Final Year Project
Weed Whisper: Smart Vehicle with Obstacle Avoidance and Weed Detection

Department of Information Technology

University of Sargodha – Pakistan

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MSc (Information Technology)

Supervisor

Dr. Hussam Ali

Submission Date:

Team

Team Leader	Moez Ali Khan	(MSIT62F21S004)
Team Member 1	Kainat Rafi	(MSIT62F21S027)
Team Member 2	Alina Fatima	(MSIT62F21S027)

Faculty of Computing & IT

University of Sargodha

Final Approval

Project Title “Weed Whisper: Smart Vehicle with Obstacle Avoidance and Weed Detection”

approved for the

Department of Information Technology

University of Sargodha

Supervisor: ___________________________________

Dr. Hussam Ali

Lecturer, Department of Computer Science, University of Sargodha

Chairman: ____

Department of IT, University of Sargodha

DEDECATION

This project is dedicated to the unwavering support and encouragement of our families and loved ones, whose understanding and patience have been the bedrock of our journey. Your steadfast belief in our abilities and dreams has provided the motivation to persevere through challenges and reach new heights.

To our mentors and teachers, whose guidance has been a guiding light on this academic journey. Your wisdom, encouragement, and shared knowledge have shaped our understanding and fueled our passion for learning.

We dedicate this work to the collaborative spirit of our team members, whose dedication and tireless efforts have turned ideas into reality. Each contribution, no matter how small, has played a pivotal role in the success of this project. To the broader community of supporters, friends, and colleagues, your words of encouragement and shared enthusiasm have been a source of inspiration. This project is a testament to the strength of collective effort and shared goals.

Finally, we dedicate this endeavor to the pursuit of knowledge, growth, and positive impact. May the lessons learned, and experiences gained contribute not only to our academic journey but also to the greater pursuit of understanding and innovation.

This dedication is a token of our gratitude to those who have played a role, big or small, in shaping this project and our academic journey.

ACKNOWLEGEMENT

In the first place the name of ALLAH, the maker of the universe, who offered his approval on me to finish this thesis. I offer my humblest, heartfelt and billions of Darood to the Holy Prophet Hazrat MUHAMMAD (ﷺ) who urges his devotees to look for information from support to grave.

I wish to recognize the caring assistance, important guidelines, scholarly idea and gainful comments of my true and sympathetic administrator and supervisor Dr Hussam Ali, without his liberal consolation and patient direction, it would have been hard for me to do the relegated task.

I might want to thank my father, my mother, my sisters, and my brother who helped me a great deal in get-together unique data, gathering information and directing me occasionally in making this undertaking, notwithstanding of their bustling timetables, they gave me various thoughts in making this venture interesting.

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Abstract

The project, titled " Weed Whisper: Smart Vehicle with Obstacle Avoidance and Weed Detection," stands as an exemplary venture at the forefront of autonomous robotic systems. Its core objective revolves around the development of an intelligent vehicle that seamlessly navigates through dynamic outdoor environments. The project's principal features encompass a sophisticated obstacle avoidance system, underpinned by ultrasonic sensors and an Arduino Uno R3. This system enables the vehicle to dynamically adjust its trajectory in real-time, ensuring secure and adaptive navigation. Furthermore, the project integrates a cutting-edge weed detection system, leveraging the YOLOv5s model trained on a bespoke dataset. This model facilitates accurate and real-time identification of diverse weed species, adding a layer of sophistication to the vehicle's capabilities and contributing to effective vegetation management.

The project's architectural design is characterized by modularity, allowing for the independent development and maintenance of discrete functionalities. The incorporation of an ESP32-CAM as the central processing unit enhances computational capabilities, serving as the nexus for video streaming and operational coordination. Adopting a microservices approach ensures scalability and flexibility, laying the foundation for seamless future enhancements without compromising the integrity of the overarching system. The provision of a user-friendly interface furnishes real-time feedback, affording users the ability to monitor and configure the vehicle's behavior with utmost ease.

Chapter 1: Project Proposal

1.1 Abstract

This project presents the development of this project introduces an approach to enhance the intelligence of autonomous vehicles by integrating obstacle and weed detection capabilities through machine learning techniques. The system employs YOLOv5s, a state-of-the-art object detection model, trained on a custom dataset to identify objects in real-time. Python's OpenCV library is utilized for processing video streams on a central device controlled by an ESP32-CAM. The central device coordinates the integration of YOLOv5s to detect and classify obstacles and weeds with high accuracy.

Additionally, an Arduino Uno R3, equipped with an ultrasonic sensor, is incorporated into the system to identify, and measure the proximity of obstacles in the vehicle's path. The system employs a customized algorithm to interpret sensor data and dynamically adjust the vehicle's course to avoid collisions. This combination of machine learning and sensor-based obstacle avoidance enhances the overall safety and efficiency of the AI-driven vehicle.

1.2 Background and Justification

1.2.1 Background

With the rapid advancements in autonomous vehicle technologies, the integration of machine learning algorithms has become pivotal in enhancing the decision-making capabilities of these vehicles. Object detection, a crucial aspect of autonomous navigation, plays a significant role in identifying obstacles and potential hazards. YOLOv5s, renowned for its speed and accuracy, is employed in this research due to its suitability for real-time applications. By training this model on a custom dataset, we tailor its capabilities to specifically recognize obstacles and weeds commonly encountered in outdoor environments.

Furthermore, the incorporation of Python's OpenCV library allows for seamless integration of YOLOv5s into the system, enabling efficient processing of video streams on a central device. In parallel, the integration of an Arduino Uno R3, equipped with an ultrasonic sensor, addresses the need for precise obstacle detection in the vehicle's immediate vicinity. This combination of cutting-edge machine learning and hardware components creates a comprehensive framework for the development of a smart AI vehicle capable of autonomously navigating complex environments. Tabassum has proposed the use of multiple ultrasonic sensors to have greater precision for the obstacle detection [1].

1.2.2. Justification

The motivation behind this research stems from the need to address challenges associated with autonomous vehicles operating in outdoor environments, where dynamic obstacles and weeds pose significant threats to safe navigation. The utilization of YOLOv5s ensures that the vehicle can quickly and accurately detect and classify objects in its path, contributing to timely decision-making and effective obstacle avoidance. The integration of an ultrasonic sensor with Arduino Uno R3 further fortifies the system's ability to detect obstacles in proximity, enabling the vehicle to make real-time adjustments to its trajectory. It also allows for personalized and future driving experiences through its adaptability to the driver's behavior and preferences [2].

By combining machine learning and sensor-based approaches, this research aims to create a robust and adaptable solution that not only identifies obstacles and weeds but also actively navigates around them. The proposed system has the potential to enhance the safety and efficiency of autonomous vehicles in diverse outdoor settings, ranging from agricultural fields prone to weed infestations to urban environments with dynamic obstacles. This technology is increasingly being adopted in various industries, with the global smart transportation market expected to reach USD 285.12 billion by 2030 [3].

1.3 Project Methodology

The methodology for developing a smart AI vehicle with obstacle avoidance and weed detection capabilities is structured into two phases. The initial phase involves establishing an independent obstacle detection and avoidance system. This includes connecting an ultrasonic sensor to an Arduino Uno R3, implementing Arduino code for autonomous obstacle detection, developing a standalone obstacle avoidance algorithm, and integrating it into the main device (ESP32-CAM). Thorough testing ensures the system's accurate and autonomous navigation.

The second phase focuses on creating an independent weed detection system. A diverse weed dataset is compiled, and the YOLOv5s model is independently trained for weed detection, with pre-trained weights for efficiency. A Python-based system using OpenCV is developed on the main device for real-time video streaming, and the trained model is integrated for autonomous weed detection. Rigorous testing assesses the system's accuracy and independence in identifying various weed species. This modular and independent approach forms the foundation for a versatile and intelligent smart AI vehicle.

1.3.1. Hardware components

1. Arduino UNO.
2. L293D Motor Drive.
3. TT Gear Motors.
4. Ultrasonic Sensor.
5. Rubber Wheels.
6. 18650 Battery and battery holder.
7. DC Switch.
8. Esp32-Cam
9. FTDI Driver
10. Servo Motors
11. Central Device (Laptop)

1.3.2. Software Components

1. Arduino IDE.
2. Python (OpenCV)
3. YoloV5s Model

1.3.3. Model

Utilizing the Scrum model for the development of a smart AI vehicle proves to be a strategic choice. This approach divides the project into short, focused sprints, typically lasting two to four weeks, allowing the team to iteratively tackle specific functionalities like obstacle detection and weed identification. The Scrum framework's roles, including the Product Owner, Scrum Master, and Development Team, foster collaboration, and transparency throughout the process. The Product Backlog captures dynamic project requirements, evolving based on stakeholder feedback. Sprint Planning, Daily Standup meetings, Sprint Reviews, and Retrospectives provide a structured yet flexible framework for managing evolving technologies and priorities. This agile and iterative nature aligns seamlessly with the dynamic challenges of developing a smart AI vehicle, ensuring adaptability and continual improvement throughout the project.

1.4 Project Scope

The project aims to develop a cutting-edge smart AI vehicle designed to autonomously navigate through dynamic outdoor environments, showcasing advanced obstacle avoidance and weed detection capabilities. This multifaceted initiative encompasses the design, development, and integration of hardware components and software systems to achieve a fully functional and intelligent vehicle.

1.4.1. Objectives

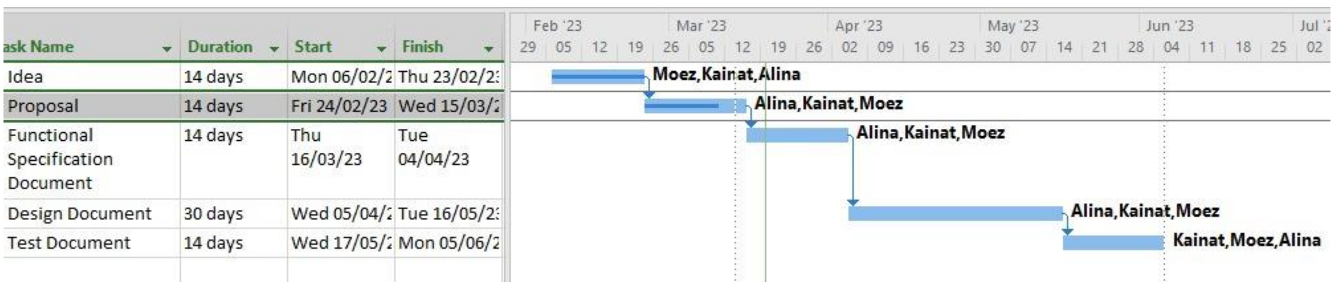
1. Develop a robust obstacle detection mechanism utilizing an ultrasonic sensor and Arduino Uno R3 for real-time sensing of obstacles.
2. Implement an adaptive obstacle avoidance algorithm capable of dynamically adjusting the vehicle's trajectory for safe navigation.
3. Train the YOLOv5s model on a diverse dataset for accurate detection and classification of various weed species in real-time.
4. Integrate the obstacle avoidance and weed detection systems seamlessly for cohesive collaboration.

5. Establish reliable communication protocols between hardware components, including the Arduino Uno R3, ultrasonic sensor, and the main device (ESP32-CAM).

1.4.2. Features

1. Autonomous Navigation: The vehicle will autonomously navigate based on informed decisions from obstacle detection and avoidance algorithms.
2. Real-time Obstacle Avoidance: Utilizing an ultrasonic sensor, the vehicle will dynamically adjust its path in real-time to avoid obstacles.
3. Weed Identification: The YOLOv5s model will enable the vehicle to identify and classify various weed species for effective weed detection.
4. Adaptive System Architecture: Implementation of an agile development approach for adaptability to changing requirements, ensuring responsiveness to evolving challenges.

1.5 High level Project Plan



ask Name	Duration	Start	Finish
Idea	14 days	Mon 06/02/2	Thu 23/02/2:
Proposal	14 days	Fri 24/02/23	Wed 15/03/2
Functional Specification Document	14 days	Thu 16/03/23	Tue 04/04/23
Design Document	30 days	Wed 05/04/2	Tue 16/05/2:
Test Document	14 days	Wed 17/05/2	Mon 05/06/2

Figure 1: High Level Project Plan

Chapter 2: Software Requirement Specification

2.1 Introduction

2.1.1 Purpose of Document

The purpose of a Software Requirements Specification (SRS) document for a smart AI vehicle with obstacle and weed detection is to provide a detailed description of the functional and non-functional requirements of the system. The document serves as a means of communication between the stakeholders, developers, and users of the system. It outlines the features and capabilities that the system must possess to meet the needs and expectations of its users. The SRS document also provides a basis for the development, testing, and validation of the system. It helps to ensure that all parties involved have a clear understanding of what is expected from the system and helps to minimize misunderstandings and miscommunications during the development process.

2.1.2 Project Overview

The project aims to develop a smart AI vehicle with obstacle and weed detection. The system will use advanced artificial intelligence and IOT technologies to allow users to detect the weed in the fields. The vehicle will also be equipped with sensors and algorithms to detect and avoid obstacles in its path, ensuring safe and efficient operation.

2.1.3 Scope

The aim of this project is to develop a smart AI vehicle with obstacle and weed detection. The vehicle will be able to detect obstacles in its path and automatically navigate around them, making it an ideal choice for use in agriculture.

2.1.3.1 Objectives

1. Design and develop an AI-powered vehicle capable of detect obstacles and avoid them.
2. Implement real-time weed detection using computer vision and deep learning techniques.
3. Develop a user-friendly interface for controlling the vehicle and monitoring its performance.
4. Test the vehicle's functionality in different environments, including outdoor settings.
5. Analyze the vehicle's performance and make necessary improvements to enhance its functionality.

2.1.3.2 Features

1. **Weed detection:** The vehicle will be equipped with a advance machine learning and computer vision algorithms that allows users to see result on central device.
2. **Obstacle detection:** The vehicle will use computer vision and deep learning algorithms to detect obstacles in its path in real-time and navigate around them.
3. **Navigation:** The vehicle will be able to navigate through different environments, including indoor and outdoor settings, using sensors and navigation algorithms.

2.2 Functional Requirements

1. The user should visualize live video streams and detection results.
2. The system utilizes YOLOv5s for real-time object detection.
3. The system focuses on a custom dataset for obstacles and weeds.
4. The central device processes video streaming using ESP32-CAM and Python-OpenCV.
5. The receiver decodes the data before feeding it into a microcontroller to induce DC motors via motor driver L293D for necessary work.
6. The system generates real-time alerts for detected obstacles or weeds.

7. The car will have the ability to detect barriers in its route and immediately stops the vehicle with the assistance of an Ultrasonic detector.

2.3 Non-functional Requirements

2.3.1 Performance Requirements

1. The system should exhibit low-latency response times for real-time object detection and obstacle avoidance.
2. The system should accurately detect obstacles and respond with a high degree of precision.
3. Response times for user interface interactions should be within acceptable limits.
4. The system should prioritize safety and be able to detect obstacles, weed and respond accordingly to prevent accidents.

2.3.2 Safety Requirements

1. The system should prevent loss, damage or harm with safeguards such as automatic braking or collision avoidance.
2. It should take appropriate safety actions such as slowing down or stopping in response to obstacles.
3. The system should be designed to prevent potentially dangerous actions. For example, it should not allow the vehicle to exceed the speed limit or make unsafe maneuvers.
4. The system should prevent dangerous actions and conform to relevant safety certifications, policies or regulations.

2.3.3 Resource Utilization

1. Efficient utilization of CPU, memory, and network resources is essential for optimal system performance.
2. The system should avoid resource bottlenecks during simultaneous tasks.
3. The system should efficiently allocate resources for real-time processing of video streams and object detection, ensuring minimal delays and optimal responsiveness.
4. Implement adaptive resource allocation mechanisms to dynamically distribute computing resources based on the complexity of the detection task, optimizing overall performance in varying environmental conditions.

2.4 Assumptions and Dependencies

2.4.1. Assumptions

1. **Consistent Weed Characteristics:** The effectiveness of weed detection assumes a consistent set of characteristics in the appearance of weeds, as defined by the custom dataset, for reliable classification.
2. **Consistent Wireless Communication:** The effective communication between the central device and the smart AI vehicle assumes consistent and reliable wireless communication, minimizing disruptions or packet loss.
3. **Regulations**: It is assumed that regulations and laws related to the operation of autonomous vehicles will remain stable and supportive.
4. **User adoption:** It is assumed that users will be willing to adopt and use the technology in the vehicle.

2.4.2 Dependencies

1. **Compatibility with Mobile Devices:** The user interface assumes compatibility with a variety of mobile devices, including smartphones and tablets, for user convenience and accessibility.
2. **Network connectivity:** The project may be dependent on network connectivity, such as cellular and Wi-Fi networks, to support the operation of the vehicle.

3. **External components:** The project may be dependent on external factors such as the integration of components being developed by another project. If these components are not supplied on schedule or do not operate correctly, it could affect the project.
4. **Weather Factor:** The weather is appropriate for driving.

2.5 System Architecture

2.5.1 Robot System Architecture:

The robot system architecture is designed to facilitate the smart AI vehicle's autonomous operation, incorporating various hardware components, sensors, and control mechanisms. At its core are the ESP32-CAM and Arduino Uno R3. The ESP32-CAM is responsible for capturing and streaming real-time video footage of the environment, while the Arduino Uno R3, equipped with an ultrasonic sensor, contributes continuous distance data for obstacle detection. The central processing unit processes the video stream, implementing an obstacle avoidance algorithm to determine a safe trajectory for the vehicle. Motors and actuators, controlled by the central unit, enable the robot's movement. The power management module ensures efficient energy utilization, incorporating power-saving modes during inactivity. The user interface, accessible through mobile devices or computers, allows users to monitor live video streams, receive alerts, and exercise manual control options.

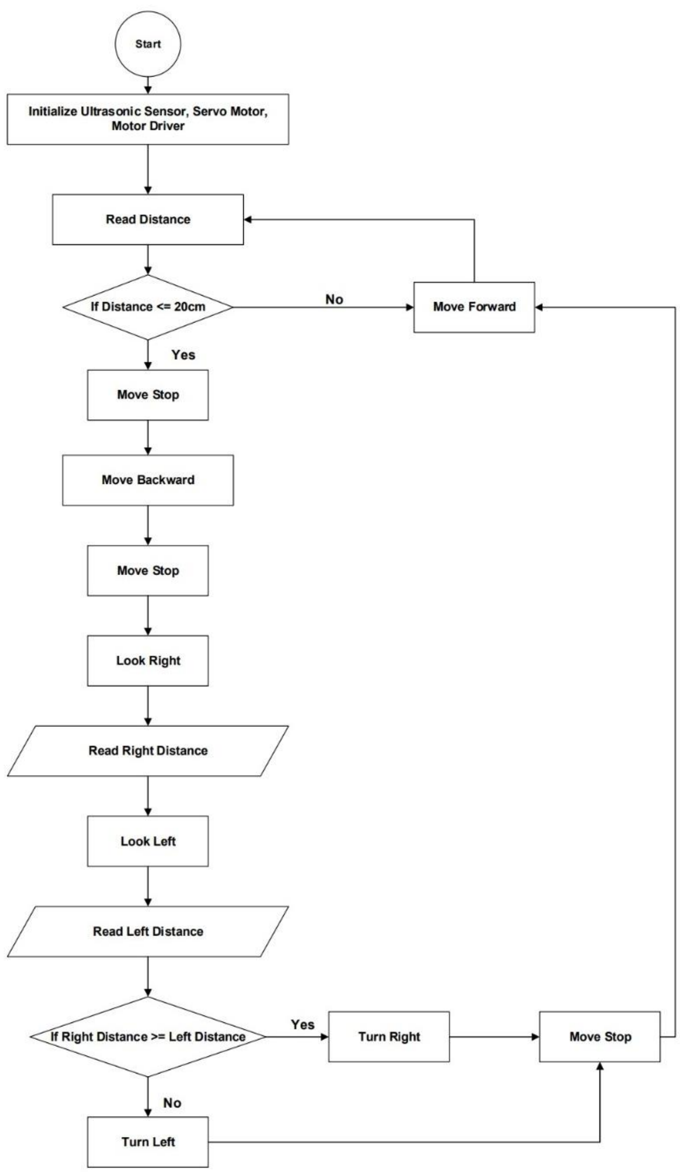


Figure 2: System Architecture of Obstacle Avoidance.

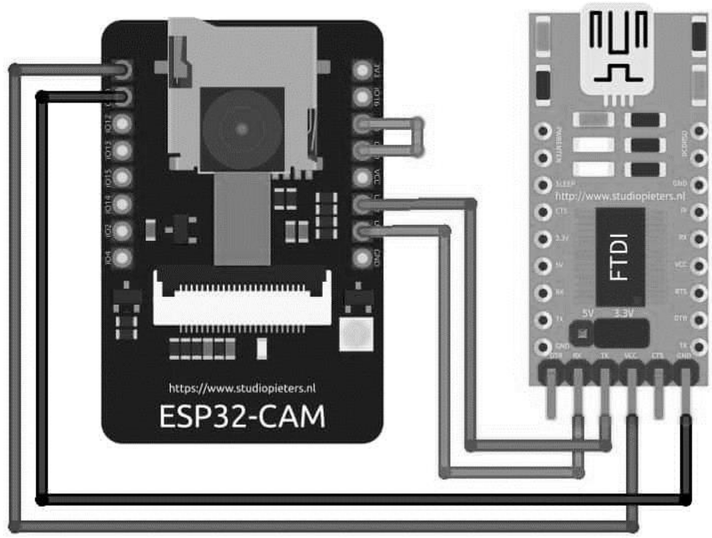


Figure 3: System Architecture of Weed Detector

2.5.2 YOLOv5n Machine Learning Model Architecture:

The backbone network, neck network, and detect network are the three main components of YOLO5s framework. These networks included the Focus module, the CBL module, the CSP module, the SPP module, the Concat module, and the unsampled module. Figure 5.2 depicts the network structure of the YOLO V5s. The YOLO5 network model has a high detection accuracy and a high inference rate, with the fastest detection rate of up to 140 frames per second. The size of the YOLOv5 pre-trained weight is 90% smaller than the size of the YOLOv4 pre-trained weight, indicating that the YOLOv5 model is suitable for deployment to embedded devices for real-time detection. The PyTorch framework is accessible and easy to train the dataset with compared to the Darknet framework used in YOLO V4.

Other performance improvement features of YOLO v5 include easy integration of computer vision technologies, quick model training, and easy environment configuration. YOLO5s, YOLO5m, YOLO5l, and YOLOv5x are the four architectures that make up the YOLO5 architecture, respectively. The distinctive features of YOLO5 architectures are the depth multiplier control model and the size of the convolution cores. Both YOLO5s and YOLO5l have depth multiples of 0.33 and 1, respectively. The recognition model had to adhere to strict real-time performance and lightweight requirements because this project focus on the detection and classification of seven different objects, of which there were three crop types and four weed species. Therefore, after careful examination and analysis of the accuracy, efficiency, and size of the detection model, the weed detection system for precise and real-time laser-based killing in fields was made by using the YOLO5s model [2].

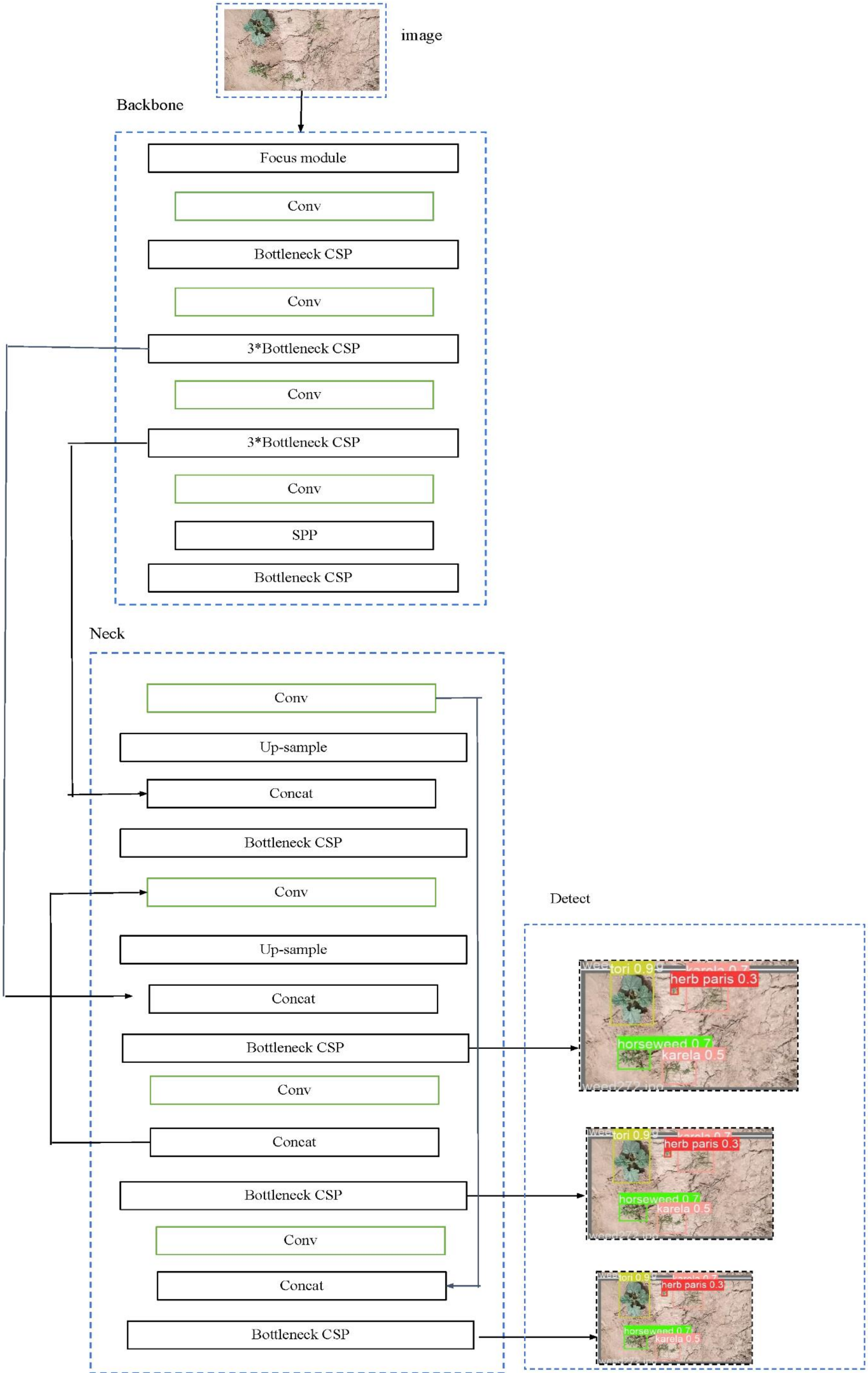


Figure 4:Architecture of Yolov5s Model

2.6 Use Cases

2.6.1 Use Case Diagrams

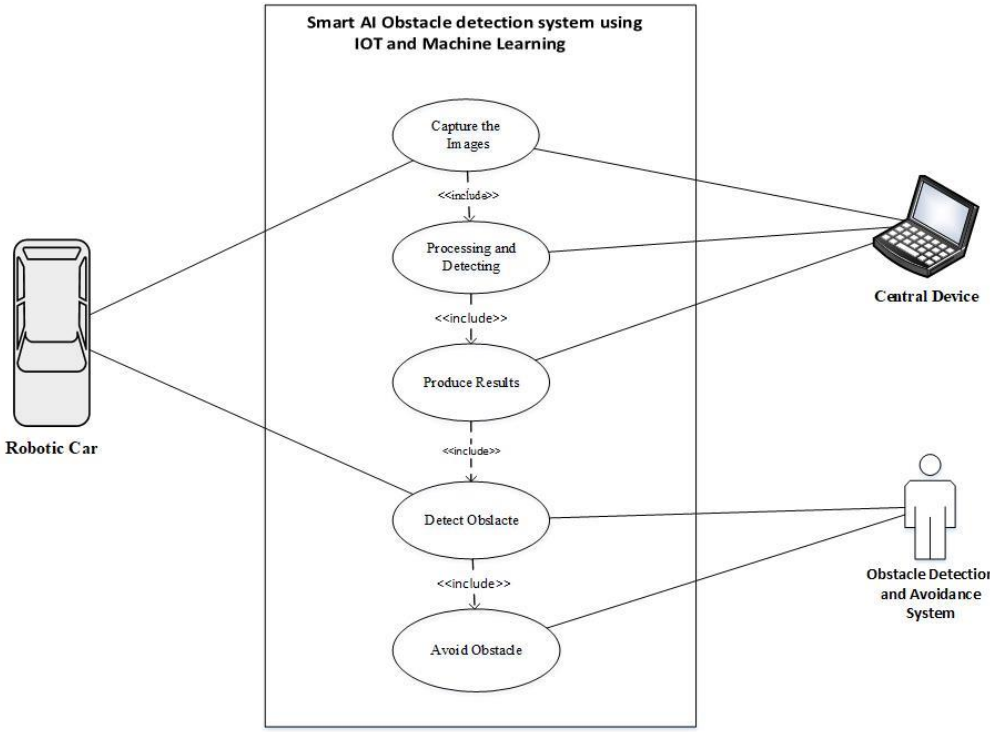


Figure 5: Use Case Diagram

2.6.2 Use Case Description

Table 1: Use Case Diagram of Streaming

UC 1: Real-Time Streaming		
Actors:	Robot, Central Device	
Feature:	Real-time Streaming	
Use case Id:	1	
Pre-condition:	The robot and central device must be connected to Internet	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	1	Central devices receive and stream data on screen
Post Conditions		
Step#	**Description**	
1	Robot and Central Device must be connected to Internet	
2	Robot must have enough power supply to accommodate all components	
Use Case Cross referenced	*UC 2*	
Concurrency and Response *Give an estimate of the following.*		

Table 2: Use Case of Weed Detection Using YOLOV5s

UC 2: Weed Detection using Yolov5s		
Actors:	Central Device	
Feature:	**Weed Detection using YoloV5s**	
Use case Id:	2	
Pre-condition:	The central device must stream data in browser	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	1	YoloV5s detect weed in frame which are streamed on browser using cv
Post Conditions		
Step#	**Description**	
1	Robot and Central Device must be connected to Internet.	
2	Robot must have enough power supply to accommodate all components.	
Use Case Cross referenced	*UC 1*	
Concurrency and Response *Give an estimate of the following.* ♦ *Only One User at one time* ♦ *In Seconds*		

Table 3: Use Case of Display Results and Alerts

UC 3: Display Results and Alerts		
Actors:	Robot, Central Device	
Feature:	Display Results	
Use case Id:	3	
Pre-condition:	The robot and central device must be connected to Internet	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	1	Detect weed and display results
Post Conditions		
Step#	**Description**	
1	Robot and Central Device must be connected to Internet	
2	Robot must have enough power supply to accommodate all components	
Use Case Cross referenced	*UC 2*	
Concurrency and Response *Give an estimate of the following.* ♦ *Only One User at one time* ♦ *In Seconds*		

Table 4: Use Case of Detect Obstacle

UC 4: Detect Obstacle		
Actors:	Obstacle Detection & Avoidance System**.**	
Feature:	Obstacle Detection	
Use case Id:	4	
Pre-condition:	The robot and central device must be connected to Internet	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	1	System detect obstacle on its path.
Post Conditions		
Step#	**Description**	
1	Robot and Central Device must be connected to Internet	
2	Robot must have enough power supply to accommodate all components	
Use Case Cross referenced	*UC 3*	
Concurrency and Response *Give an estimate of the following.* ♦ *Only One User at one time* ♦ *In Seconds*		

Table 5:Use Case of Avoid Obstacle

UC 5: Avoid Obstacle		
Actors:	Obstacle Detection & Avoidance System**.**	
Feature:	Obstacle Avoidance	
Use case Id:	5	
Pre-condition:	The robot and central device must be connected to Internet	
Scenarios		
Step#	**Action**	**Software Reaction**
1.	1	System stop movement when it detects obstacle in its path and change its path accordingly
Post Conditions		
Step#	**Description**	
1	Robot and Central Device must be connected to Internet	
2	Robot must have enough power supply to accommodate all components	
Use Case Cross referenced	*UC 4*	
Concurrency and Response *Give an estimate of the following.* ♦ *Only One User at one time*		

2.7 Circuit Diagram

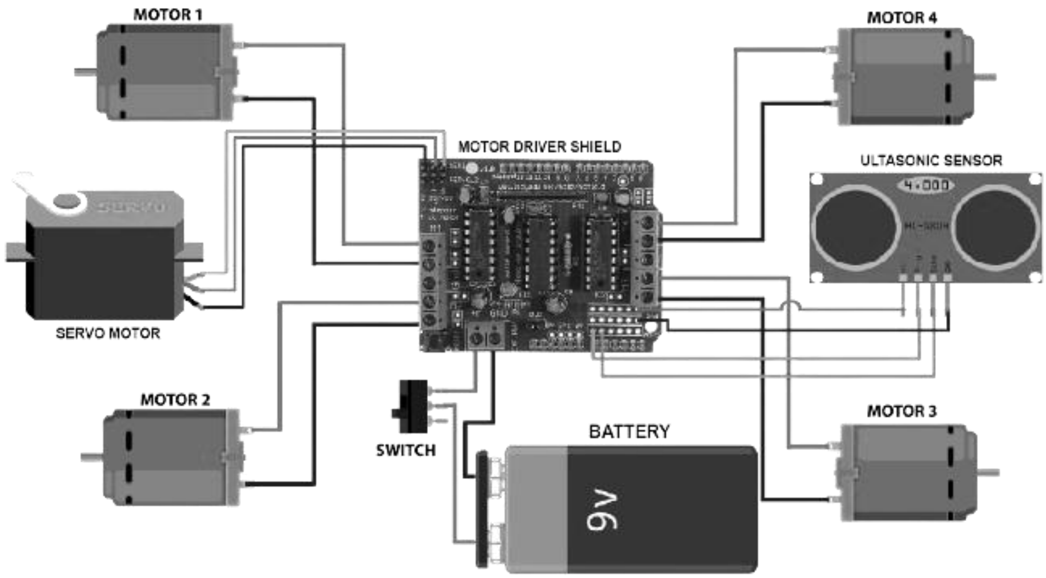


Figure 6:Circuit Diagram of System

2.8 Requirements Traceability Matrix

Table 6: Requirements Traceability Matrix

Sr. #	Feature	Use case ID	UI ID	Priority	Build Number	Use Case Cross reference. (Related Use Cases)
1.	Obstacle Detection System	1		1	V1.0	
2.	Weed Detection Model	2		2	V2.0	

The columns carry the following meaning:

- *Feature:* *Lists system features based on which use cases are built.*
- *Use Case ID:* *Write the ID of the use case for easy lookup.*
- *UI ID:* *Write the user interface ID for this use case.*
- *Priority:* *Give an appropriate rating to each use case according to its priority*
- *Build Number:* *Write the reference number to which this feature belongs.*
- *Use Case Cross Ref:* *Write the related use cases separated with commas.*

2.9 Risk Analysis

2.9.1 Risk Identification

1. Reliability of the obstacle detection system.
2. Accuracy of weed detection.
3. Communication Issues
4. Power Supply Issues

2.9.2. Risk Drivers

1. Perception variation and disparity in real-time obstacle detection [4].
2. Sensor Failure.
3. Communication Disruption.

2.9.3 Risk Mitigation Plan:

1. To mitigate the risk of perception variation and disparity in real-time obstacle detection, further research and development can be conducted to improve the accuracy and reliability of various approaches to obstacle detection, including ultrasonic sensors, laser range scanners, and stereo vision cameras [1].
2. To mitigate the risk of sensor failure, implement redundancy by incorporating duplicate sensors for critical functions. If one sensor fails, the redundant sensor can provide essential data.
3. To mitigate the risk of Communication Disruption, establish redundant communication channels, utilizing multiple protocols or communication paths to ensure continuous connectivity even if one channel experiences disruptions.

2.10 Cost Estimation Sheet

Table 7: Cost Estimation Sheet

1.	**Software development cost**		15000
2.	**Packaged software**		5000
3.	**Hardware**		19000
4.	**Network**		6000
5.	**Client**		0
6.	**Misc.**		0
		Total cost	**45000**

Chapter 3: Design Document

3.1 Introduction

3.1.1 Purpose of Document

The purpose of a design document for a smart AI vehicle with real-time obstacle and weed detection is to provide a comprehensive guide for the development team on how to build the vehicle. The document should include detailed information on the vehicle’s design, functionality, and features. It should also outline the project’s goals and objectives, as well as any constraints or limitations that may affect the development process.

3.1.2 Project Overview

The project focuses on developing a smart AI vehicle equipped with advanced obstacle avoidance and weed detection capabilities. With a primary goal of autonomous navigation in dynamic outdoor environments, the vehicle integrates cutting-edge technologies, including an ultrasonic sensor, Arduino Uno R3, and YOLOv5s model. The system employs an adaptive obstacle avoidance algorithm for real-time path adjustment, ensuring safe navigation.

3.1.3 Scope

The project involves developing a smart AI vehicle with autonomous navigation capabilities, emphasizing advanced obstacle avoidance, and weed detection functionalities. The scope encompasses the integration of an ultrasonic sensor, Arduino Uno R3, and YOLOv5s model for real-time obstacle detection and adaptive avoidance. The system further includes the training of the YOLOv5s model on a diverse dataset for accurate weed identification. The project aims for seamless hardware integration, robust communication protocols, and an agile development approach, ensuring adaptability and responsiveness. Key deliverables include a fully functional smart AI vehicle, comprehensive documentation, and presentations on testing results and performance metrics.

3.1.4 Objectives

1. Design and develop an AI-powered vehicle capable of detect obstacles and avoid them.
2. Implement real-time weed detection using computer vision and deep learning techniques.
3. Develop a user-friendly interface for controlling the vehicle and monitoring its performance.
4. Test the vehicle's functionality in different environments, including outdoor settings.
5. Analyze the vehicle's performance and make necessary improvements to enhance its functionality.

3.1.5 Features

1. **Weed detection:** The vehicle will be equipped with an advance machine learning and computer vision algorithms that allows users to see result on central device.
2. **Obstacle detection:** The vehicle will use computer vision and deep learning algorithms to detect obstacles in its path in real-time and navigate around them.
3. **Navigation:** The vehicle will be able to navigate through different environments, including indoor and outdoor settings, using sensors and navigation algorithms.

3.2 Design Considerations

Designing the smart AI vehicle entails careful considerations, starting with the selection of a precise ultrasonic sensor compatible with the Arduino Uno R3. The YOLOv5s model, chosen for its accuracy and real-time processing, is tailored for obstacle detection, and weed identification through customization and training. Harmonizing hardware integration involves cohesive system design, prioritizing power efficiency, and establishing effective communication protocols. Adaptive algorithms dynamically adjust the vehicle's trajectory based on sensor data, seamlessly integrating obstacle avoidance, and weed identification functionalities. The user interface is crafted for real-time feedback and user-friendly configuration. Adopting an agile Scrum framework facilitates iterative progress and collaboration. Rigorous testing ensures accuracy across diverse environments. Additionally, considerations for scalability, modularity, safety features, and power efficiency contribute to the system's adaptability, reliability, and user safety.

3.2.1 Assumptions and Dependencies

3.2.1.1 Assumptions

1 **Technological advancements**: It is assumed that the technology used in the vehicle, such as weed and obstacle detection, will continue to advance and improve over time.
2 **Infrastructure:** It is assumed that the infrastructure, such as roads and traffic systems, will support the operation of the vehicle.
3 **Regulations**: It is assumed that regulations and laws related to the operation of autonomous vehicles will remain stable and supportive.
4 **User adoption:** It is assumed that users will be willing to adopt and use the technology in the vehicle.

3.2.1.2 Dependencies

1 **Hardware compatibility**: The project may be dependent on the compatibility of hardware components, such as sensors and processors, to support the operation of the vehicle.
2 **Network connectivity**: The project may be dependent on network connectivity, such as cellular and Wi-Fi networks, to support the operation of the vehicle.
3 **External components:** The project may be dependent on external factors such as the integration of components being developed by another project. If these components are not supplied on schedule or do not operate correctly, it could affect the project.
4 **Weather Factor**: The weather is appropriate for driving.

3.2.2 Risks and Volatile Areas

The risks associated with a smart AI voice-controlled vehicle with real-time obstacle detection can include the following:

1. **Hardware failure**: The hardware used for obstacle detection may fail, leading to accidents.
2. **Software failure**: The software used for obstacle detection may fail, leading to accidents.
3. **Cybersecurity**: The vehicle may be vulnerable to cyber attacks that could compromise its safety.
4. **Legal issues**: There may be legal issues associated with the use of smart AI vehicles with real-time obstacle detection [5].

3.3 System Architecture

The system architecture for the smart AI vehicle is designed to ensure seamless integration and optimal functionality. It comprises three main components: the hardware layer, the obstacle avoidance and weed detection algorithms, and the user interface. The hardware layer includes an ultrasonic sensor, Arduino Uno R3, and ESP32-CAM, working in tandem to provide real-time data for decision-making. The obstacle avoidance and weed detection algorithms, powered by the YOLOv5s model, analyze incoming data to dynamically adjust the vehicle's trajectory and identify various weed species. The user interface offers real-time feedback and allows for intuitive configuration. Embracing a modular and scalable approach, the system architecture ensures adaptability to evolving requirements while maintaining a robust and efficient framework for the smart AI vehicle's operation.

3.3.1 System Level Architecture

The system level architecture of smart AI voice-controlled vehicle with real-time obstacle detection includes:

3.3.1.1 Chassis

The chassis of a car is the main support component in a car's structure. It bears the forces experienced by a car while it's standing still or moving at high speeds. A vehicle chassis is like a human skeleton. It provides the structural shape and support to the entire body of a vehicle. The chassis is typically made of steel or aluminum and is designed to be strong and rigid.

Figure 7: Chassis

3.3.1.2 TT Gear Motor

A DC motor is a class of rotary electrical machine that converts t\direct current into mechanical energy. All types of DC motors have internal mechanism either electronic or electromechanical, so it can change the direction of flow of current in path of motor periodically.

Figure 8: TT Gear Motor

3.3.1.3 Wheels

A wheel is circular block of durable and hard material, which is placed in axil about which the wheel rotates when a moment is applied by torque or gravity, thereby making one of the simple machines. When placed under a load baring platform, the wheel turning on the horizontal axil makes it possible to transport heavy loads.

Figure 9: Wheels

3.3.1.4 Arduino UNO

Arduino UNO is an open-source micro controller board placed on the microchip ATmega328p micro controller and developed by Adruino.cc. The board has 6 Analog pins, 14 digital pins programmable with Arduino IDE via a Type B USB cable. It can power by external main volt battery.

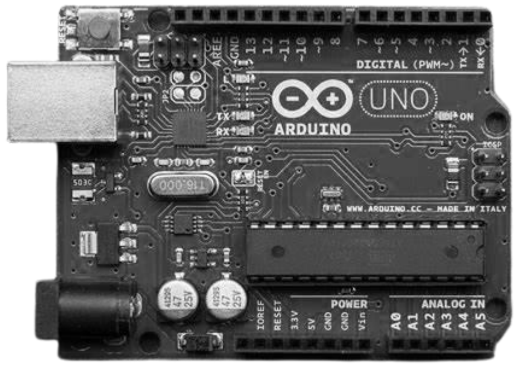


Figure 10: Arduino Uno R3

3.3.1.5 L293D Motor Driver

The L293D motor driver is a popular integrated circuit (IC) that is used to control DC motors with an Arduino1. It is a quadruple high current half-H driver IC that can provide a bidirectional drive current up to 1 A at voltages from 4.5 V to 36 V2. The L293D motor driver is designed specifically to control DC motors, stepper motors, solenoids, and any other load with a high impedance.

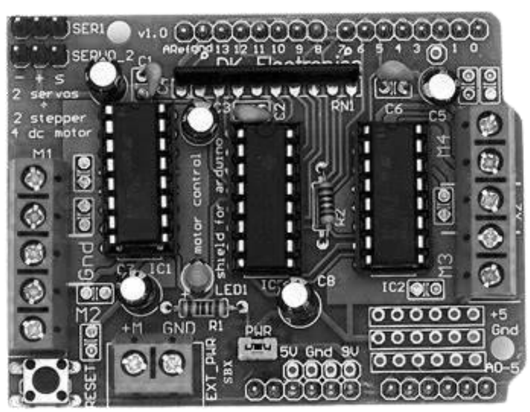


Figure 11: L293D Motor Driver

3.3.1.6 ESP32-CAM

The ESP32-CAM is a versatile and compact development board featuring the ESP32 microcontroller and a camera module. This integrated module is designed for applications requiring image and video processing capabilities. The ESP32-CAM supports Wi-Fi connectivity, making it suitable for IoT projects and applications that demand wireless communication. Its camera module, often based on the OV2640 sensor, allows for image capture and processing.

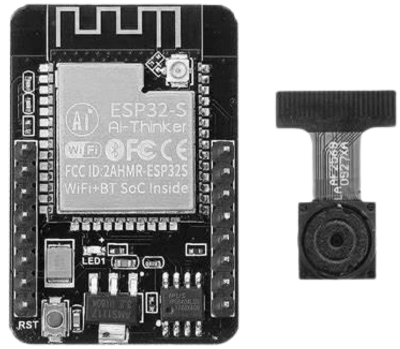


Figure 12:ESP32-CAM

3.3.1.7 FTDI Driver

FTDI (Future Technology Devices International) drivers are essential software components that enable communication between a computer and devices equipped with FTDI USB (Universal Serial Bus) chips. FTDI drivers are commonly used for devices like USB-to-serial converters, Arduino boards, and other microcontroller development platforms.

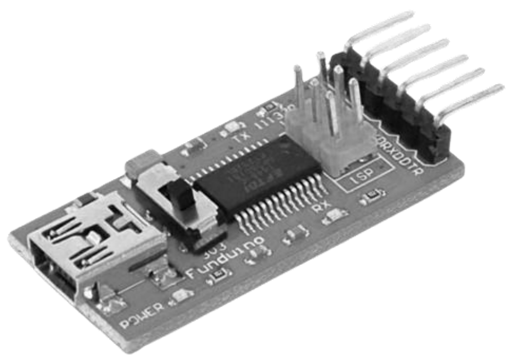


Figure 13: FTDI Driver

3.4 Design Strategies

The design strategies for the smart AI vehicle center around creating a robust and adaptable system. Adopting a modular architecture enables the independent development and maintenance of distinct functionalities, such as obstacle avoidance and weed detection. Leveraging a microservices approach ensures scalability and flexibility, facilitating future enhancements without disrupting the entire system. Real-time processing and edge computing are prioritized to enable quick and adaptive responses in dynamic environments while minimizing latency.

3.4.1 Strategy 1…n

3.4.2 Modular Architecture:

Implement a modular system architecture, allowing independent development and maintenance of components like obstacle avoidance, weed detection, and communication modules.

3.4.3 Microservices Approach:

Adopt a microservices architecture for individual functionalities, enabling scalability, ease of maintenance, and flexibility in deploying updates without affecting the entire system.

3.4.4 Real-time Processing:

Prioritize real-time data processing for time-sensitive tasks like obstacle detection and avoidance, ensuring quick and adaptive responses in dynamic environments.

3.4.5 Edge Computing:

Leverage edge computing capabilities to process data locally on the smart AI vehicle, reducing latency and minimizing dependency on centralized processing.

3.4.6 Scalability and Flexibility:

Design the system to be scalable, accommodating future enhancements or additions to functionalities without major overhauls.

3.4.7 User-friendly Interface:

Develop an intuitive user interface for monitoring and configuring the smart AI vehicle's behavior, promoting ease of use, and providing real-time feedback.

3.4.8 Power Efficiency:

Implement power-efficient algorithms and hardware configurations to extend the operational lifespan of the smart AI vehicle, considering energy consumption in dynamic outdoor environments.

3.4.9 Secure Communication:

Prioritize secure communication protocols to protect data exchange between the smart AI vehicle and external systems, mitigating potential security risks.

3.4.10 Adaptive Algorithms:

Employ adaptive algorithms for obstacle avoidance and weed detection, allowing the system to dynamically adjust based on real-time sensor data for optimal performance.

3.4.11 Agile Development Practices:

Embrace agile development methodologies, particularly the Scrum framework, for iterative and incremental progress, promoting collaboration, and responsiveness to changing requirements.

3.4.12 Comprehensive Testing:

Implement a rigorous testing strategy covering various scenarios, including controlled environments and real-world conditions, to validate the accuracy, reliability, and robustness of the system.

3.4.13 Continuous Monitoring and Improvement:

Establish mechanisms for continuous monitoring of system performance and user feedback. Use this information to identify areas for improvement and implement iterative enhancements.

3.5 Detailed System Design

3.5.1 Sequence diagram:

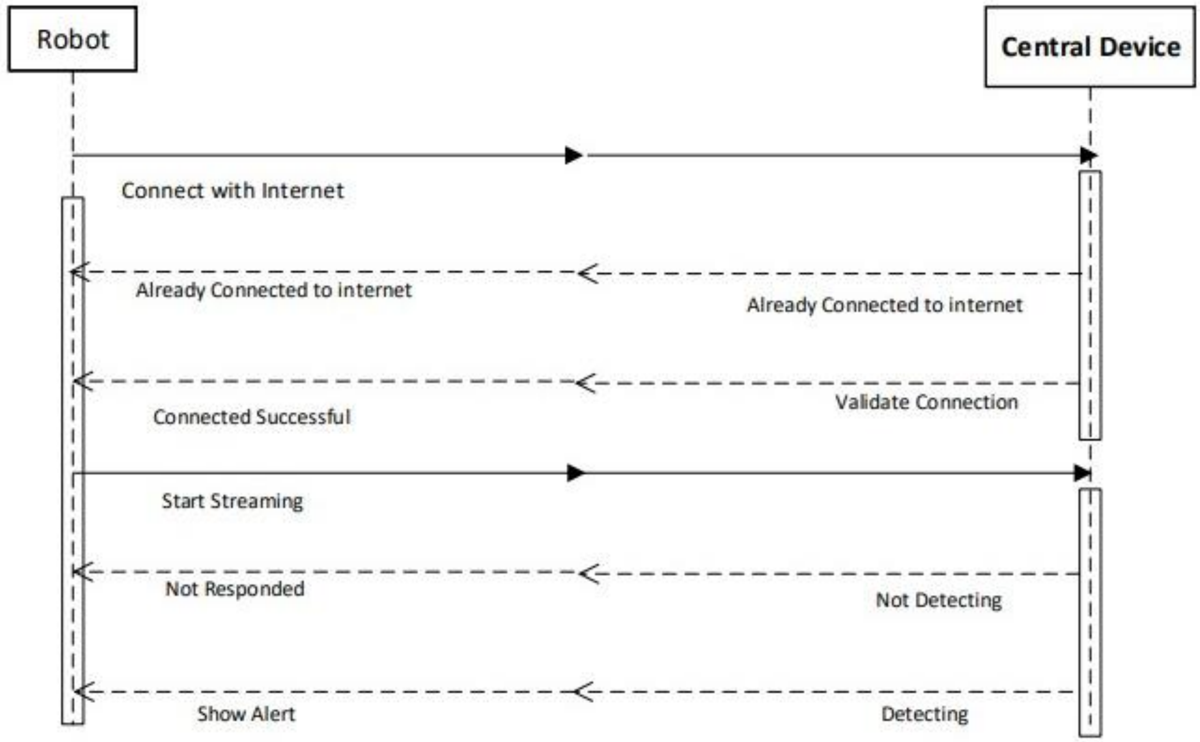


Figure 14: Sequence Diagram of Weed Detection

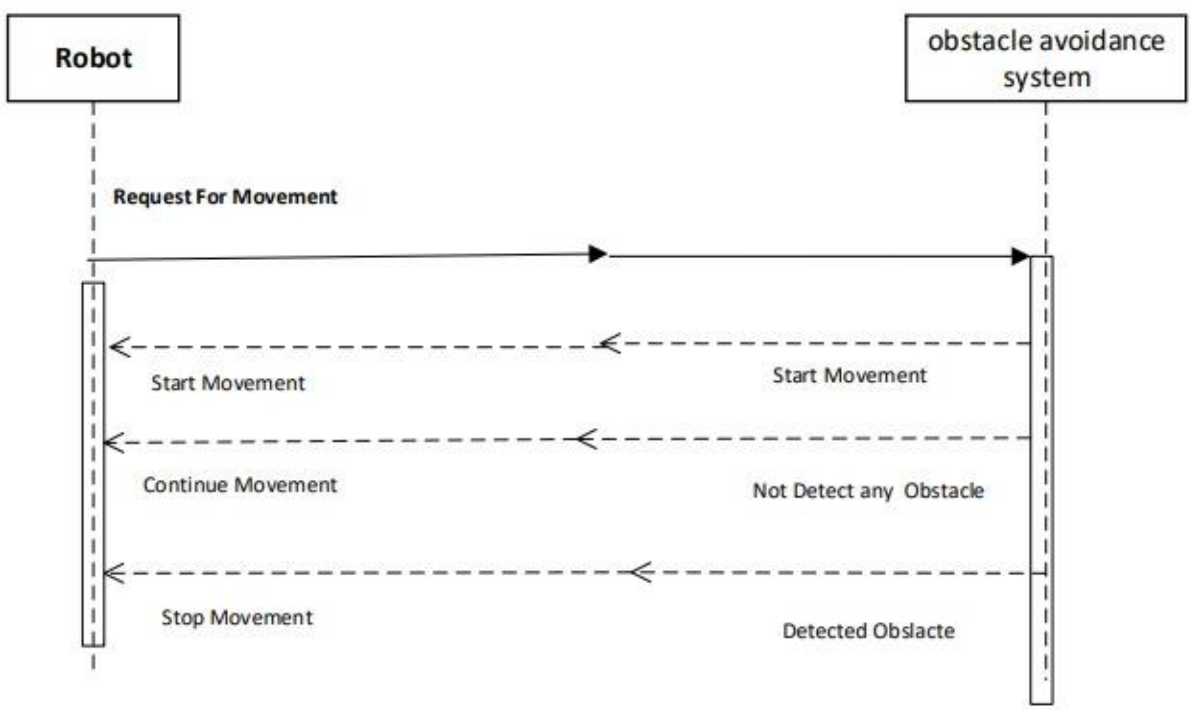


Figure 15:Sequence Diagram of Obstacle Avoidance

3.5.2 State Transition Diagram

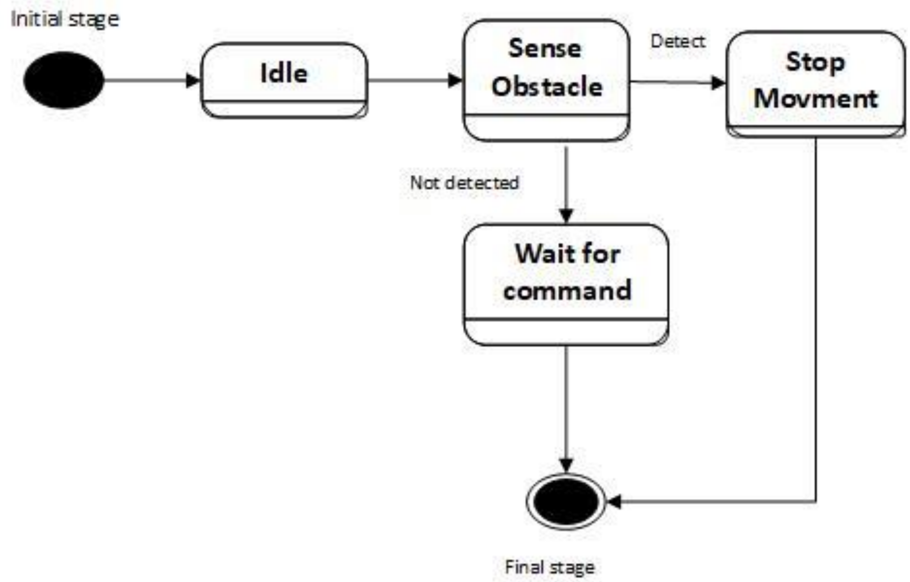


Figure 16: State Transition Diagram of Obstacle Detection

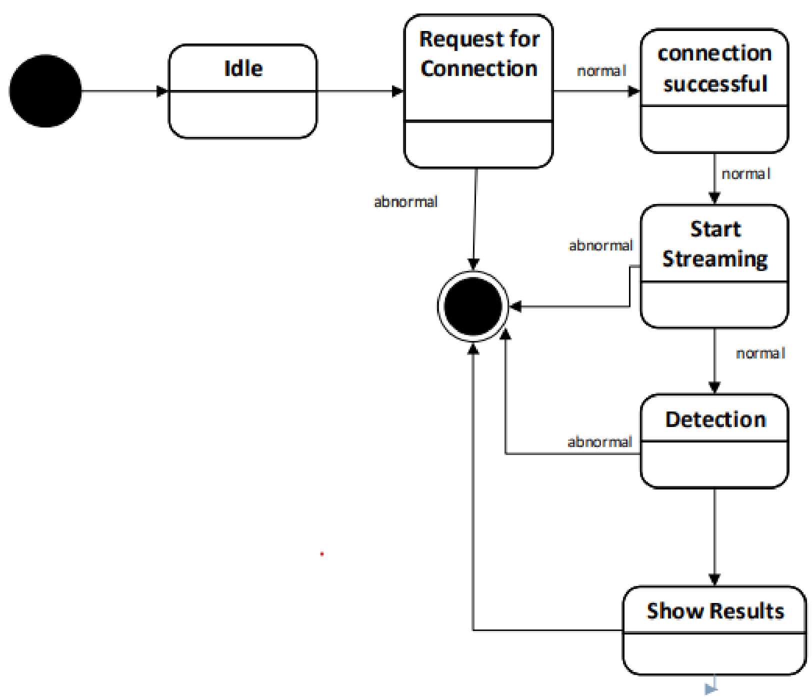


Figure 17: State Transition Diagram of Weed Detection

3.5.3 Circuit Diagram

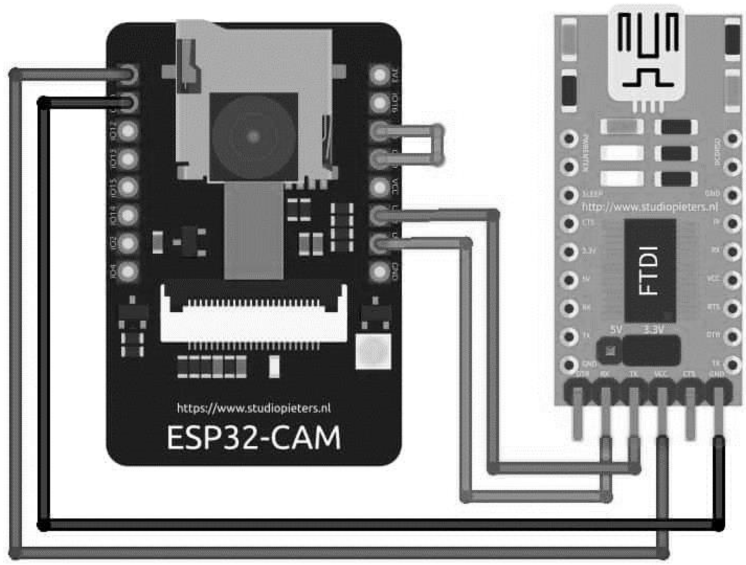


Figure 18: Circuit Diagram of Weed Detector

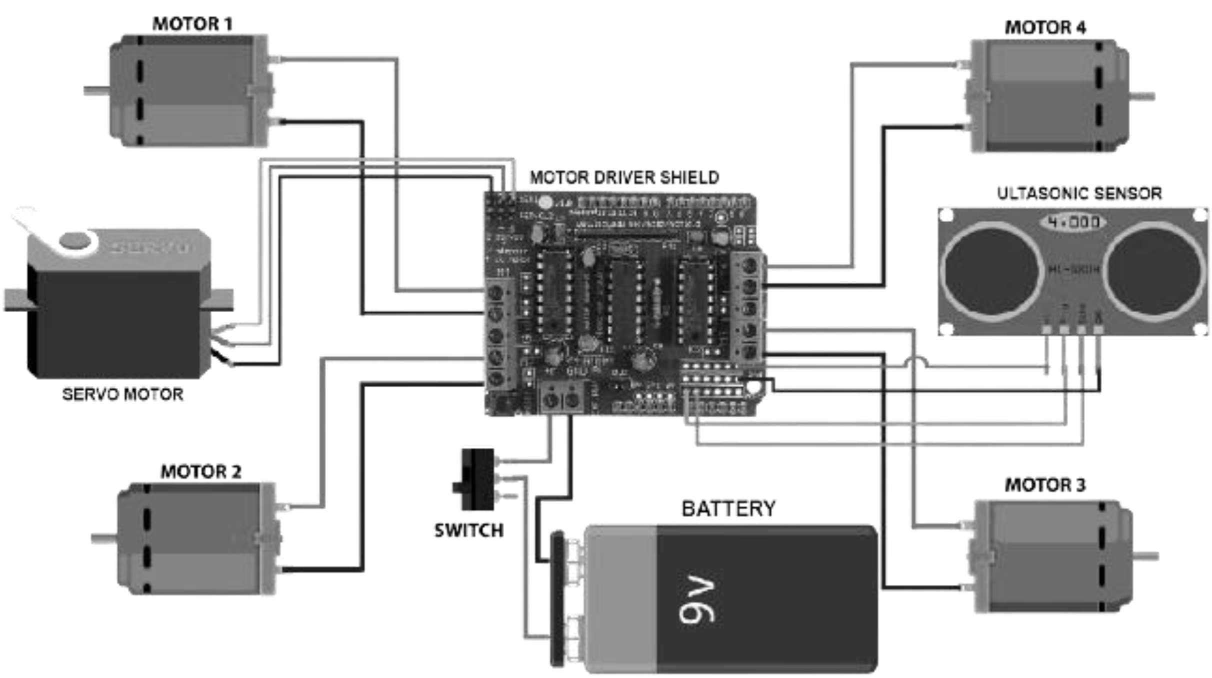


Figure 19: Circuit Diagram of Obstacle Avoidance

3.5.4 Block Diagram

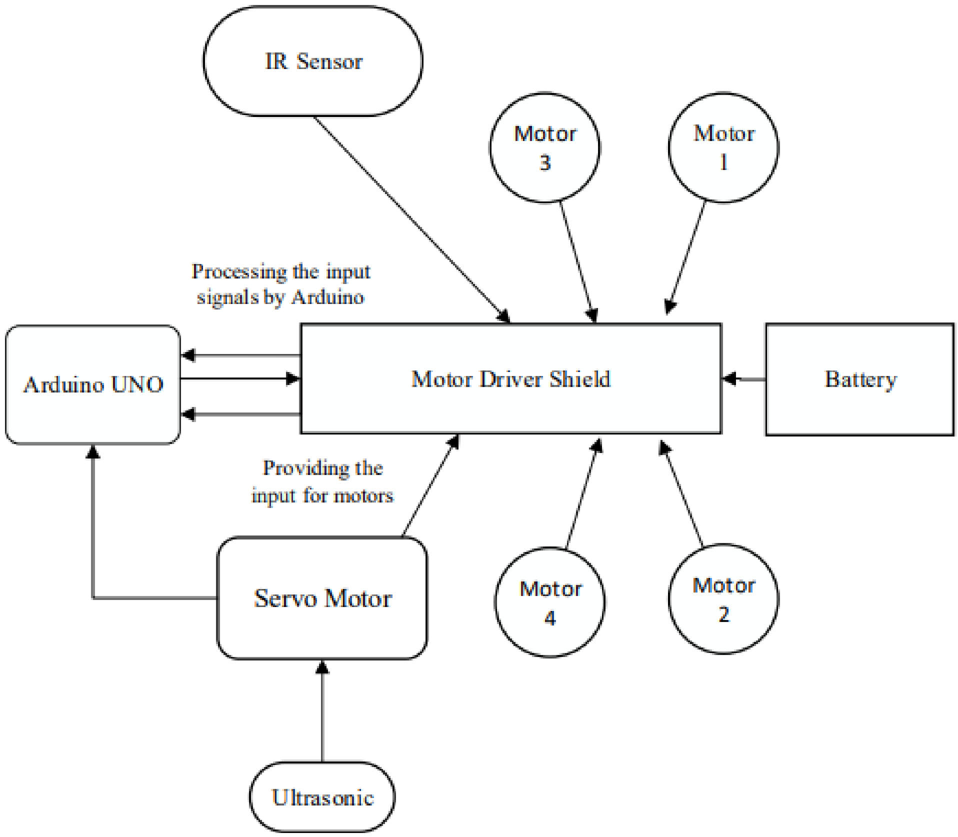


Figure 20: Block Diagram of Obstacle Avoidance

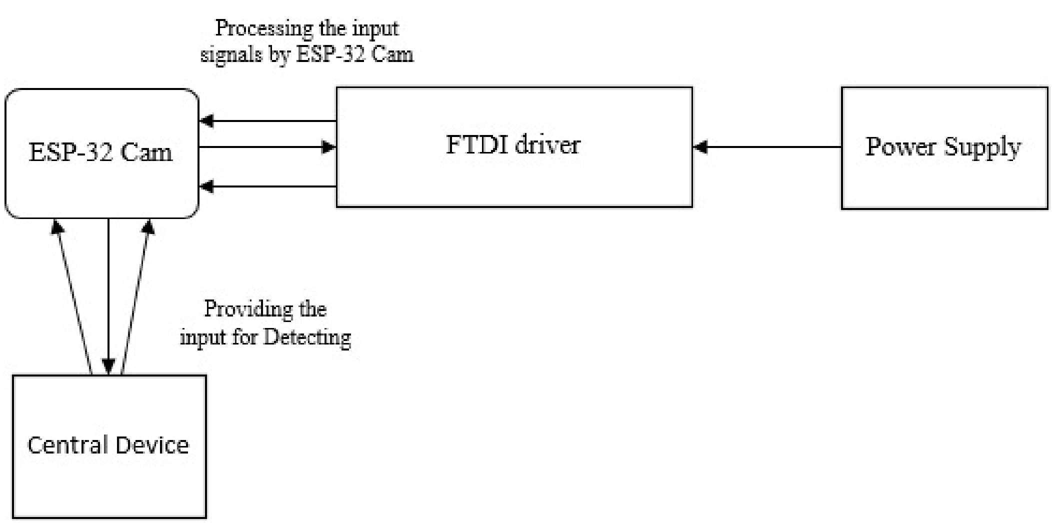


Figure 21:Block Diagram of Weed Detection

Conclusion

In concluding this project, " Weed Whisper: Smart Vehicle with Obstacle Avoidance and Weed Detection" we reflect on the transformative journey it has been. This endeavor was not merely a technical exploration but a collaborative effort that transcended individual contributions. It represents the synthesis of ideas, expertise, and relentless dedication from a diverse group of individuals.

The adaptive obstacle avoidance system, precision weed detection capabilities, and the integration of cutting-edge technologies have rendered this smart vehicle a testament to innovation. The modular architecture and user-friendly interface exemplify a commitment to not only technical excellence but also practical usability and accessibility.

As we step back and contemplate the challenges overcome and lessons learned, we recognize the iterative nature of progress. The agile development methodologies, the emphasis on continuous improvement, and the resilience in the face of challenges have been defining aspects of this journey.

Looking ahead, the knowledge gained from this project serves as a foundation for future endeavors and a testament to the capabilities of collaborative innovation. The interdisciplinary nature of this project reinforces the importance of diverse perspectives, fostering an environment where creativity thrives.

In conclusion, " Weed Whisper: Smart Vehicle with Obstacle Avoidance and Weed Detection " stands not only as a technical achievement but as a symbol of what can be accomplished through dedication, collaboration, and a shared vision. As we embark on new challenges, this project remains a source of inspiration and a reminder of the limitless potential that emerges when minds come together in pursuit of a common goal.

Reference

[1] S. L. M. M. T. B. J. F. Faiza Tabassum, "Obstacle Avoiding Robot," *Global Journal of Researches in Engineering: H Robotics & Nano-Tech*, vol. 17, no. 1, pp. 18-24, 2017.

[2] D. &. P. P. &. R. M. Umakirthika, " Internet of Things in Vehicle Safety – Obstacle Detection and Alert System. International Journal Of Engineering And Computer Science," *International Journal Of Engineering And Computer Science*, vol. 7, pp. 23540-23551, 2018.

[3] Grand View Research, Inc., "Smart Transportation Market to be Worth $285.12 Billion by 2030: Grand View Research, Inc.," Grand View Research, Inc., 6 Feb 2023. [Online]. Available: https://www.prnewswire.com/news-releases/smart-transportation-market-to-be-worth-285-12-billion-by-2030-grand-view-research-inc-301739205.html. [Accessed Tuesday March 2023].

[4] Chavan, Y.V., Chavan, P.Y., Nyayanit, A. et al. Obstacle detection and avoidance for automated vehicle: a review. J Opt 50, 46–54 (2021). https://doi.org/10.1007/s12596-020-00676-

[5] Nhawkar, Yogiraj & Bhikule, Abhishek & Khot, Sanika & Mankame, Shubham & Baste, Shrikant. (2021). Obstacle Avoidance and Voice Control Unit for Autonomous Car. 10.13140/RG.2.2.24039.16803.