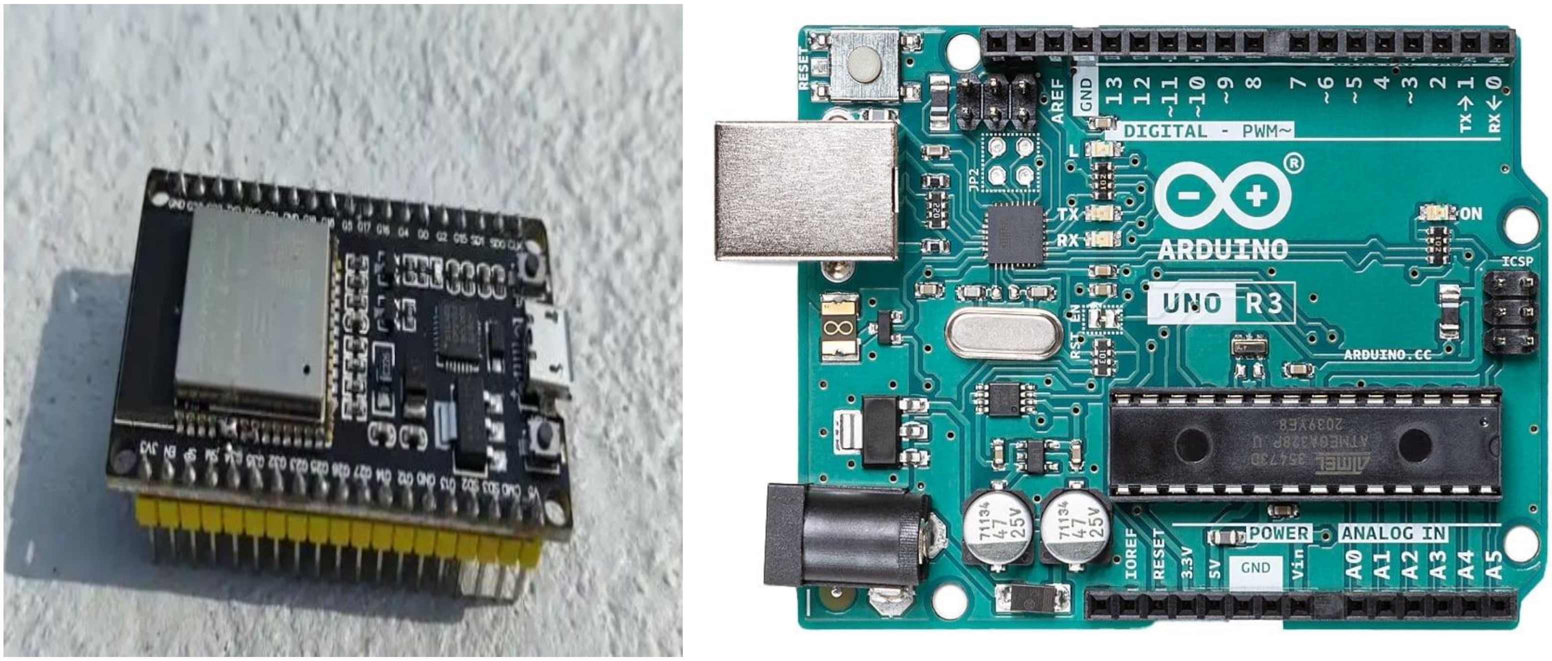

FIG 3.1: Image of an ESP32 (left) and arduino uno R3 (right) microcontrollers

3.2.2 Motor Driver (L293D)

The motor driver is important for controlling and managing how the motor operates. We made use of the L293D motor driver, the L293D is a 16-pin Motor Driver IC which can be used to control 4 DC motors simultaneously in any direction. We used it for controlling the speed and direction of the 4 DC motors used for driving the wheels of the vehicle.

FIG 3.2: L293D Motor Driver

3.2.3 Motors:

Motors help the wheels (tyres) to rotate. We made use of 4 DC motors, to control the drive, and to control the steering of the vehicle.

FIG 3.3: DC Motor

3.2.4 GPS Module:

The GPS module is used to select the desired destination we want for the car, and also to track the location of the car. The NEO-6M GPS module was used in this project, it is a GPS receiver compatible with most microcontroller boards. It can get data about location, speed, altitude, and time. It has an external EEPROM, a tiny backup battery, and an LED signal indicator that will blink when it receives a position fix (Dejan, 2022). We'll connect the NEO-6M GPS Module using the ESP32 default UART2 pins, the pin connection can be seen in the circuit design section below. The NEO-6M GPS Module communicates with the ESP32 microcontroller using serial communication protocol.

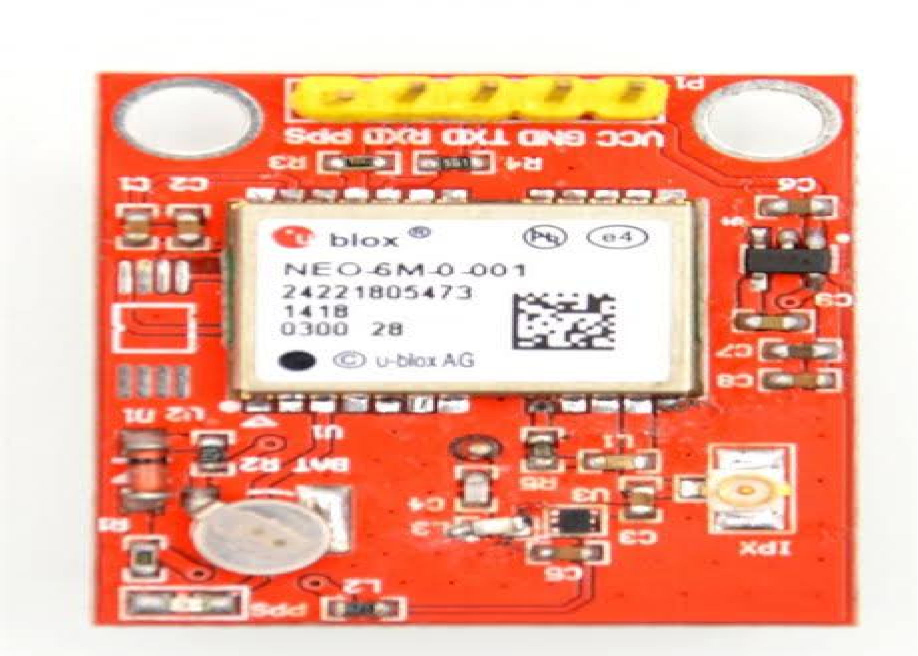

FIG 3.4: GPS Module

3.2.5 Ultrasonic Sensor:

At regular intervals, ultrasonic sensors send out brief, high-frequency sound pulses that travel through the atmosphere at the speed of sound. If the pulses hit an object, they are reflected back to the sensor as echo signals, and the sensor uses the time interval between sending out the signal and receiving the echo to determine how far away the target is. We made use of the HC-SR04 ultrasonic sensor, which has a range of up to 400cm (about an inch to 13 feet). The sensor is composed of two ultrasonic transducers. One is transmitter which outputs ultrasonic sound pulses and the other is receiver which listens for reflected waves.

The sensor has four pins: VCC and GND connect to the ESP32's 3.3V and GND pins, while Trig and Echo connect to a GPIO pin. We send the ultrasonic wave from the transmitter using the Trig pin, and we listen for the reflected signal using the Echo pin. We can determine the distance by taking into account the travel time and the speed of the sound generated by the module, which emits an ultrasound at 40,000 Hz that travels through the air and bounces back to the module if it encounters any obstacles or objects. Considering the travel time and the speed of the sound we can calculate the distance. By knowing the distance between the car and an object, the microcontroller will be able to process this input and subsequently send a command to the motor driver in order to avoid collision with any obstacle.

FIG 3.5: Ultrasonic Sensor

3.2.6 Power Source:

We made use of three 3.7v rechargeable batteries. This provides the power needed by the vehicle to operate properly.

FIG 3.6: 3.7V Rechargeable Battery

3.2.7 Chassis:

This is the base frame of the car, which contains the wheels(4 wheels in this case), the other components/parts of the car are mounted on the chassis. We made use of a 4 wheel drive chassis with caster wheel. Fig 3.1 represents two images showing the design of a 4 wheel chassis we made using solid works software.

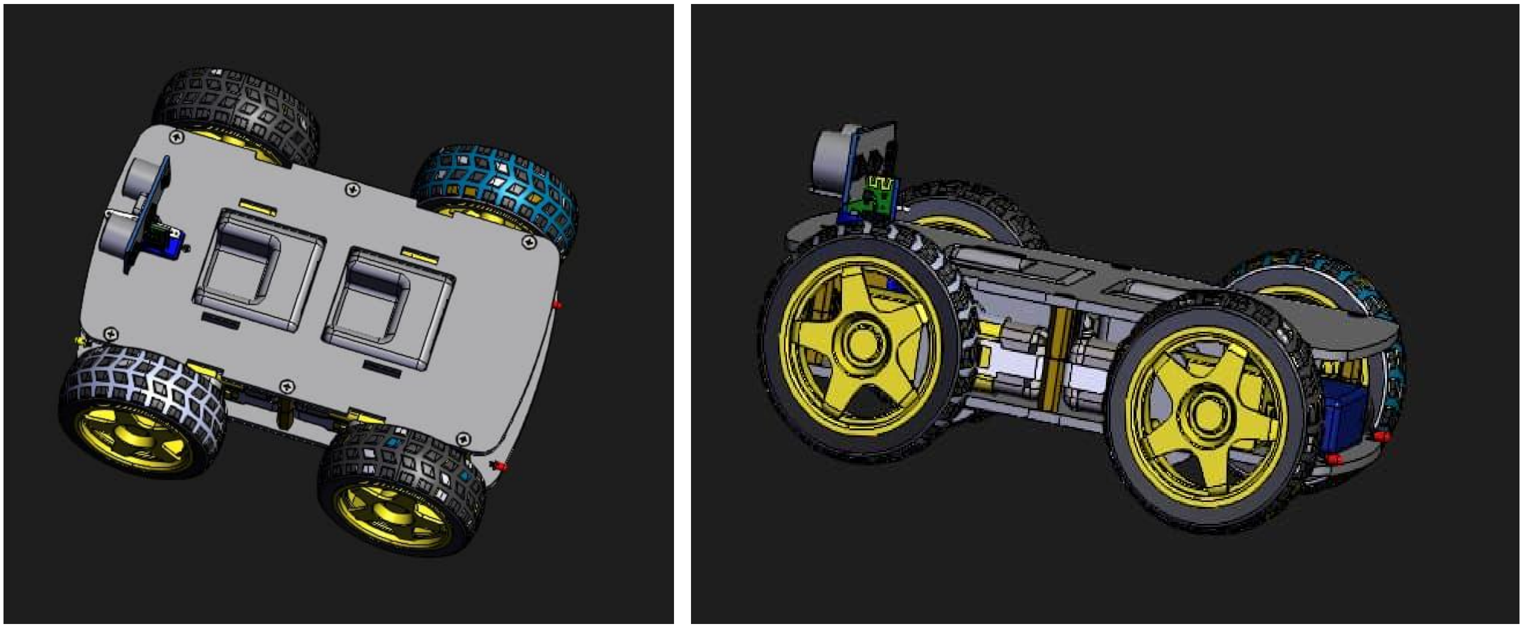

FIG 3.7: Solidworks design of the 4 wheel chassis used for the project

3.2.8 Wires and Connectors:

This involves materials such as jumper wires and breadboard used for connecting the various components together to form the required circuit.

3.2.9 Other Components:

These are the other materials/components used such as servomotor, capacitors, switches e.t.c

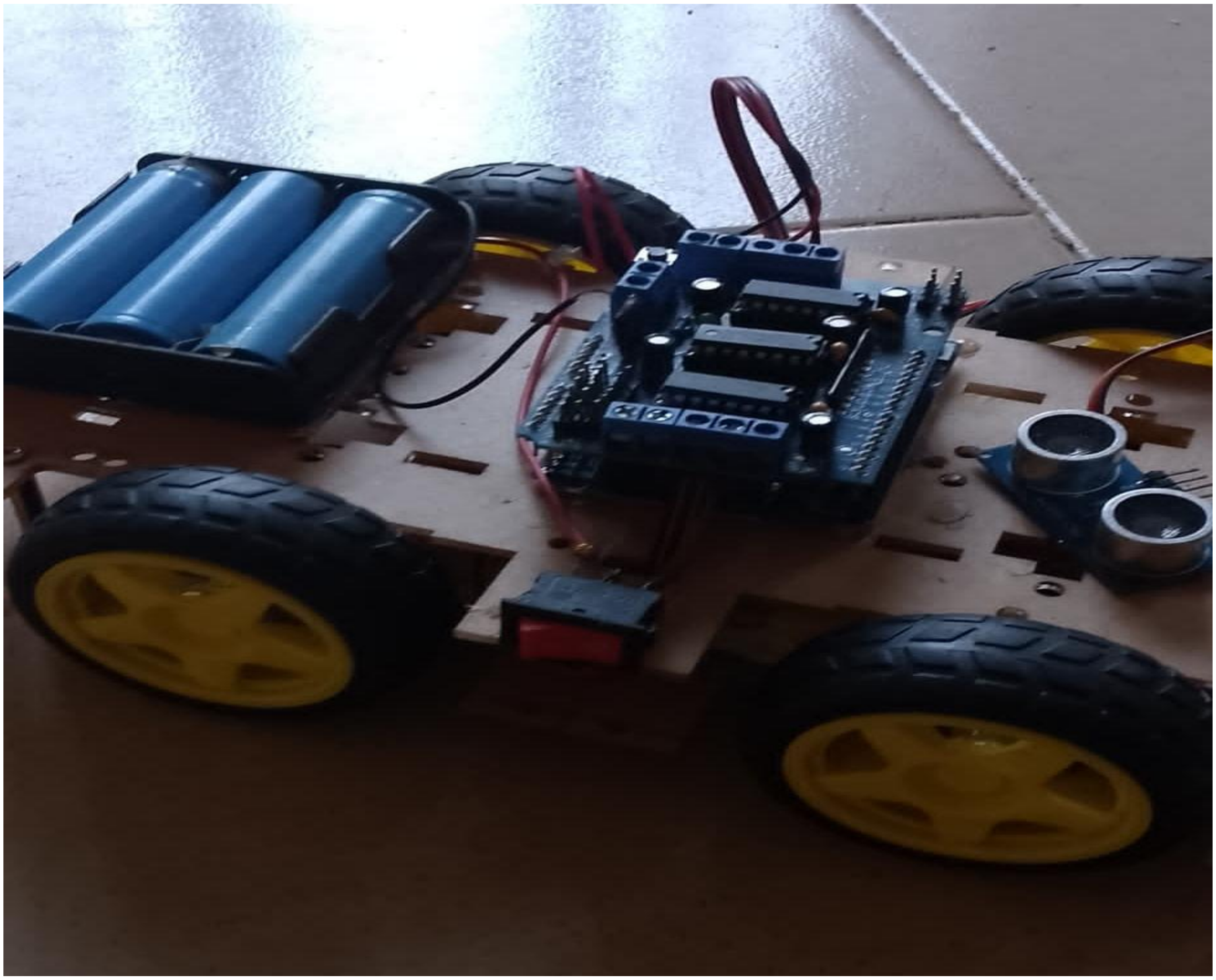

FIG 3.8: Image of our project (mini autonomous vehicle)

3.3 System Architecture

1. GPS Navigation: Fetch location data (latitude and longitude) via the GPS module.
2. Obstacle Avoidance: Detect obstacles and avoid collisions using an ultrasonic sensor.
3. Motor Control: Control the direction and speed of the motors through the L293D motor driver.
4. Microcontroller: The ESP32 processes GPS data and sensor inputs, subsequently commanding the motor driver.

3.4 Circuit Design

1. **Connecting the GPS Module**

- VCC: Connect to the 3.3V pin on ESP32.
- GND: Connect to ground.
- TX: Connect to RX2 of ESP32.
- RX: Connect to TX2 of ESP32.

2. **Connecting the L293D Motor Driver**

- Motor Inputs (IN1, IN2, IN3, IN4): Connect to GPIO pins of ESP32 (e.g., GPIO26, GPIO27 for one motor, and GPIO14, GPIO12 for the other).
- Motor Outputs (OUT1, OUT2, OUT3, OUT4): Connect to the DC motors.
- Enable Pins: Connect ENA and ENB to PWM-capable GPIO pins (e.g., GPIO25, GPIO33).
- VCC1: Connect to 5V.
- VCC2: Connect to the motor power supply.
- GND: Connect to ground.

3. **Connecting the Ultrasonic Sensor**

- VCC: Connect to 3.3V.
- GND: Connect to ground.
- TRIG: Connect to a GPIO pin (e.g., GPIO4).
- ECHO: Connect to another GPIO pin (e.g., GPIO5).

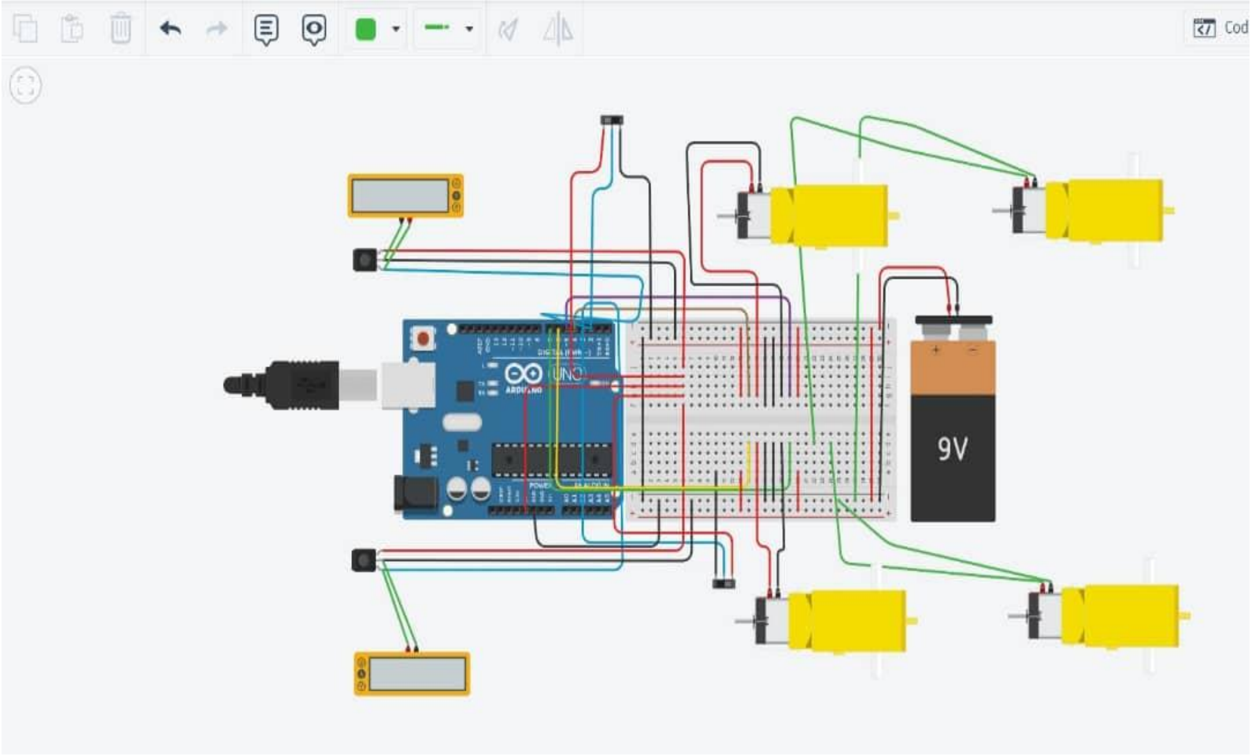

FIG 3.9: Circuit design

3.5 Software Implementation

3.5.1 Install Required Libraries

Installation of the following libraries in Arduino IDE:

- TinyGPS++ for GPS parsing.
- ESP32 Servo (optional for servo-based obstacle avoidance).

3.5.2 Writing the Code:

Key Functions:

- GPS Navigation: Parse GPS data to determine current location, compare it to target coordinates, and control motors accordingly.

- Obstacle Avoidance: Use the ultrasonic sensor to measure distance to obstacles and stop or change direction if an obstacle is detected.
- Motor Control: Use PWM signals to control motor speed and set direction via L293D inputs.

Basic code outline of the bot(car) :

```
#include <TinyGPS++.h>
#include <HardwareSerial.h>


TinyGPSPlus gps;
HardwareSerial gpsSerial(1);


#define TRIG_PIN 4
#define ECHO_PIN 5
#define MOTOR1_IN1 26
#define MOTOR1_IN2 27
#define MOTOR2_IN3 14
#define MOTOR2_IN4 12
#define ENA 25
#define ENB 33


Void setup() {
```

```
    Serial.begin(115200);

    gpsSerial.begin(9600, SERIAL_8N1, 16, 17); // RX, TX


    pinMode(TRIG_PIN, OUTPUT);

    pinMode(ECHO_PIN, INPUT);

    pinMode(MOTOR1_IN1, OUTPUT);

    pinMode(MOTOR1_IN2, OUTPUT);

    pinMode(MOTOR2_IN3, OUTPUT);

    pinMode(MOTOR2_IN4, OUTPUT);

    pinMode(ENA, OUTPUT);

    pinMode(ENB, OUTPUT);

}


Void loop() {

      While   (gpsSerial.available() > 0) {

            Gps.encode(gpsSerial.read());

             If (gps.location.isUpdated()) {

                  Serial.print("Latitude: ");

                 Serial.println(gps.location.lat());

                 Serial.print("Longitude: ");

                 Serial.println(gps.location.lng());

         }

   }
```

```
}
```

Code outline for GPS and movement;

```
#include <Wire.h>
#include <TinyGPS++.h>
#include <HardwareSerial.h>
#include <Servo.h>

#define trigPin  12
#define echoPin  14
#define servoPin  13

#define motor1A  26
#define motor1B  25
#define motor2A  33
#define motor2B  32
#define motor3A  27
#define motor3B  4
#define motor4A  19
#define motor4B  18

HardwareSerial gpsSerial(1);
TinyGPSPlus gps;
```

```
Servo myServo;

Float targetLat = 37.7749, targetLon = -122.4194;
Float kp = 1.5, ki = 0.01, kd = 0.1;
Float error, lastError, integral, derivative;
Float minDist = 20.0;

Void moveForward() {
  digitalWrite(motor1A, HIGH);
  digitalWrite(motor1B, LOW);
  digitalWrite(motor2A, HIGH);
  digitalWrite(motor2B, LOW);
  digitalWrite(motor3A, HIGH);
  digitalWrite(motor3B, LOW);
  digitalWrite(motor4A, HIGH);
  digitalWrite(motor4B, LOW);
}

Void moveBackward() {
  digitalWrite(motor1A, LOW);
  digitalWrite(motor1B, HIGH);
  digitalWrite(motor2A, LOW);
  digitalWrite(motor2B, HIGH);
```

```
  digitalWrite(motor3A, LOW);

  digitalWrite(motor3B, HIGH);

  digitalWrite(motor4A, LOW);

  digitalWrite(motor4B, HIGH);

}


Void turnLeft() {

  digitalWrite(motor1A, LOW);

  digitalWrite(motor1B, HIGH);

  digitalWrite(motor2A, HIGH);

  digitalWrite(motor2B, LOW);

  digitalWrite(motor3A, LOW);

  digitalWrite(motor3B, HIGH);

  digitalWrite(motor4A, HIGH);

  digitalWrite(motor4B, LOW);

}


Void turnRight() {

  digitalWrite(motor1A, HIGH);

  digitalWrite(motor1B, LOW);

  digitalWrite(motor2A, LOW);

  digitalWrite(motor2B, HIGH);

  digitalWrite(motor3A, HIGH);
```

```
  digitalWrite(motor3B, LOW);

  digitalWrite(motor4A, LOW);

  digitalWrite(motor4B, HIGH);

}


Void stopMotors() {

  digitalWrite(motor1A, LOW);

  digitalWrite(motor1B, LOW);

  digitalWrite(motor2A, LOW);

  digitalWrite(motor2B, LOW);

  digitalWrite(motor3A, LOW);

  digitalWrite(motor3B, LOW);

  digitalWrite(motor4A, LOW);

  digitalWrite(motor4B, LOW);

}


Float getDistance() {

  digitalWrite(trigPin, LOW);

  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);

  delayMicroseconds(10);

  digitalWrite(trigPin, LOW);

  return pulseIn(echoPin, HIGH) * 0.034 / 2;
```

```
}

Void controlServo(int angle) {
  myServo.write(angle);
  delay(500);
}

Float getHeading(float lat1, float lon1, float lat2, float lon2) {
  Float dLon = (lon2 – lon1);
  Float y = sin(dLon) * cos(lat2);
  Float x = cos(lat1) * sin(lat2) – sin(lat1) * cos(lat2) * cos(dLon);
  Float heading = atan2(y, x) * 180.0 / PI;
  If (heading < 0) heading += 360;
  Return heading;
}

Void controlRobot(float currentLat, float currentLon, float heading) {
  Float targetHeading = getHeading(currentLat, currentLon, targetLat, targetLon);
  Error = targetHeading – heading;
  Integral += error;
  Derivative = error – lastError;
  Float correction = kp * error + ki * integral + kd * derivative;
  lastError = error;
```

```
  if (getDistance() < minDist) {
    stopMotors();
    controlServo(90);
    delay(1000);
    controlServo(0);
    turnRight();
    delay(500);
  } else {
    If (abs(correction) > 15) {
      If (correction > 0) turnRight();
      Else turnLeft();
    } else {
      moveForward();
    }
  }
}

Void setup() {
  Serial.begin(115200);
  gpsSerial.begin(9600, SERIAL_8N1, 16, 17);
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
```

```
  pinMode(motor1A, OUTPUT);
  pinMode(motor1B, OUTPUT);
  pinMode(motor2A, OUTPUT);
  pinMode(motor2B, OUTPUT);
  pinMode(motor3A, OUTPUT);
  pinMode(motor3B, OUTPUT);
  pinMode(motor4A, OUTPUT);
  pinMode(motor4B, OUTPUT);
  myServo.attach(servoPin);
  myServo.write(0);
}

Void loop() {
  While (gpsSerial.available()) {
    Gps.encode(gpsSerial.read());
    If (gps.location.isUpdated()) {
      Float currentLat = gps.location.lat();
      Float currentLon = gps.location.lng();
      Float heading = gps.course.deg();
      controlRobot(currentLat, currentLon, heading);
    }
  }
}
```

3.6 Testing and Calibration

1. GPS Testing: Verify the GPS module outputs accurate location data.
2. Obstacle Avoidance: Test the ultrasonic sensor to ensure it detects objects at the correct distance.
3. Motor Control: Calibrate motor speed and direction for smooth movement.

By following this steps, we have been able to create a functional self-driving robot car capable of GPS navigation and basic obstacle avoidance, laying the groundwork for more sophisticated autonomous vehicles.

CHAPTER 4

RESULTS AND ANALYSIS

This chapter contains the results and analysis we got from testing the performance of the mini autonomous vehicle. Table 1 shows the data we got from the ultrasonic sensor showing different distance between the car and objects/obstacles it encounters in its path, and the action taken to avoid the object/obstacles.

4.1 RESULTS

4.1.1 TABLE 1:

Measured Distance (cm)	Remark	Action
10	Obstacle detected	Car stops, while the system scans for alternative route
15	Obstacle detected	Car stops, while the system scans for alternative route
75	Obstacle detected	Car keeps moving forward
25	Obstacle detected	Car keeps moving forward
19	Obstacle detected	Car stops, while the system scans for alternative route

From the above table it can be seen that when the distance between an object/obstacle and the vehicle is less than 20cm, the car stops while the ultrasonic sensor keeps scanning for alternative (obstacle free) routes. The process of scanning and determining a new route takes the system a maximum of 3 seconds.

4.1.2 TABLE 2:

Parameter	Observation	Remark
Navigation accuracy	The car successfully followed the predefined path	There was some minor deviations in complex environments

Obstacle detection	Ultrasonic sensor was able to detect obstacles within a range of up to 400cm	The sensor performance can be compromised by environmental factors such as humidity, air pressure, and temperature.
Obstacle avoidance	Successful avoided static obstacles	Struggled with unpredictable moving objects
Decision making speed	Scanning and determining a new route takes approximately 3 seconds	Response time needs optimization for dynamic obstacles

4.2 ANALYSIS

Key findings:

- The mini autonomous vehicle demonstrated a high level of autonomy in structured (static) environments.
- Reliable obstacle detection ensured smooth navigation.
- Efficient power consumption allowed for prolonged operation.
- Performance declined in environments with bad terrain and dynamic obstacles.
- Wireless communication faced occasional interference, leading to minor delays.

CHAPTER 5

CONCLUSION

This project report presents the details of an autonomous vehicle system capable of avoiding obstacles and getting to a predetermined location using a GPS module. The autonomous system is able to track the objects in its path and with the aid of a decision making algorithm it maneuvers as required in order to avoid collision with the objects. Despite facing challenges such as environmental variability and occasional sensor limitations, the vehicle's overall performance underscores its robust design and adaptability.

This project has highlighted several critical insights, including the importance of sensor integration, real-time decision-making, and effective power management. These lessons are invaluable for guiding future improvements and advancements in autonomous vehicle technology.

5.1 LIMITATIONS

Weather conditions:

The mini autonomous vehicle makes use of an ultrasonic sensor. An ultrasonic sensor's detection range may get smaller as the temperature and humidity rise.

Computational Limitations:

Future iterations could benefit from high-performance edge computing solutions because the onboard processing unit was limited in its ability to handle complex real-time computations, which occasionally caused delays in decision-making.

5.2 RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE WORK

- Add a compass module for improved direction sensing.
- Use a camera module with OpenCV for advanced obstacle detection.
- Implement a web-based dashboard for real-time monitoring and control.
- Improve safety mechanisms by implementing emergency braking, fault-tolerant systems, and redundancy in perception modules will further enhance reliability.

The feasibility of designing and building a mini autonomous vehicle with intelligent navigation and decision-making was shown by this project, although there are still issues to be resolved, the advancements made provide a strong basis for future autonomous mobility, research, and development.

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