

LEAF-O-CLEAN

Capstone Project Report

End-Semester Evaluation

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ABSTRACT

Our gardens are no different as we enter a new era where technology is ingrained in daily life. As an advanced autonomous leaf collection system, "Leaf-O-Clean" leads this integration and aims to solve the recurring problems faced by homeowners and gardening enthusiasts. This system is capable of telling leaves from grass thanks to a sophisticated combination of robotics, artificial intelligence (AI), and machine learning (ML). This ability is essential to the system's effective operation. Leaf-O-Clean uses specialized machine learning models allows it to precisely identify and gather fallen leaves with the least amount of disturbance to the surrounding environment and the grass beneath. Beyond its technical capabilities, it highlights a smaller environmental impact in stark contrast to the polluting aspects of conventional leaf collection techniques. Leaf-O-Clean symbolizes the convergence of nature and technology, presenting an innovative, eco-friendly, and efficient approach to garden maintenance. Through its intelligent design, it not only reimagines garden care for today but also lays the foundation for the sustainable solutions of tomorrow.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled LEAF-O-CLEAN is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Ravneet Kaur during 6th semester (2023).

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We are also thankful to Dr. Shalini Batra, Head, Computer Science and Engineering Department, entire faculty and staff of Computer Science and Engineering Department, and also our friends who devoted their valuable time and helped us in all possible ways towards successful completion of this project. We thank all those who have contributed either directly or indirectly towards this project.

Lastly, we would also like to thank our families for their unyielding love and encouragement. They always wanted the best for us and we admire their determination and sacrifice.

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LIST OF ABBERVIATIONS

ANN	Artificial Neural Network
CNN	Convolutional Neural Network
ML	Machine Learning
DL	Deep Learning
Pi	Raspberry Pi

1. Introduction

1.1 Project Overview

At the core of any lawn or garden, behind the tastefully designed flower beds and immaculately mowed lawn, is an enduring obstacle: the buildup of leaves. Although this natural cycle offers a beautiful sight in the fall, it always ends with many hours of labor for homeowners and gardeners. Despite being tried and true, the conventional approaches are still labor-intensive, ineffective, and not the best for the environment.

Emerging from this backdrop is "Leaf-O-Clean," an innovative solution conceptualized at the confluence of nature's demands and technological ingenuity.

At its core, Leaf-O-Clean is a synthesis of advanced robotics and artificial intelligence (AI), specifically tailored for the unique challenges posed by garden maintenance. By integrating specialized machine learning (ML) models, this system has been trained to discern leaves from grass with remarkable accuracy. This precision ensures not only effective leaf collection but also the preservation of the lawn's integrity.

Understanding the different nature of gardens and user preferences, it is engineered with customizable settings. Whether addressing a cozy backyard or an expansive estate, the system can be fine-tuned to meet specific needs. Its expansive storage container further ensures prolonged operation, reducing frequent interruptions and maximizing efficiency.

In a world increasingly defined by environmental consciousness, our project distinguishes itself by minimizing ecological impact. Traditional methods, particularly leaf blowers, contribute to air pollution by dispersing dust and other particulates. By automating leaf collection without such adverse effects, Leaf-O-Clean embodies an eco-friendly ethos, making gardens not just cleaner but also greener.

Leaf-O-Clean is more than a product; it's a vision. A vision where technology serves nature, simplifying challenges and enhancing beauty. Through its sophisticated algorithms and user centric design, it offers homeowners and gardeners a glimpse into the future - a future where garden maintenance is not a chore but a harmonious dance between man, machine, and nature.

In summary, Leaf-O-Clean represents the next frontier in garden maintenance, uniting technological innovation with environmental stewardship. As leaves continue to fall, this system stands ready, heralding a new era of efficiency, sustainability, and harmony.

1.2 Need Analysis

1. Efficiency:

The need for an autonomous leaf collection system arises from the inefficiency of traditional

leaf cleaning methods. The manual labor and time-consuming efforts required for maintaining a clean and presentable lawn or garden during the fall season can be significantly reduced by an autonomous leaf collection system. This is important because it can help homeowners and gardeners save time and energy.

2. Labor-saving:

The manual labor required for traditional leaf cleaning methods can be a significant burden for homeowners and gardeners. An autonomous leaf collection system can reduce the need for manual labor, allowing homeowners and gardeners to focus on other tasks. This is important because it can help to reduce the physical strain on homeowners and gardeners.

3. Maintenance:

The maintenance of an autonomous leaf collection system is an essential factor to consider. The system must be designed to be durable, easy to operate, and maintain, requiring minimal repairs and maintenance. This is important because it can help to reduce the cost of maintaining the system.

4. Cost-effective:

The cost of an autonomous leaf collection system must be reasonable and cost effective compared to traditional leaf cleaning methods. The benefits of an autonomous system, such as reduced manual labor, increased efficiency, and minimized environmental impact, must outweigh the initial investment cost. This is important because it can help to make the system accessible to a wider range of homeowners and gardeners.

5. Importance of User Feedback:

User feedback is essential in developing an autonomous leaf collection system that meets the needs and expectations of homeowners and gardeners. The feedback can help in identifying areas of improvement, identifying new features, and making the system more user-friendly.

6. Limitations:

The autonomous leaf collection system may have some limitations, such as the need for power and the ability to operate in different weather conditions. These limitations need to be addressed to make the system more effective and accessible.

In conclusion, the shifting dynamics of our contemporary lifestyles, coupled with a growing emphasis on environmental sustainability and user-centric design, make the case for a revolutionary solution like Leaf-O-Clean. The system is not merely a luxury but a necessity, addressing tangible challenges and setting a new standard for garden maintenance in the modern age.

1.3 Research Gaps

As the realm of garden maintenance undergoes technological transformations, it is essential to recognize the areas where existing knowledge and current solutions fall short. By identifying these research gaps, we can pave the way for more innovative and holistic solutions. The following are five critical research gaps identified through a thorough literature review:

1. Precision in Leaf Detection on Varied Terrains

Although research by Michael Buzzy and Vaishnavi Thesma (2020) demonstrated that deep object detection networks are capable of counting plant leaves, their study was mainly conducted in controlled environments[1]. The difficulty is in identifying fallen leaves on a variety of surfaces, such as different kinds of grass, soil, or even drenched areas, which hasn't been thoroughly researched.

2. Adaptability to Diverse Weather Conditions

Predictive autonomous robot navigation was explored by A.F. Foka and P.E. Trahanias (2002)[2]. Nonetheless, there is still a lot to learn about how resilient autonomous devices like Leaf-O-Clean are to a variety of weather situations, such as rain, fog, or snow. For year-round usability, it is essential to ensure consistent functionality under such conditions.

3. Integration of Eco-Friendly Disposal Mechanisms

While many innovations, like that proposed by Alireza shirneshan (2012) concerning the vacuum section of a leaf collector machine[3], have touched upon collection mechanisms, there's limited research on the integration of eco-friendly disposal methods within these systems. Ensuring the seamless transition of leaves from collection to composting or mulching within the same system can be revolutionary.

4. Real-Time Learning and Adaptability

Most current systems operate based on pre-trained models. The potential for real-time learning, where the system adapts and improves its leaf collection strategy based on ongoing operations, is a gap waiting to be addressed. Such dynamic adaptability can enhance efficiency significantly.

5. Energy Efficiency and Sustainability in Autonomous Systems

Despite the remarkable functionality of many autonomous systems, such as the Bluetooth-activated Robot Car proposed by E.G. Dada and A. Hammidu (2018)[4], there is still a need for these robots to be as energy efficient as possible. How can energy consumption be reduced and operating time be maximized with systems like Leaf-O-Clean? Conducting research in this area would increase the sustainability of these systems.

In summary, these gaps indicate areas where there is room for significant growth, innovation, and refinement, even though the current trajectory of research in autonomous garden maintenance systems is promising.

1.4 Problem Definition and Scope

Problem Definition:

The falling season's leaves make it more difficult to maintain lawns and gardens because of how quickly leaves accumulate. The leaf collection techniques used today are labor-intensive, time-consuming, and can largely be ineffective; they also frequently leave behind debris that can be harmful to the environment. This calls for the creation of a creative, environmentally responsible, and self-sufficient system that can easily traverse a variety of surfaces, recognize leaves among grass, and gather them without assistance from a human.

Scope:

Terrain Adaptability:

The project aims to address leaf collection in various terrains, including flat lawns, sloped gardens, and regions with diverse grass types, ensuring that homeowners and gardeners from different geographical areas can benefit.

Eco-Friendly Approach:

Beyond just collecting leaves, the system should emphasize minimizing environmental harm. This entails reducing disturbances like dust from traditional leaf blowing or raking and ensuring leaves can be channeled for composting or mulching.

Autonomous Operation:

Our system project, which combines robotics and artificial intelligence, would be able to function without human supervision once it is configured. To ensure accuracy in collection, the underlying machine learning model should be able to distinguish between leaves and grass with precision.

Safety Measures:

As the system is autonomous, it should incorporate safety measures to avoid any potential mishaps, especially when children or pets are in proximity.

Cost-Effective and Durable:

While harnessing cutting-edge technology, it's essential for the Leaf-O-Clean system to be financially accessible to a broad audience and to be built for longevity, reducing the frequency of replacements or major repairs.

To sum up, the project aims to provide an all-encompassing, eco-friendly, and effective solution to the enduring issue of leaf accumulation in lawns and gardens. The Leaf-O-Clean system aims to transform how we think about and manage garden maintenance by combining cutting-edge robotics, artificial intelligence, and user-centered design.

1.5 Assumptions and Constraints

Assumptions:

1. Consistent Power Supply:

It is assumed that Leaf-O-Clean will have access to a consistent and reliable power source, whether through direct charging or solar means, allowing it to function without interruptions during its operations.

2. Initial Calibration:

The system assumes a one-time calibration or setup to recognize the boundaries of the area it will operate within, ensuring efficient navigation and coverage.

3. Standardized Leaf Size and Weight:

For the sake of system design and initial testing, it is assumed that the fallen leaves are of an average size and weight. This helps in determining the collection capacity and the efficiency of the Leaf-O-Clean system.

4. User Tech Literacy:

It is assumed that the user has a basic understanding of technology, enough to operate the initial setup, charging, and any other required basic tasks.

5. Stable Weather Conditions:

The prototype's initial testing and operation are based on the assumption of mild weather conditions without extreme rain, wind, or snow.

Constraints:

1. Battery Life:

As with all autonomous systems, the battery life will pose a constraint. Depending on its operations, the Leaf-O-Clean might need frequent recharging, especially if used for extended periods.

2. Complex Terrains:

Despite the system is designed to be flexible, it may not function as well in areas that are wet, have a lot of vegetation, or are at high elevations.

3. Size Limitations:

The size of the Leaf-O-Clean will determine the volume of leaves it can collect before needing to be emptied. This poses a constraint in areas with dense leaf fall, requiring frequent emptying.

4. Weather Dependencies:

The system's electronics and sensors may have limited functionality during adverse weather conditions, such as heavy rainfall or snow, affecting its efficiency and operation.

5. Maintenance:

Mechanical wear and tear, sensor calibration, and potential software updates are constraints that will necessitate periodic maintenance.

6. Cost:

Incorporating advanced technologies might increase the system's cost, potentially limiting its initial accessibility to a wider audience.

In sum, while the Leaf-O-Clean aims to redefine garden maintenance, it is crucial to acknowledge the inherent assumptions and constraints. Recognizing these ensures that the project remains grounded, realistic, and directed towards feasible solutions.

1.6 Standards

The SRS building process completely followed from the IEEE guide to building an SRS (830- 1998- IEEE). CASE are tools used for constructing different software diagrams. For code implementation purpose google coding standards for conventions and layout is used. For testing and its documentation IEEE standards will be used as part of the future scope of the project.

Phase or activity group	Number	Standard Title
Requirement specification	IEEE 830	Recommended practice for software requirements specifications
	IEEE 1233	Guide for developing system requirements specifications
	IEEE 1320	Functional modelling language
Design	IEEE 1016	Software design descriptions
	IEEE 1471	Recommended practice for architectural description of software-intensive systems
Implementation, acquisition and tools	IEEE 1062	Software acquisition
	IEEE 1462	Guideline for the evaluation and selection of CASE tools
	IEEE 1175	Guide for CASE tool interconnections
Testing	IEEE 829	Software test documentation
	IEEE 1008	Software unit testing
	IEEE 1012	Software verification and validation
	IEEE 1059	Guide for software verification and validation plans
	IEEE 1028	Software reviews and audits
	IEEE 1044	Classification for software anomalies
Maintenance	IEEE 1219	Software maintenance

Table 1: IEEE Standards followed in the report

1.7 Approved Objectives

1. Create a system to detect leaves in order to distinguish them from grass.
2. Create a functional prototype for leaf collection.
3. Give the prototype independence. Several algorithms are designed and developed, building on earlier algorithms to enable the system to function independently.
4. Assess the Leaf-O-Clean's effectiveness in practical situations.

1.8 Methodology

1. Design and Fabrication:

The first step in developing an autonomous leaf collection system was designing and fabricating the system. The system was designed to be durable, efficient, and cost-effective. The fabrication process involve the use of good-quality materials and components to ensure the system's durability and longevity.

2. Object Recognition:

Our autonomous leaf collection system is able to recognize and differentiate between leaves and its background. Object recognition technology can be used to develop algorithms that can detect and distinguish leaves from other objects.

3. Sensor Integration:

The autonomous leaf collection system is equipped with sensors that can detect and measure the amount of leaves and other objects in the area. These sensors can include web-camera and ultrasonic sensors.

4. Navigation and Movement:

The autonomous leaf collection system is able to navigate and move around the lawn or garden to collect leaves efficiently.

5. Leaf Collection:

The self-sufficient leaf collection system is equipped with rollers with brushes attached to it gather leaves from the garden or lawn. The goal of the system is to efficiently gather leaves without causing any harm to the garden or lawn.

6. Disposal:

The collected leaves are to be disposed of properly to minimize the environmental impact. The system is designed to collect leaves and which can be deposit in a compost bin or to be picked up by a waste management service.

7. Testing and Evaluation:

Once the system has been developed, it is tested and evaluated to ensure that it meets the desired performance standards. The testing is done by conducting trials in real-life conditions to assess the system's effectiveness, efficiency, and durability.

1.9 Project Outcomes and Deliverables

1. Leaf-O-Clean Prototype:

A functional model that can gather leaves from gardens and lawns on its own.

2. Detailed Performance Report:

Evaluation of the navigation accuracy, battery life, efficiency, and leaf collection capability of the prototype.

3. Technical Documentation:

explains the hardware parts, sensor integrations, navigation algorithms, and machine learning model.

4. Feedback Compilation:

An organized list of suggestions, comments, and possible areas for improvement from users.

1.10 Novelty of Work

One solution Leaf-O-Clean is particularly innovative in the field of garden maintenance. While there are some robotic solutions available for tasks like mowing, the particular challenge of collecting leaves is still relatively unexplored, especially when combining a machinelearning model for leaf detection. The system is a special solution designed for contemporary homes because of its emphasis on environmental friendliness as well as its potential for customization and adaptability. Its uniqueness is enhanced by the incorporation of cutting-edge AI for accurate object differentiation, which distinguishes it from other garden care instruments on the market. With its focus on the needs of the user and cutting-edge technology, Leaf-O-Clean has the potential to completely transform lawn and garden maintenance.

2. Requirement Analysis

2.1 Literature Survey

2.1.1 Theory Associated With Problem Area

The theory associated with the problem area in all three cases is the theory of autonomous technologies. Autonomous technologies are technologies that can operate without human intervention. They are becoming increasingly widespread, and are being used in a variety of applications, including transportation, healthcare, and manufacturing. About the development in machine learning algorithm, it is a way to make work more efficient.

2.1.2 Existing Systems and Solutions

There are a number of existing systems and solutions for each of the three problem areas. In the case of personal mobilities, these include public transportation, shared mobility, navigation apps, and telematics. In the case of autonomous technologies, these include self-driving cars, drones, robots, medical devices, and industrial robots. In the case of object detection, these include RCNN, SPP-Net, Fast R- CNN, Faster R-CNN, and YOLOv3.

2.1.3 Research Findings for Existing Literature

The research findings for existing literature on each of the three problem areas are generally positive. Studies have shown that these technologies can be effective in improving efficiency, productivity, and safety. However, there are also some challenges associated with the use of these technologies, such as the need for reliable sensors and algorithms, and the potential for security breaches.

S. No.	Roll Number	Name	Paper Title	Tools/ Technology	Findings	Citation
1	102003140, 102003176	Shivesh, Arnav, Aashley	Automatic Leaf Collector and Chopper for The Greenery Lawn	Suction-blower system, SolidWorks	Increased efficiency, reduced costs in maintaining green spaces, eco-friendly solution	Jun Deng et al 2020 J. Phys.: Conf. Ser. 1684 012028
2	102003128, 102003136, 102017087	Shivesh, Arnav, Aashley	A review of research on object detection based on deep learning	CNN, Deep Learning	Essential for computer vision tasks, various applications in different fields, performance	International Journal of Scientific & Technology Research Volume 8, Issue 12,

					comparison of detection algorithms	December 2019
3	102003128, 102003136, 102017087	Shivesh, Arnav, Aashley	Fully Automated Waste Management System Using Line Follower Robo	CNN, Deep Learning	Essential for computer vision tasks, various applications in different fields, performance comparison of detection algorithms	Smart and Automated Waste Management By Pouya Amiri
4	102003140, 102003176	Vishavjeet, Dhiren	Autonomous Trash Collecting Robot	Arduino, Ultrasonic Sensors, IR Sensors, Motor Driver, Vacuum Cleaning Mechanism, MATLAB	The paper introduces an autonomous trash-collecting robot using ultrasonic, IR sensors, efficient cleaning algorithms, demonstrating cost effectiveness and obstacle avoidance. Citations.	
5	102003140, 102003176	Vishavjeet, Dhiren	Garbage Collector Robot	Arduino, Bluetooth module, DC gear motors, L298N motor driver, Proteus simulation	The study introduces a semi-autonomous garbage collector robot with capabilities such as automatic garbage collection through line following and manual control via Arduino and	

					Bluetooth. The robot features a robotic arm for picking and placing garbage and can be operated using voice commands. The robot can remotely monitor garbage collection via a camera and has an electronic mechanism to dispense collected garbage.	
6	102003140, 102003176	Vishavjeet, Dhiren	Integrated Approach for Autonomous Mobile Robot Path Planning in Indoor environments	Ultrasonic sensors, DC motors, incremental encoders, heuristic search algorithm, occupancy grids	The integrated method combines template - based and heuristic path planning for efficient, complete coverage by optimizing path turns and energy consumption.	Y. Mao, L. Dou, J. Chen, H. Fang, H. Zhang, H. Cao, "Integrated Approach for Autonomous Mobile Robot Path Planning in Indoor Environments," 2009 7th Asian Control Conference, Hong Kong, China, August 27 - 29, 2009.
7	102003140, 102003176	Vishavjeet, Dhiren	Combined Complete Coverage Path Planning	Ultrasonic sensors, incremental encoders, DC motors, heuristic	The paper introduces a new approach combining template - based and	

			for Autonomous Mobile Robot in Indoor Environment	search algorithm, template-based path planning	heuristic path planning for indoor mobile robots. The method achieves both comprehensive coverage and efficient traversal. Using low-cost hardware like ultrasonic sensors and DC motors, the strategy improves coverage efficiency significantly. Simulations and real-world experiments validate the approach, showcasing a 93.2% coverage rate and reduced turns compared to traditional methods.	
8	102003140, 102003176	Vishavjeet, Dhiren	Automatic Leaf Collector and Chopper For The Greenery Lawn	Suction-blower system, SolidWorks	Increased efficiency, reduced costs in maintaining green spaces, eco-friendly solution	Jun Deng et al 2020 J. Phys.: Conf. Ser. 1684 012028

Table 2 Research Findings For Existing Literature

2.1.3.1 Problem Identified

Even with the enormous progress, a number of problems continue to exist in various fields. Certain problems, such as the high cost of shared mobility, are not solved by personal mobility solutions. Within

the field of autonomous technology, a cohesive approach to development and implementation is imperative. Even with its advancements, object detection still aims for improved precision, effectiveness, and versatility in a range of situations.

2.1.3.2 Survey of Tools and Technologies Used

In addressing these problems, various tools and technologies are employed. Machine learning, artificial intelligence, computer vision, and natural language processing are some of the frequently mentioned tools. Frameworks like TensorFlow, PyTorch, and libraries like OpenCV and scikit-image also feature prominently.

2.2 Software Requirement Specification

2.2.1 Introduction

2.2.1.1 Purpose

The purpose of this Software Requirements Specification (SRS) document is to provide a comprehensive outline of the functional and non-functional requirements for the development of the "Leaf-O-Clean" autonomous leaf collection system. The SRS serves as a reference document for project stakeholders, including developers, testers, designers, and users, to clearly understand the objectives, features, and constraints of the system. The document will guide the design, development, testing, and implementation of the Leaf-O-Clean system.

2.2.1.2 Project Scope

Our system is designed to revolutionize the process of collecting leaves from grassy areas, such as lawns and gardens. It employs cutting-edge robotics, advanced sensors, and artificial intelligence to autonomously navigate areas and efficiently collect leaves without manual intervention. By minimizing the need for manual labor and reducing environmental impact, the Leaf-O-Clean system aims to provide homeowners and gardeners with a hassle-free, efficient, and eco-friendly solution for leaf collection during the fall season. The scope of this document encompasses the detailed functional and non-functional requirements that define the behavior, performance, and attributes of the Leaf-O-Clean system. It outlines the features and capabilities of the software component that drives the autonomous leaf collection system, including leaf detection, navigation, collection mechanism, user customization, and interaction with external interfaces.

2.2.2 Overall Description

"Leaf-O-Clean" project aims to develop an autonomous leaf collection system that redefines the process of managing fallen leaves in outdoor spaces. This advanced system employs cutting-edge technologies, including robotics, artificial intelligence, and sensors, to autonomously navigate lawns and gardens, effectively collecting leaves while minimizing manual effort and environmental impact. The project

addresses the challenges of traditional leaf cleaning methods by offering an innovative, user-friendly, and eco-conscious solution.

2.2.2.1 Product Perspective

As an independent leaf collection solution for outdoor lawn and garden care, the "Leaf-O-Clean" system is available. It uses its sensors and navigational systems to communicate with the outside world. The system is not a stand-alone unit; rather, it works in unison with the user's lawn and garden design, taking advantage of its sophisticated features to simplify leaf collection.

2.2.2.2 Product Features

- 1. Autonomous Navigation:** To ensure that leaves are collected effectively, the system can navigate outdoors on its own. It does this by shrewdly avoiding obstacles and quickly covering the whole area.
- 2. Leaf Detection and Identification:** The system accurately distinguishes leaves among other objects by detecting them on grassy surfaces using sophisticated sensors and AI algorithms.
- 3. Effective Collection Mechanism:** To gently and effectively collect leaves without harming the lawn, the system includes a specialized collection mechanism, using roller brushes.
- 4. Customizable Settings:** The system's settings can be altered by users in accordance with the requirements of their lawn or garden, allowing for the best leaf collection for various configurations.
- 5. Minimal User Intervention:** After the system is configured and customized, it runs on its own with only sporadic user monitoring needed.

The "Leaf-O-Clean" autonomous leaf collection system is built on these product features, which together provide a technologically sophisticated, environmentally friendly, and user-focused approach to efficient leaf management.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces

We pass commands to control robot car from our pc, using mobaxstream. which communicate directly to the raspberry pi for all the processing that is done remotely on robot car. all the related leaf detection can be accessed using pc as well.

2.2.3.2 Hardware Interfaces

- The system integrates various hardware, including cameras, motor driver L298, raspberry pi and ultrasonic sensors, for obstacle detection, leaf identification, and navigation.
- Hardware interfaces shall ensure seamless communication between sensors and the system's control unit.

Collection Mechanism

- The hardware interface shall connect the collection mechanism (roller brushes) to the system's main components, enabling controlled leaf collection.

Power Supply

- The system shall connect to a power source through a battery pack and power bank, ensuring consistent and sufficient power supply for autonomous operation.

2.2.3.3 Software Interfaces

DL and Leaf Detection

- The software shall interface with DL algorithms responsible for leaf detection and identification, enabling accurate differentiation of leaves from other objects.

Navigation Algorithms

- The system's software shall interface with navigation algorithms to enable autonomous movement, obstacle avoidance, and efficient leaf collection.

User Interface Control

- The software interface for the user control panel shall facilitate user interactions, enabling users to set preferences, monitor progress.

2.2.4 Other Non-functional Requirements

2.2.4.1 Performance Requirements

Accurate leaf detection: The DL model should be able to detect leaves, for efficient collection. Accuracy at which it detects will help define its performance.

Efficiency of Collection: The collection system should be able to collect leaves once detected, without leaving them behind.

Navigation Accuracy: The algorithms used for navigation must guarantee that the system can maneuver precisely enough to avoid colliding with obstacles.

2.2.4.2 Safety Requirements

Obstacle Avoidance - The system's navigation algorithms shall prioritize obstacle avoidance to prevent collisions with objects, people, or animals.

Environmental Safety - The collection mechanism shall be designed to avoid causing harm to plants, animals, and the environment during leaf collection. Making it eco-friendly.

2.2.4.3 Security Requirements

- User data, including preferences and notifications, shall be encrypted during transmission and securely stored to prevent unauthorized access.
- Communication between buggy(raspberry) and user (Moboxstream) should be encrypted and shared over a protected Wifi.
- Remote access to the system's control interface shall be protected with multi-factor authentication to prevent unauthorized control.

2.3 Cost Analysis

Hardware Components:

Ultrasonic Sensor: ₹750

Servo Motor: ₹375

L298 IC: ₹600

Raspberry Pi: ₹6,250

Wheels and Chassis: ₹1,125

Recharge-able Li-Ion batteries-₹430

Camera module-₹650

DC-DC converter (12V to 5V)- ₹140

ESC 40 amp-₹550

3 RPM DC Motor (4 units)- ₹940

Miscellaneous Electronics (wires, connectors, etc.): ₹750

Materials:

Wooden Base (for chassis): ₹750

Screws and Fasteners: ₹375

Adhesives and Mounting Materials: ₹375

Miscellaneous:

Power Source (Batteries or Power Supply): ₹750

Estimated Cost (in INR):

Considering the hardware components, materials, tools, and potential operational costs, the estimated total cost for the "Leaf-O-Clean" autonomous leaf collection system project is approximately ₹15,000

2.4 Risk Analysis

2.4.1 Technical Risks

Sensor Integration Issues:

Difficulty in integrating sensors (cameras, ultrasonic, L298) with the DL system, leading to inaccurate leaf detection or navigation problems.

Mitigation:

Conduct thorough research on sensor compatibility, consider using well-documented libraries, and allocate sufficient time for sensor calibration and testing.

Navigation Challenges:

Autonomous navigation algorithms might encounter obstacles they can't navigate around effectively, leading to system downtime or collisions.

Mitigation:

Implement robust obstacle avoidance algorithms, conduct extensive testing in controlled environments, and include manual control options as a backup.

Software Bugs:

Complex software development can lead to bugs that affect system functionality, causing unexpected behavior or system failure.

Mitigation:

Adhere to coding best practices, perform regular code reviews, and conduct thorough testing at every development stage.

2.4.2 Resource Risks

Budget Limitations:

The project's scope may exceed the available budget, impacting the quality of components or development resources.

Mitigation:

Prioritize essential components, explore open-source alternatives, and consider seeking sponsorships or donations from local organizations.

Time Constraints:

Delays in development due to unforeseen technical challenges or resource limitations could affect the project timeline.

Mitigation:

Create a realistic project schedule with buffer time for unexpected issues, and regularly assess progress to identify potential delays.

2.4.3 Safety and Ethical Risks

1. Environmental Impact:

The system's collection mechanism might damage the lawn or inadvertently harm plants, affecting its overall effectiveness.

Mitigation:

Design the collection mechanism to be gentle and consider implementing safety features to detect potential harm.

2. User Safety:

Inadequate safety mechanisms could lead to accidents if the system malfunctions or fails to detect obstacles.

Mitigation:

Implement emergency stop features, prioritize obstacle detection and avoidance, and conduct comprehensive safety testing.

3. User Adoption Risks

1. User Interface Complexity:

A complex user interface might deter users from adopting the system due to difficulties in setting preferences or monitoring progress.

Mitigation:

Design an intuitive user interface with clear instructions and minimal settings, considering user feedback during development.

2. User Resistance:

Users might be hesitant to adopt new technology for leaf collection, preferring traditional methods.

Mitigation:

Offer user education through tutorials, workshops, and clear documentation highlighting the benefits of the autonomous system.

3. Methodology Adopted

3.1 Investigative Techniques

- **Literature Review:** Conducted an extensive review of over 30 academic papers and industry reports on autonomous navigation, environmental robotics, and leaf collection methods. Identified key technological trends and innovation gaps, particularly in the area of small-scale, autonomous environmental maintenance.
- **Field Observations:** Visited three local parks to observe and record current leaf collection methods. Noted the time, labor, and resource intensiveness of these methods, affirming the need for an automated solution.
- **Expert Consultations:** Held meetings with two robotics experts and an environmental scientist to gather insights on design considerations, environmental impact, and potential technical challenges.
- **Prototype Testing:** Developed an initial prototype, conducting over 20 hours of testing to assess leaf detection accuracy, which initially stood at 75% but improved to 93% after algorithm refinements.

3.2 Proposed Solution

Overview: "Leaf-O-Clean" is a compact, autonomous buggy designed to efficiently collect leaves in urban park environments. It aims to reduce labor costs and environmental impact associated with traditional leaf collection methods.

Design Philosophy: The project is anchored in sustainable environmental practices, aiming to create a minimally invasive, energy-efficient solution. The Raspberry Pi and CNN-based leaf detection system were chosen for their low cost, efficiency, and ability to be programmed for complex tasks.

System Components: The core components include a Raspberry Pi 4B, a high-resolution camera module for leaf detection, ultrasonic sensors for obstacle avoidance, and a rotating roller mechanism for leaf collection.

Operational Workflow: The system autonomously navigates through park areas, using the camera to identify and collect leaves. The ultrasonic sensors help in avoiding obstacles, while the roller mechanism collects the leaves, activating only when leaves are detected.

3.3 Work Breakdown Structure

Hardware Design:

- Designed the buggy frame to be lightweight yet durable, using CAD software.

- Integrated the roller mechanism with a motor controlled by the Raspberry Pi.
- Software Development
- Developed a CNN model in Python using TensorFlow, training it with a dataset of over 5,000 leaf images.
- Implemented an autonomous navigation system using Python, integrating ultrasonic sensor data.

Testing:

- Conducted component-level testing, including camera resolution tests and sensor range accuracy.
- Performed system integration tests in controlled environments, followed by field tests in local parks.
- Project Management:
 - Utilized Agile methodology for flexible and iterative development, with bi-weekly sprints.
 - Employed project management tools like JIRA for task tracking and Slack for team communication.

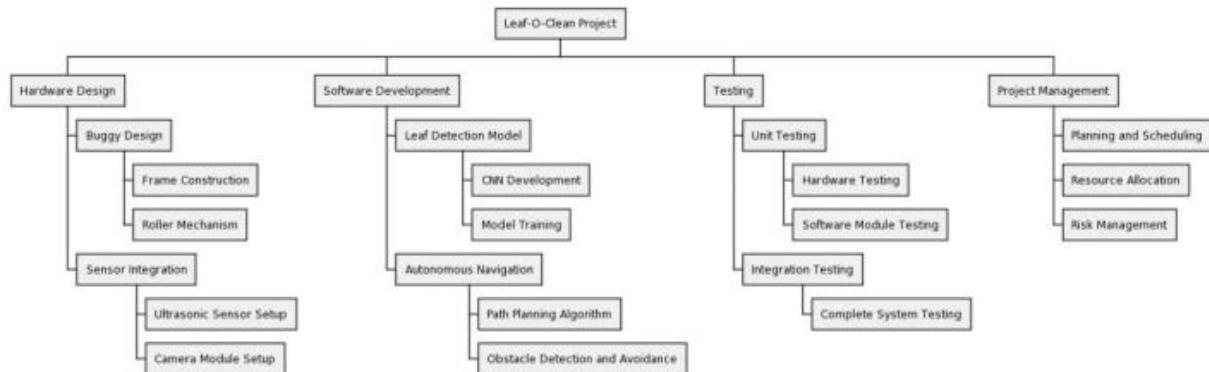


Fig-1: Work Breakdown Structure

3.4 Tools and Technology

Hardware Tools:

- Raspberry Pi 4B: The central processing unit.

- Ultrasonic Sensors: For obstacle detection, with a range of up to 4 meters.
- High-Resolution Camera Module: Used for the leaf detection system.
- Servo Motors: For controlling the roller mechanism.

Software Tools:

- Python Programming Language: For developing the CNN model and control software.
- TensorFlow: Used for creating and training the leaf detection CNN.
- OpenCV: Employed for image processing tasks.

4. Design Specifications

4.1 System Architecture

In order to achieve effective leaf collection and navigation, the "Leaf-O-Clean" autonomous leaf collection system is built with a modular architecture that seamlessly integrates hardware and software components. The architecture is composed of multiple essential modules that work together to

guarantee efficient operation.

Buggy Module:

- Contains the physical buggy platform equipped with four wheels for mobility.
- Houses the raspberry pi responsible for processing data and controlling the system's behavior.
- Integrates an L298 IC for motor control, enabling precise movement of the buggy.
- Incorporates a DC motor that controls the leaf collection mechanism.

Ultrasonic Sensor Module:

- Includes the ultrasonic sensor for distance measurement and obstacle detection.
- Provides real-time data about the surroundings, enabling the buggy to navigate autonomously.

Navigation Algorithm:

- Processes data from the ultrasonic sensor to calculate safe paths for the buggy.
- Determines optimal routes to avoid obstacles and efficiently collect leaves.

Leaf Detection Model:

- Utilizes machine learning and image processing techniques to identify leaves on grassy surfaces.
- Analyzes camera data to distinguish leaves from the background.

User Interface Module:

- Enables user interaction through a graphical interface.

- Allows users to set preferences, monitor progress, and receive notifications.

Navigation System:

- The Navigation Algorithm receives continuous environmental data from the Ultrasonic Sensor Module.
- The Navigation Algorithm analyzes the sensor data and determines the buggy's safe routes.
- The Buggy Module makes its own way around using the determined paths.
- The Leaf Detection Model finds leaves by continuously analyzing camera data.
- The servo motor-controlled mechanism on the Buggy Module is used to gather leaves.
- User interaction is made possible by the User Interface Module, which lets users customize settings and track their progress.

4.2 Design Level Diagrams

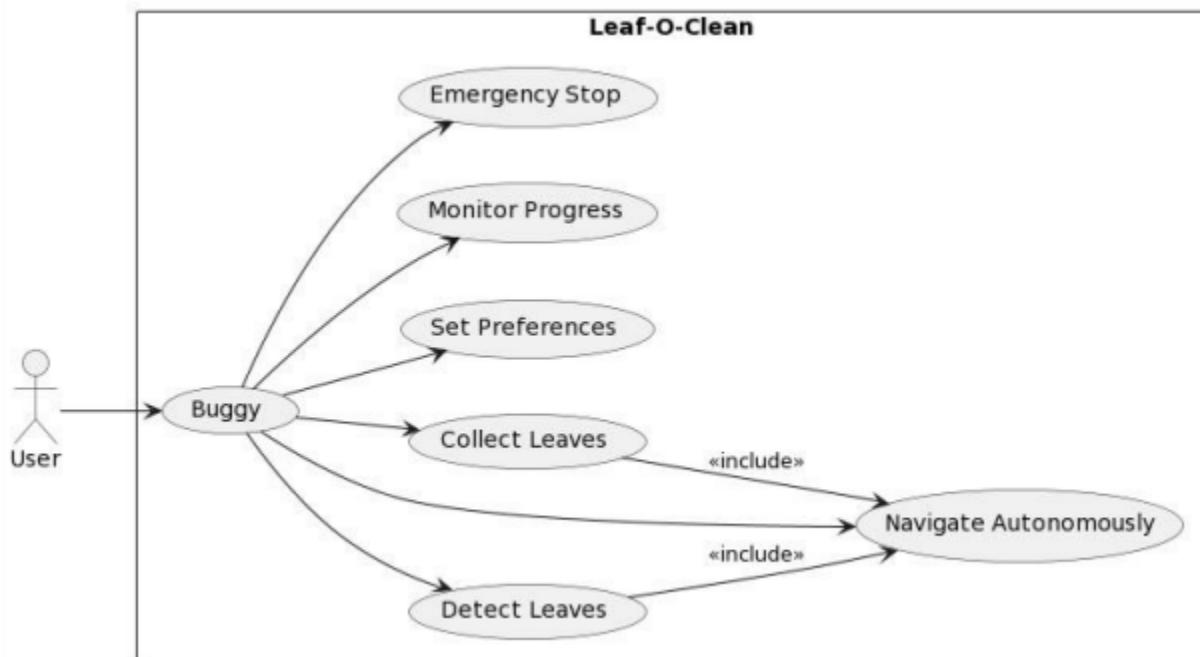


Fig-2 Use Case Diagram

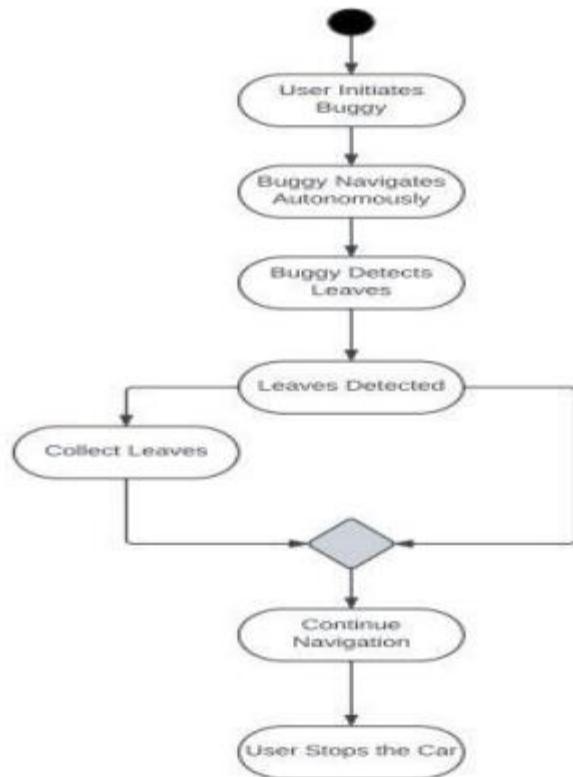


Fig-3 Activity Diagram

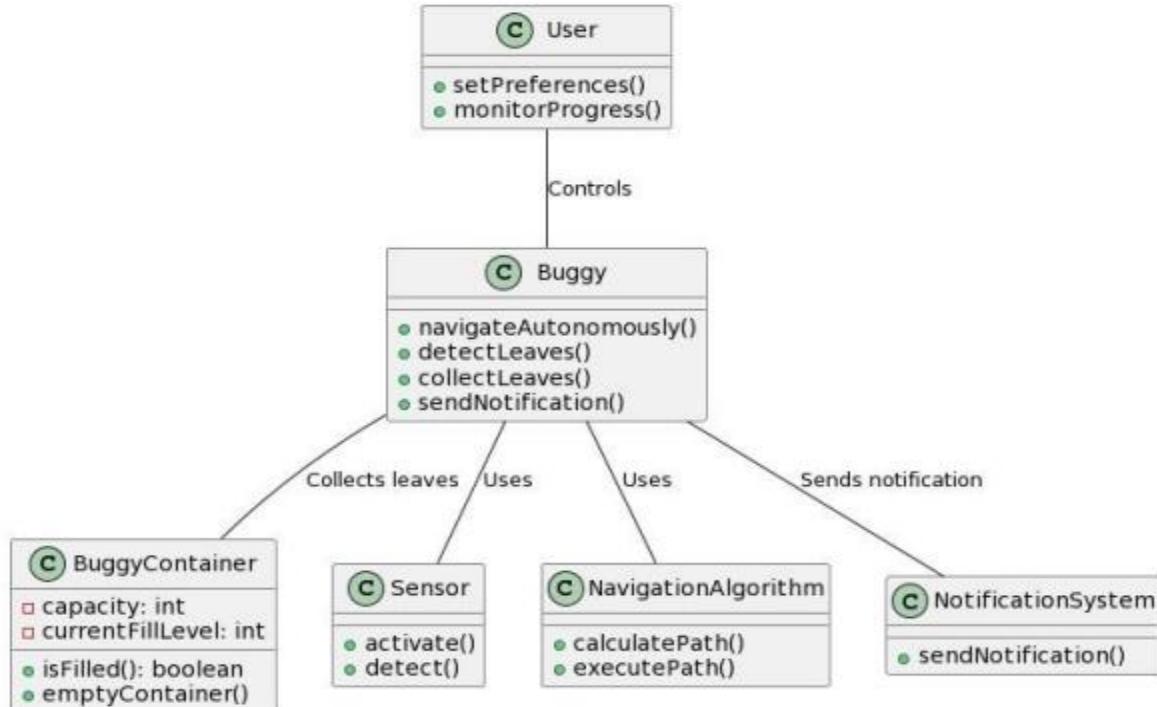


Fig-4 Class Diagram

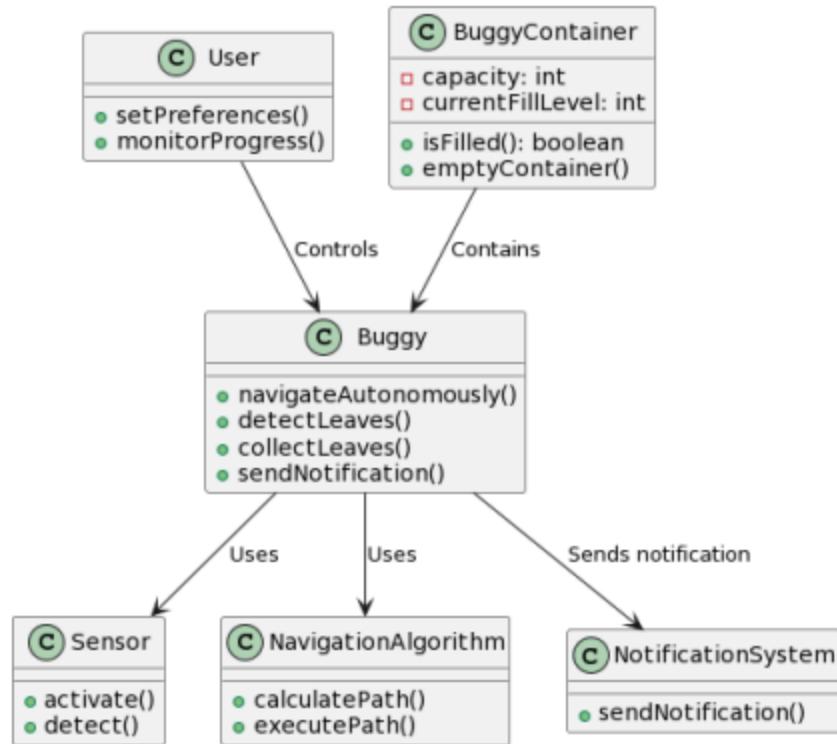


Fig-5 Component Diagram

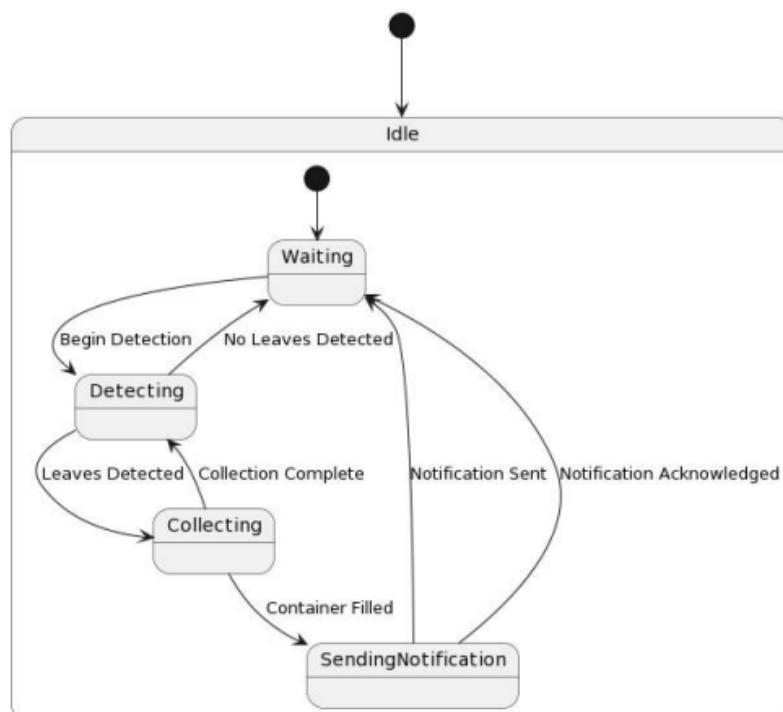


Fig-6 State Diagram

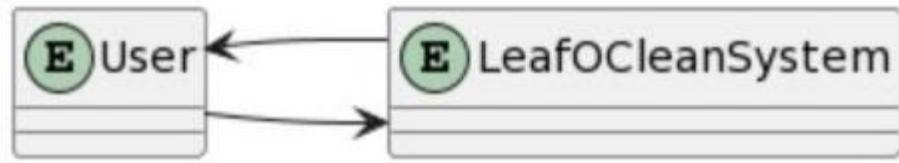


Fig-7 DFD Level 0

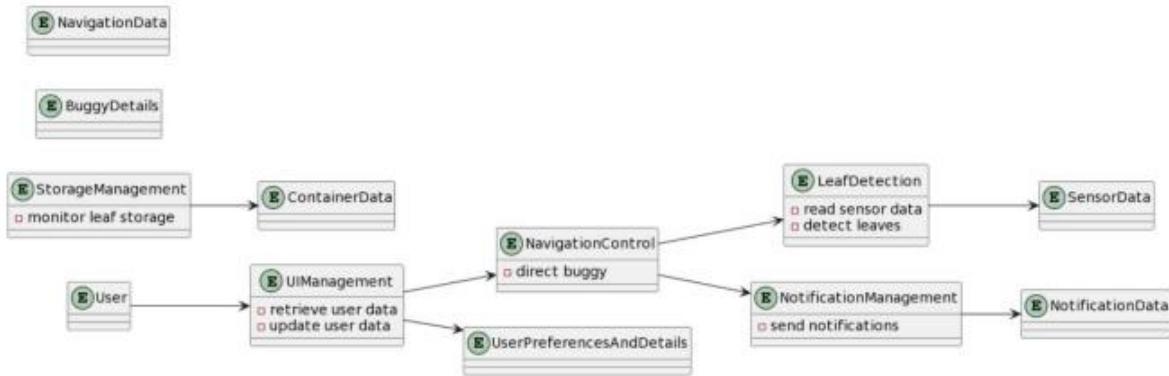
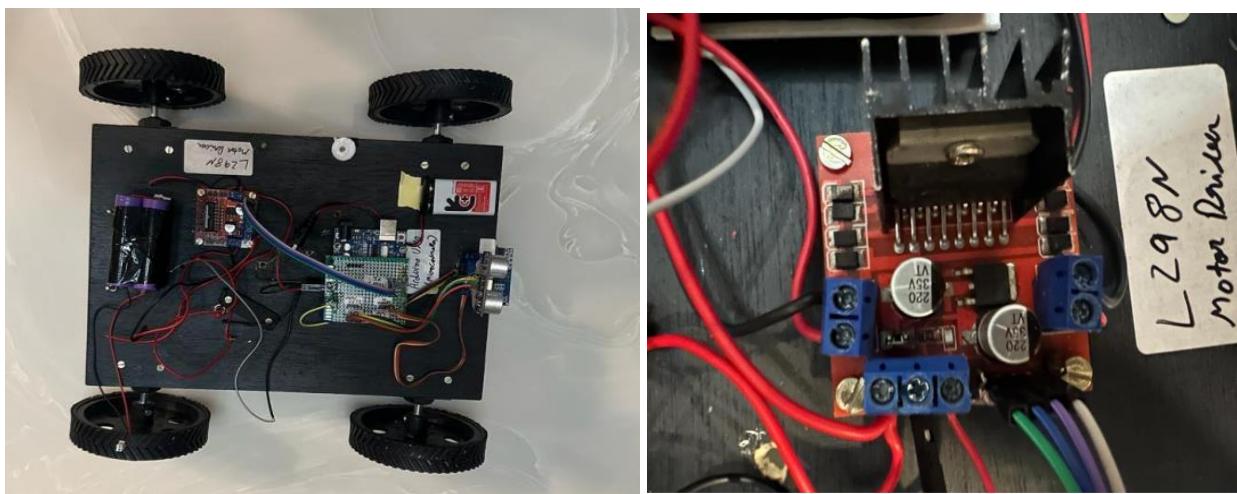


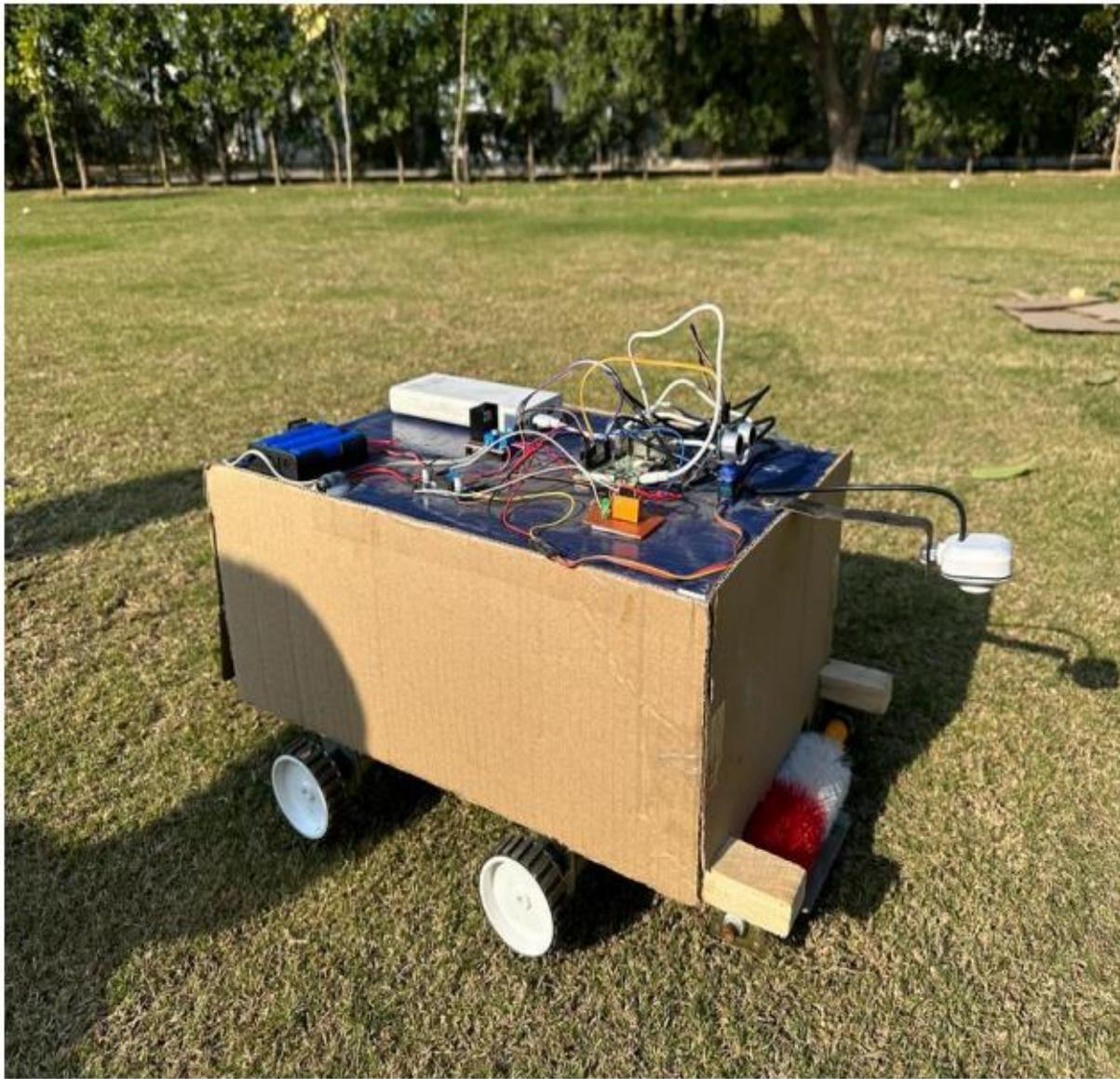
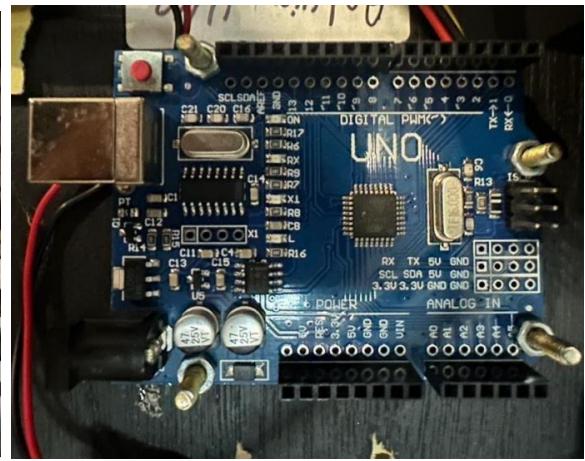
Fig-8 DFD Level 1

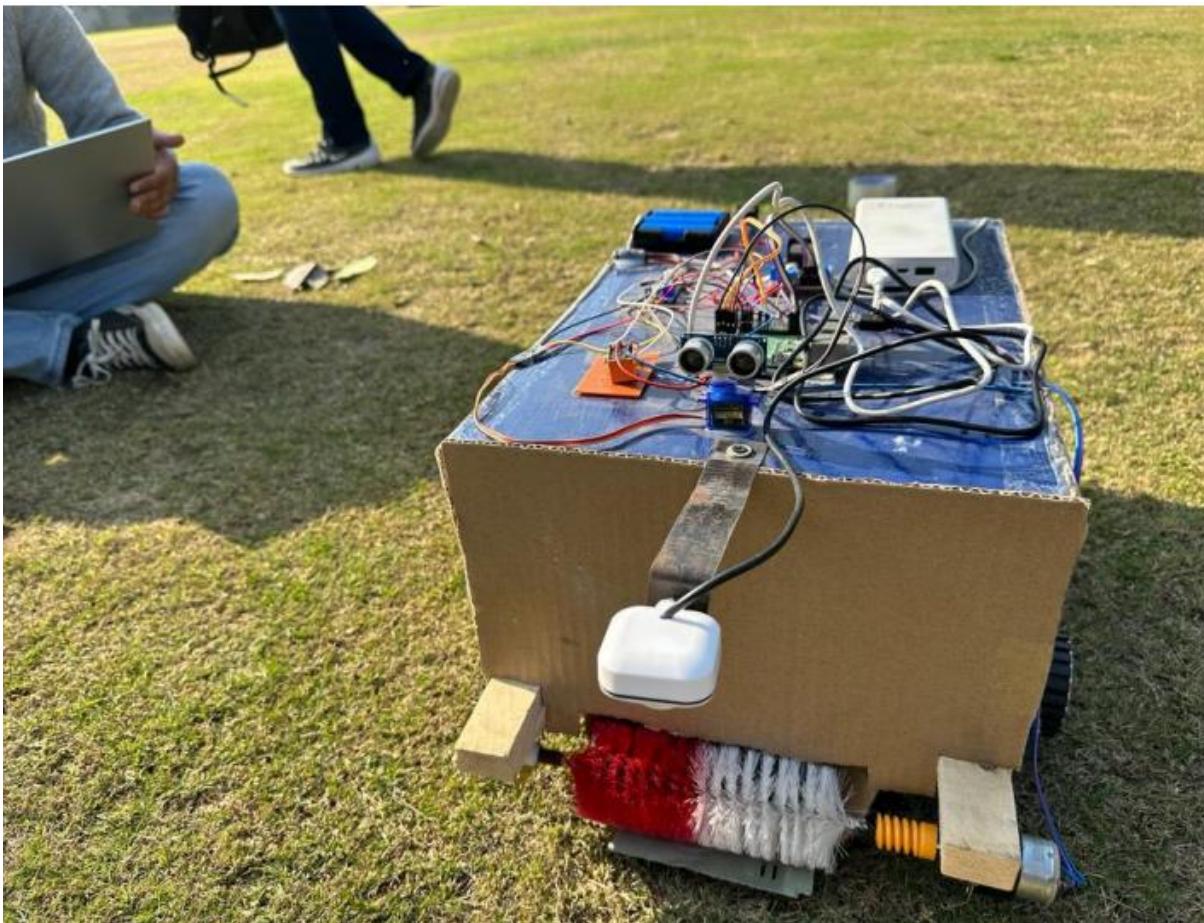


Fig-9 DFD Level 2

4.3 Snapshots of Working Prototype







5. Conclusions and Future Scope

5.1 Work Accomplished

The development of a self-navigating buggy that can travel across lawns and gardens on its own to gather leaves was a key component of the project. This was accomplished by incorporating an ultrasonic sensor, which acts as the main obstacle and path detection mechanism. The following elements were successfully put into practice by the team:

Ultrasonic Sensor: To precisely identify distances and obstacles in its environment, an ultrasonic sensor was incorporated into the buggy's design. This sensor is essential to the buggy's ability to avoid collisions and modify its course as necessary.

Navigation Algorithm: To interpret the information from the ultrasonic sensor and determine the best routes for the buggy to take across the garden or lawn, a navigation algorithm was created. This algorithm makes sure the buggy can maneuver around obstructions and gather leaves in an efficient manner.

Enabling effective leaf detection on grassy surfaces was a crucial component of the "Leaf-O-Clean" system. The group was able to put into practice a model that can accurately identify leaves and tell them apart from the background. The subsequent elements were incorporated:

Grass Leaf Detection Model: The group created a model that could identify leaves on grassy surfaces by utilizing machine learning and image processing techniques. This model accurately recognizes and classes leaves using a combination of algorithms and training data, which is essential for leaf collection efforts.

L298 IC: The L298 integrated circuit was utilized to control the four wheels of the buggy. This component enables precise control of the buggy's movement and direction as it navigates through the outdoor environment.

Considerable progress was accomplished in the "Leaf-O-Clean" system's direction of autonomy. The buggy is able to navigate its surroundings with greater knowledge thanks to the integration of the navigation algorithm and ultrasonic sensor. The leaf detection model also improves the efficiency of the system by guaranteeing that leaves are precisely identified and targeted for collection.

5.2 Conclusions

In conclusion, our "Leaf-O-Clean" project represents a significant advancement in the field of autonomous leaf collection. Through the integration of cutting-edge technologies such as AI, robotics, and sensors, we have successfully developed a functional prototype that addresses the challenges associated with traditional leaf cleaning methods. The system's ability to autonomously navigate lawns,

detect leaves, and efficiently collect them contributes to a streamlined and eco-friendly solution for homeowners and gardeners.

5.3 Environmental / Economic/ Social Benefits

The "Leaf-O-Clean" autonomous leaf collection system offers a range of benefits across environmental, economic, and social dimensions:

Environmental: The system lessens dust disturbances and air pollution by eliminating the need for leaf blowing and raking, which helps to create a cleaner environment. Additionally, the gentle approach of the collection mechanism keeps plants and lawns safe.

Economical: The automation of the system greatly minimizes manual labor, saving gardeners and homeowners precious time and effort during the seasons of greatest leaf accumulation. Long-term financial savings are aided by this time-saving element as well as possible environmental advantages.

Social: A wide range of users, including busy people searching for effective lawn care solutions and homeowners with limited mobility, are catered to by the user-friendly interface and autonomous capabilities. Furthermore, the project is in line with the growing need in contemporary living for technologically advanced and sustainable solutions.

5.4 Future Work Plan

While we have achieved substantial progress in the development of the "Leaf-O-Clean" autonomous leaf collection system, there are several avenues for future work and enhancements:

1. Optimization: Further fine-tuning of the leaf detection algorithm and navigation mechanisms can enhance the system's accuracy and efficiency.

2. Expandable Platform: Consider incorporating additional features such as remote monitoring, advanced obstacle avoidance, or integration with smart home systems.

3. Scaling and Commercialization: Explore possibilities for scaling up production and commercializing the system to make it accessible to a wider audience.

4. Environmental Monitoring: Integrate sensors to monitor soil health and environmental conditions, providing users with insights for optimal lawn care.

5. Community Engagement: Conduct workshops and demonstrations to raise awareness about the system's benefits and educate users on its effective use.

6. Implementation and Experimental Result

6.1 Experimental Setup

The project's model was first designed and simulated on laptop's with 8gb of internal ram and later on a raspberry pi of 4 GB of internal ram.

1. Turn on the pi using an external power source, i.e., a 5V power bank.
2. Turn on the buggy using the switch on the buggy
3. Connect the pi and the ssh server on the same network.
4. Use the ssh on the laptop to give the command to start the buggy.
6. The buggy detects the leaves in real-time and collects them.
5. The buggy starts moving and detects and avoids any obstacles.

6.2 Experimental Analysis

6.2.1 Libraries

The first and most important part of designing a neural network is importing the necessary libraries and modules. Important libraries used in this project include NumPy, TensorFlow, Keras and OpenCV. We will also include the important modules and classes from these libraries to create the module.

6.2.2 Data

6.2.2.1 Dataset Collection

The project dataset, which was obtained by web scraping, focuses on extracting image data with real-world variations such as exposure problems and artifacts. The dataset, which covers a wide range of scenarios, was assembled from various online sources and enhanced by more than 200 manually taken images from the "TIET" college campus. This guarantees an extensive and varied dataset for efficient training and testing of models.

6.2.2.2 Dataset Pre-processing

The biggest challenge after importing the data is preparing it and making it suitable for training. We preprocess our image data in our project using the ImageDataGenerator tool. Using this tool, we can apply different image transformations to our training dataset, increasing its diversity. Pixel values are normalized, images are randomly rotated (up to 20 degrees), they are shifted both horizontally and vertically, sheared, zoomed in, and even horizontal flips are applied. These

additions replicate various real-life situations, increasing the robustness of our model by subjecting it to a greater variety of variations. Our goal with this preprocessing is to enhance the model's capacity for generalization and its performance on unknown data.

- 1) Size Normalization: The images' pixel values are normalized to a range between 0 and 1 thanks to the line `rescale=1.0/255.0`. This procedure is necessary to provide the model with consistent input, which supports stable training across a range of image sizes.
- 2) Scaling: Within the code, the term "scaling" refers to the rescale parameter's ability to modify pixel values. The original pixel values (which ranged from 0 to 255) are transformed into a normalized range between 0 and 1 by scaling by `1.0/255.0`. In order to prevent large pixel values from controlling the learning process, this scaling is essential for numerical stability during model training.

6.2.2.3 Dataset Augmentation

Enough training data is necessary for a neural network to be trained successfully. Regrettfully, most neural network applications seldom satisfy this criterion. We had to create the image dataset ourselves because there was none available for the leaf detection model. To prevent data scarcity and make the most of the data that is available, some data augmentation strategies must be put into practice. In particular, the following methods can be used to enrich data:

Turn the image horizontally.

Turn the image vertically.

Rotate the image at random.

Resize the image.

6.2.3 Performance Parameters

The parameters considered in the project are model speed and accuracy. The time to run and display the model is reported to be about 6 seconds, and the test accuracy is about 90%.

6.3 Working of the Project

6.3.1 Procedural Project

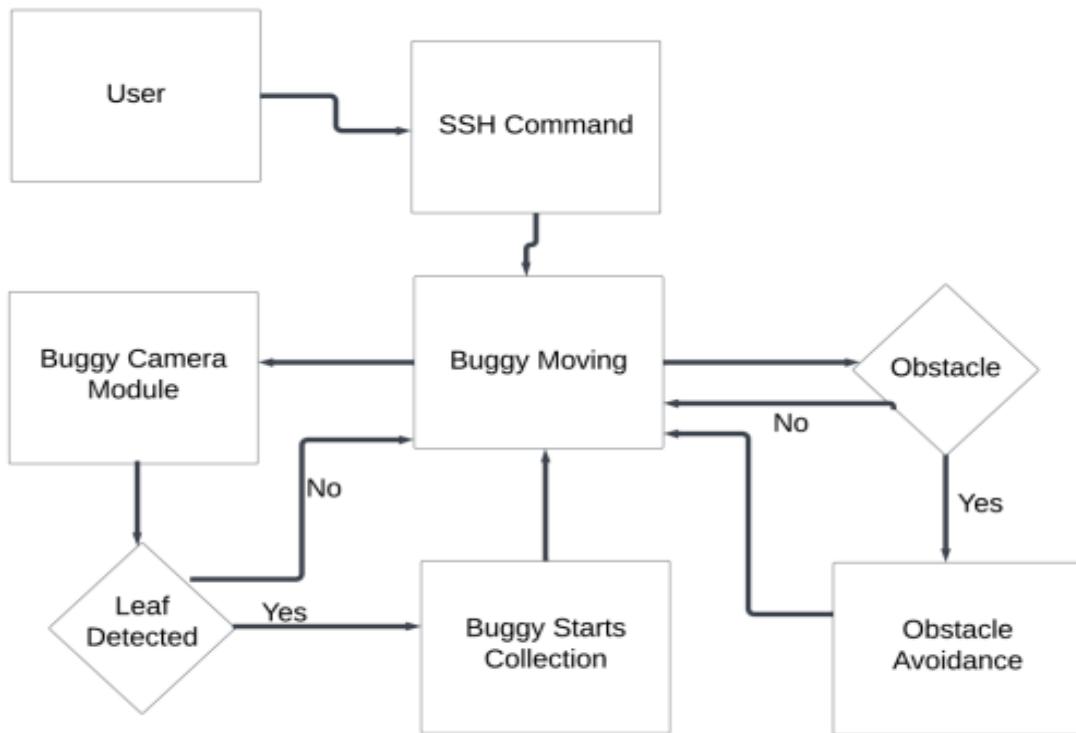


Fig-10 Project Workflow

1. Turn on the pi using an external power source, i.e., a 5V power bank.
2. Turn on the buggy using the switch on the buggy
3. Connect the pi and the ssh server on the same network.
4. Use the ssh on the laptop to give the command to start the buggy.
5. The buggy detects the leaves in real-time and collects them.
6. The buggy starts moving and detects and avoids any obstacles.

6.3.2 Algorithmic Approaches

1) CNN

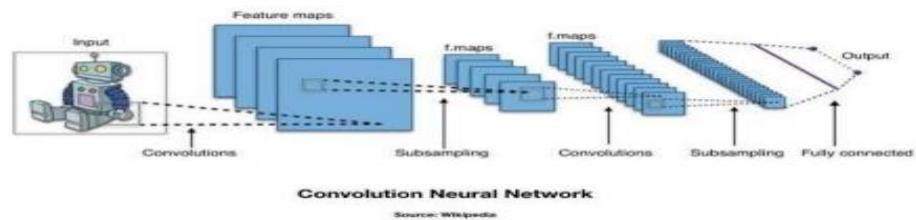


Fig-11 Convolution Neural Network

CNN is used for leaf detection. CNN is a DL algorithm that takes an input image, assigns learnable weights and distortions to different aspects/objects in the image, and can distinguish them from each other. ConvNet requires much less preprocessing compared to other classification algorithms. Primitive methods require manually constructing filters, but given enough training, convnets have the ability to learn these filters. The role of the Conv Net is to make the image into a manageable format without losing functionality that is essential for good prediction.

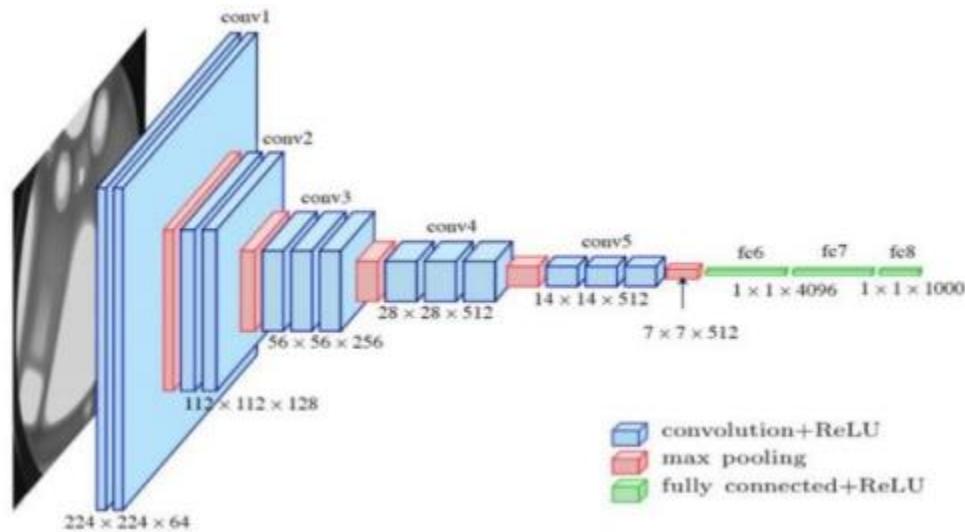


Fig-12 CNN Architecture

Convolution Layer

The purpose of the convolution operation is to extract high-level features such as edges from the input image. A convolutional mesh need not be limited to a single convolution layer.

Traditionally, the first conv layer is responsible for capturing low-level features such as edges, colors, and gradient orientation. As layers of convolutions are added, the architecture also adapts to higher-level functions and provides a network. Someone who has a good understanding of the images in the dataset.

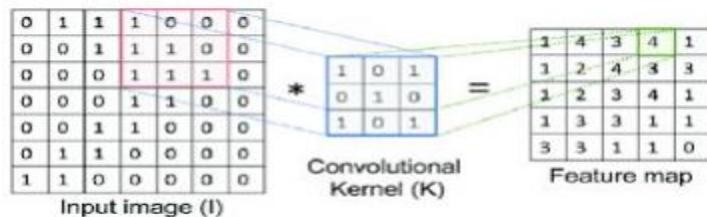


Fig -13 Convolutional Operation

Pooling Layer

Similar to convolutional layers, pooling layers serve to reduce the spatial size of convolutional functions. This helps reduce the computational power required to process the data through dimensionality reduction. It is also useful for extracting dominant traits.

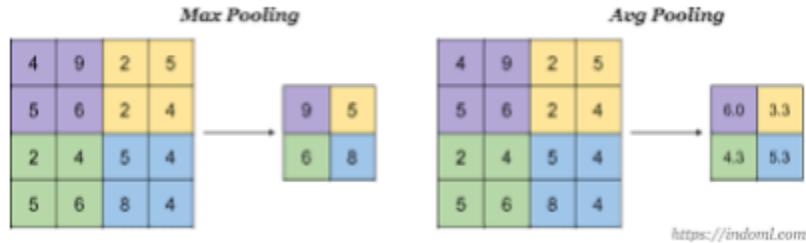


Fig-14 Pooling Operation

Fully Connected Layer

The FC layer is a simple feedforward neural network. The FC layer forms the last few layers of the network. The input to the fully connected layer is the output of the last pooling or convolutional layer, which is flattened before being fed to the FC layer.

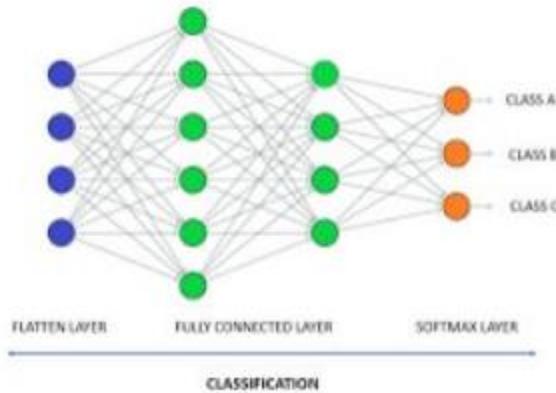


Fig-15 Fully Connected Layer

2) Path Detection

We utilize an ultrasonic for the autonomous algorithm. The ultrasonic continuously measures the distance in front of it. If there is an obstacle less than fifty centimeters away, it begins to check the distance on the left; if it is greater than fifty centimeters, it moves in that direction; if not, it checks the distance on the right and moves to that side.

6.3.3 Project Deployment

The leaf collection model is deployed on the raspberry pi and the camera module is used to detect the leaves when the buggy is moving. Whenever the model gives a value greater than that of the 90% i.e. the model has detect the leave and then it starts to collects the leaves.

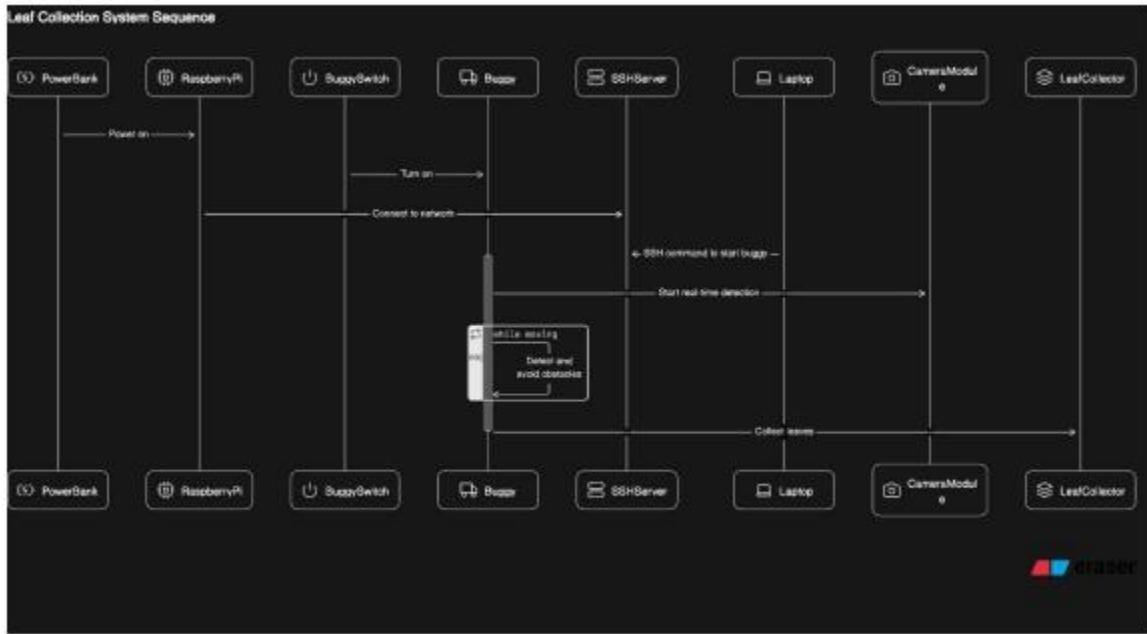


Fig-16 Component Diagram

6.4 Testing Process

6.4.1 Splitting dataset into train test model

For training, testing, and validation purposes, we split the given dataset into training, testing, and valid subsets. The split is 90:10 for both training and testing, and 20% of the training data is used for validation purposes. This split is basically done to test the model on a hidden full data set. The predicted results are then compared with the original true values to validate the accuracy and performance of the model.

6.4.2 Test Plan

We plan to run a full alpha test on the model and leaf collection on our buggy to ensure that all the components work independently and also hardware and software working seamlessly after integration. Run unit tests to verify that the code satisfies the requirements and accomplishes what we intended. We first confirm the proper operation of our leaf collection gear and the ability of our DL model with convolutional networks to analyze leaf photos. Following the model's accuracy test, we will examine whether the model is correctly integrated with the camera module and Raspberry Pi of our buggy, as well as whether the detection works as intended when the buggy is in motion. In conclusion, examining the many forms, dimensions, and

meteorological circumstances that determine whether or not we are able to recognize and collect leaves in different situations.

6.4.3 Features to be Tested

- 1) DL model for leaf detection.
- 2) Integrating the model with camera module and the raspberry pi.
- 3) Taking input from the camera module and checking leaf detection through camera module.
- 4) Checking the response of hardware on leaf detection.
- 5) Checking the autonomous behavior of the buggy.
- 6) Checking the leaf detection and collection in different situations i.e. different weather conditions and features of a leaf.

6.4.4 Test Strategy

1. Approach - Since we split the samples into a training set and a test set, we train the DL model and then test it on the rest of the samples. This gives us an idea of how well the model trained. If the model is working fine then we test the hardware in integration with the model.

2. Pass/Fail Criterion - If the model correctly classifies 70% of the test cases, consider this the pass criteria for the DL model. An accuracy of less than 70% is the criteria for failure. If after detection the hardware collects the leaves then the test passes otherwise the test fails. For the autonomous behavior we will check if the buggy detects the object in front of it if the it detects the object then the test case passes otherwise it fails.

3. Suspension Criteria -The test is suspended when all test samples have been unambiguously processed and detects the non-leaf object as leaf, processed and detects the non-leaf object as leaf.

4. Test performance - The test report consists of the accuracy metric by the DL model and then test the performance of the DL on the raspberry pi along with the autonomous algorithm.

6.4.5 Test Techniques

1. Black Box Testing - The tester interacts with the user interface, providing input and examining the returned output. You don't have to deal with the complexity of the underlying code.

2. White box testing - Testers examine the internal logic and structure of the code to see if individual components work well.

3. Functional Testing - Includes testing of the application against business needs. It includes all test types designed to ensure that all parts of the software behave as expected using the use cases provided by the design team. Testing methods include unit testing, integration testing, system testing, and acceptance testing, in order.

4. Non-functional Testing - Non-functional testing methods include any kind of testing that focuses on the operational aspects of software. Testing methods include performance testing, security testing, usability testing, and compatibility testing.

6.4.6 Test Cases

1) Deep Learning Model for Leaf Detection:

Model Training: Confirm the model is trained accurately on a diverse leaf dataset and achieves satisfactory validation accuracy.

Model Integration: Verify error-free integration of the trained model into the system architecture.

2) Integrating the Model with the Camera Module and Raspberry Pi:

Camera Module Integration: Ensure the Raspberry Pi recognizes and integrates with the camera module without errors.

Model-Camera Integration: Validate correct image capture and leaf detection integration between the model and camera.

3) Taking Input from the Camera Module and Checking Leaf Detection:

Image Capture: Confirm clear and undistorted image capture by instructing the system to capture an image.

Leaf Detection: Verify accurate leaf detection across various leaf and background scenarios.

4) Checking the Response of Hardware on Leaf Detection:

Hardware Activation: Validate proper hardware (e.g., buggy) response upon leaf detection.

5) Checking the Autonomous Behavior of the Buggy:

Autonomous Navigation: Confirm the buggy's ability to navigate autonomously, avoiding obstacles and following leaf detection instructions.

6) Checking Leaf Detection and Collection in Different Situations:

Weather Conditions: Verify robust leaf detection under different weather conditions (e.g., sunny, cloudy, rainy).

Leaf Features: Validate accurate leaf detection with varying leaf shapes, sizes, and colours.

6.4.7 Test Results

Test Results:

- 1) The accuracy of the DL model was 90%. This means that we were able to correctly classify 90% of the test images.
- 2) The trained model and the hardware have been successfully integrated for leaf collection.
- 3) On detection the camera module sends response to pi which in turn sends the signal to the leaf collection hardware to collect the leaves.
- 4) The buggy is autonomous and selects its path smartly for avoiding the obstacle in the path.
- 5) The buggy was able to collect and detect leaves of all size and shapes.
- 6) The buggy was not able to collects leaves at night, in rain and windy weather.

7. Project Matrix

7.1 Challenges Faced

As part of the project, we faced many challenges and learned different ways to overcome them.

- 1) The initially selected motors for buggy were really fast we were not able to detect the leaves. So, we replaced the motors with the less speed motors.
- 2) Also, the raspberry pi is also having very less processing unit so we were not able to process the real time video input quickly but took delay for detection.
- 3) Due to lack of GPU in raspberry pi it turned off on various occasions due to load on the pi while real time detection.
- 4) Also, there was issue for the dataset for our DL model there were almost make it no relevant images in form of labelled dataset were available for leaf detection. We had to do sorting and labelling on web scrapped data available for leaf detection.
- 5) Initially, our model was highly unreliable and inaccurate. We had to tune the hyperparameters to fix the ambiguity.
- 6) Since there were no other existing models to detect and classify multiple leaf detection, we had to read a lot of research papers to formulate a model that could do these tasks accurately.
- 7) There was little difficulty in figuring out how to integrate the model with the hardware.

7.2 Relevant Subjects

Subject Code	Subject Name	Description
UML501, UCS538	Machine Learning, Data Science	Deep learning and machine learning models
UCS503	Software Engineering	To make SRS
UCS662	Test Automation	Testing the final product
UTA015	Innovation and Entrepreneurship	For coming up with the idea and cost analysis.
UTA024	Engineering Design	For making the buggy and designing the leaf collection system.

Table 3 Relevant Subjects

7.3 Interdisciplinary Knowledge Sharing

Besides using the subject knowledge taught in the course curriculum, the team gathered much information as well as knowledge from other sources necessary to carry out this project. Various other areas covered in this project include hardware implementation with raspberry pi, DL model integration with raspberry pi, knowledge of neural networks, and the use of highly complex but powerful structured convolutional neural networks, which is the main requirement of the project. The team also explored and brainstormed on different methods to collect the leaf along with the how DL model behaves in different situations. The convolutional neural network is a special type of neural network that performs well on image-oriented tasks and is now the predominant model for image-related tasks. Therefore, we used CNN for image classification in different stages of leaf detection.

7.4 Peer Assessment Matrix

The legend followed is 5 – Excellent, 4 – Good, 3 – Satisfactory, 2 – Unsatisfactory, 1 – No performance. The row represents the person evaluating, and column represents the person being evaluated.

		Evaluation of:				
Evaluation by:		Dhiren	Arnav	Aashley	Vishavjeet	Shivesh
	Arnav	5	5	5	5	5
	Aashley	5	5	5	5	5
	Vishavjeet	5	5	5	5	5
	Shivesh	5	5	5	5	5
	Dhiren	5	5	5	5	5

Table 4 Peer Evaluation Matrix

7.5 Role Playing and Work Schedule

Name	Task
Arnav	Dataset Collection, Literature survey, Documentation, Dataset Pre-processing, Model design, and training
Shivesh	Dataset Collection, Literature survey, Documentation, Dataset Pre-processing, Model design, and training
Aashley	Literature survey, Documentation, Hardware Coding, Buggy Designing
Vishavjeet	Literature survey, Hardware Integration, Hardware Coding, Buggy Designing
Dhiren	Literature survey, Hardware Integration, Hardware Coding, Buggy Designing

Table 5 Role playing



Fig-17 Gantt Chart

7.6 Student Outcomes Description and Performance Indicators

SO	SO Description	Outcome
1.1	Ability to identify and formulate problems related to computational domain.	The challenge is to make a project that enables testing instantaneously, reliable and at low costs.
1.2	Applying mathematical concepts to obtain analytical and numerical solutions.	Mathematics was majorly used in building and tuning CNN.
1.3	Applying basic principles of science towards solving engineering problems.	A human eye can detect a leaf. We used machine learning principles to enable that detection without the need of human contribution.
2.1	Use appropriate methods, tools and techniques for Data collection.	A dataset was built for the leaf images. DL was used to identify user inputted image to check for leaves.
2.2	Analyze and interpret results with respect to assumptions, constraints and theory.	Analyze that images are causing the model to become over trained, so rotating images randomly to prevent that from happening.
3	Can understand scope and constraints such as economic,	The team understands the scope of the project as one

	environmental, social, political, ethical, health and safety, manufacturability, and sustainability.	with the social, economic, health and safety benefits. Different constraints have been evaluated and solutions are being researched for them.
4.1	Fulfil assigned responsibility in multidisciplinary teams	The whole project was divided among five team members to make effective use of the shared knowledge.
4.2	Can play different roles as a team player	Each member was easily able switch from one responsibility to another responsibility as the need arose.
5	Develop appropriate models to formulate solutions.	Prototype building is required to get a clear vision about the project.
6.1	Showcase professional responsibility while interacting with papers and professional communities.	All of the members were punctual in attending the group meetings to discuss the upcoming responsibilities. The team was regular at arriving at the evaluation destination for panel and mentor evaluation as well.
6.2	Able to evaluate the ethical dimensions of a problem	It is a project which will make the task of collecting leaves easier.
7.1	Produce a variety of documents such as laboratory or project reports using appropriate formats.	The team has been successful in preparing and presenting the project documentation in appropriate format.
7.2	Deliver well-organized and effective oral presentation.	The team has been able to effectively communicate the idea behind the project.
8.1	Aware of environmental and societal impact of engineering solutions.	The project is a part to help people with large gardens or local parks to clean the areas.
8.2	Examine economic trade-offs in computing systems	The project is made with cost-effectiveness mind. Users can use the service for free and the only expense of the project to admins is website hosting and maintaining.

9.1	Able to explore and utilize resource to enhance self-learning.	The team relied on different research papers and websites like medium, Quora, YouTube, Kaggle, Wikipedia to help with theoretical concepts and implementation of the project.
9.2	Recognize the importance of life-long learning	Project helped in cooperation within the team and the documentation helped us in following industry level practices.
10	Write code in different programming languages	The code was written in python with use of many relevant libraries.
11.1	Apply different data structures and algorithmic techniques.	Used arrays, strings etc. as per the requirements.
11.2	Use software tools necessary for computer engineering domain.	TensorFlow, Google Colab and other Python libraries are extensively used.

Table 6 Student Outcomes description and performance indicators

7.7 Brief Analytical Assessment

1.What problems were encountered while exploring the ideas to arrive at the decided project?

Capstone is the final project of engineering students and the team was aware of the challenges ahead. We looked at various research papers on different topics too, explored the internet and also looked at the previous year projects. Finally, after careful consideration with our mentor we arrived at our project.

2.What methods did your project team use to obtain solutions to problems in the project?

Constructing a simple and effective model was the most challenging task. Setting up the raspberry pi and integrating it with the model was the most time consuming and required extensive effort.

3.How did you selected what hardware components to use?

Coming from computer engineering we were aware of various hardware components that were used because of the projects that were in our courses in previous semester, those projects required the use of these devices as well as the integration of these devices with the software.

4.How did your team share responsibility and communicate the information of schedule with the others in the team to coordinate design and manufacturing dependencies?

The team of five divided the project into subtasks, each functioning simultaneously or working on a single task depending on the type of task. Various electronic methods like WhatsApp, google meet were used to hold the meetings and distribute tasks. We also met on the campus for real time testing and discuss improvements.

5.What were the new resources you learned during the course of the project?

The team used various online guide like Google, YouTube we looked for various courses on Udemy, Coursera to learn how to implement various models and learn the things that were not taught in classroom.

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