WATER SURFACE CLEANER

Capstone Project Report

MID SEMESTER EVALUATION

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ABSTRACT

The necessity for creative and long-lasting solutions to preserve pure water bodies has been brought to light by the growing concern over water contamination. The goal of this project is to build and create an autonomous robot that can clean water surfaces by effectively removing floating garbage. The robot incorporates multiple technologies, such as servo motors for precise movement, ultrasonic sensors for object identification and collision avoidance, Arduino for central control, and a conveyor system for rubbish collection and disposal. The robot, which operates by renewable solar energy, can be controlled manually or automatically with the help of an Android smartphone. While the robot can be remotely navigated in manual mode, it can also independently execute cleaning duties in automatic mode. This project not only addresses environmental challenges by providing a sustainable solution for water surface cleaning but also demonstrates the potential of autonomous systems in environmental management.

DECLARATION

We at this moment declare that the design principles and working prototype model of the project entitled Water Surface Cleaner is an authentic record of our work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr Javed Imran and during the 7th semester (2024).

Date: 18-Dec-24

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They always wanted the best for us and we admire their determination and sacrifice.

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INTRODUCTION

1.1 Project Overview

One of the most important environmental problems affecting aquatic ecosystems globally is water pollution. Urban water bodies—lakes, rivers, and reservoirs—are especially susceptible to pollution from human activity, which includes trash and plastic waste. These contaminants seriously endanger human health and marine life in addition to lowering the quality of the water. Innovative approaches that effectively clean water surfaces with the least amount of negative environmental impact are needed to address this problem.

In order to address this difficulty, our project will build a small-scale, autonomous robot that can traverse water surfaces and gather different kinds of trash. It is intended to be an environmentally friendly, reasonably priced way to lessen the effects of pollution in urban water bodies.

Problem Statement

Water bodies are becoming more and more contaminated with garbage, hazardous pollutants, and organic waste as shown in the figure. Conventional techniques for cleaning water surfaces, like manual collection, are labor-intensive, slow, and frequently fail. These techniques can also be expensive and might not be practical for continual use. In order to maintain the long-term health of aquatic ecosystems, an autonomous system that can clean water surfaces without human involvement is desperately needed.

By creating a robotic system that can navigate water bodies on its own, identify debris, and collect it effectively, this project aims to solve this issue. By doing this, it will lessen the negative effects of pollution on the ecosystem, preserve marine life, and improve the quality of the water.

Figure 1:Manual Efforts for Cleaning Severely Polluted Water Bodies

Proposed Solution

To address the issue of water surface pollution we created an autonomous water surface cleaning robot as a solution as shown in figure. This solution builds a robot that effectively removes waste from water bodies by fusing sustainability and cutting-edge technology.

The robot's control system, which is based on Esp32, is used to regulate motor operations and sensor inputs, providing accurate and dependable performance. The robot can navigate through aquatic settings with effectiveness, avoiding obstacles and guaranteeing comprehensive cleaning without the need for human intervention & with the integration of ultrasonic sensors for collision avoidance and object detection.

We used conveyor system to collect debris, which collects waste from the water's surface and deposits it into a net fastened to the robot's frame. Because of its design, the robot can function. This design allows the robot to operate continuously with minimal manual interference, enhancing its efficiency.

We used solar panels that charge onboard batteries to power the robot. In addition to lowering operating expenses, this renewable energy source guarantees the robot's sustainability and longer field operation duration.

We are using an Android application for human interaction that enables the robot to operate both manually and automatically. Depending on the circumstance, users can operate the robot autonomously or remotely, giving them flexibility.

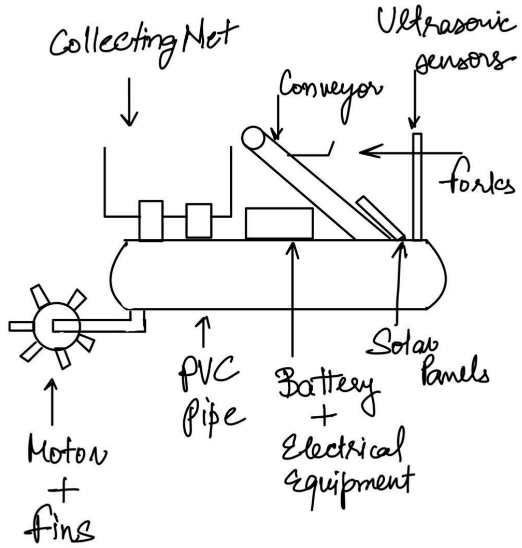


Figure 2: Proposed Autonomous Water Surface Cleaning Robot Design

Societal Impact

This project's implementation could have a big social impact, especially in cities where water pollution is becoming a bigger problem. In addition to being vital for human health, clean water is also necessary for the long-term viability of local economies that depend on bodies of water for activities like fishing and tourism. It improves these populations' general quality of life by keeping their water surfaces cleaner. Additionally, the project has the ability to reach out and educate. This prototype was created as a college capstone project and can be used as an example by academics and students who are interested in sustainability, environmental science, and robotics. It can inspire future advances in environmental conservation and increase public awareness of water contamination by being demonstrated at educational institutions and public events.

Future Prospects

This project offers room for substantial growth and development in the future. Subsequent iterations of the robot may integrate sophisticated functionalities like artificial intelligence-based decision-making, enabling it to adapt to novel situations and surroundings.

Opportunities for cooperation with government agencies, technology businesses, and environmental organisations are also presented by the project. These collaborations may result in the creation of improved robots that can handle increasingly difficult environmental problems. In the end, this initiative is a step toward a day when autonomous systems are crucial to preserving and enhancing the condition of the ecosystems in our world.

1.2 Need Analysis

1. Water pollution is a serious environmental problem that has an impact on human health, biodiversity, and marine ecosystems. Even with attempts to reduce pollution, there are still a lot of obstacles to overcome due to the size and complexity of the issue. Conventional approaches to cleaning the surface of water, like physical labor and large-scale containers, may not be as effective, efficient, or environmentally sustainable as they may be given the extent of the pollution.

2. Additionally, a lot of the current techniques for cleaning water surfaces involve manual labor, which can be expensive, time-consuming, and labor-intensive. Large vessels with nets or skimmers may be useful in some circumstances, but they are not always feasible, especially in isolated or difficult-to-reach places.

3. Innovative approaches that can effectively and autonomously remove trash from the water's surface while having the least negative effects on the environment are obviously needed. To meet this need, autonomous robots present a viable method that makes cleaning water surfaces both affordable and scalable.

4. On the other hand, the accuracy, efficiency, and scalability of the current water surface cleaning systems might be constrained. To improve these and increase their effectiveness in combating the problems associated with water pollution, more research and development are required.

In conclusion, the necessity for novel approaches to water surface cleaning stems from the pressing need to combat water pollution, the shortcomings of the cleaning techniques currently in use, and the possibility for autonomous robots to offer scalable and reasonably priced solutions. The goal of the water surface cleaner project is to produce a prototype robot that can clean debris off the water's surface on its own. This will help to solve the requirement.

1.3 Research Gaps

1. Cost-Effective Design for Smaller Applications

Large-scale autonomous cleaning systems are the subject of the majority of current research and development, which frequently leads to expensive designs that are inappropriate for smaller settings like backyard pools or little ponds. Further study is required to identify affordable, scalable designs that small enterprises and individual consumers can use widely.[1]

2. Environmental Impact of Cleaning Materials and Energy Sources

The incorporation of renewable energy sources, such as solar panels, into robotic systems has advanced significantly, but little is known about how the materials used in these systems affect the environment, especially with regard to sustainability and biodegradability. To reduce damage to aquatic habitats, further research is required to investigate energy-efficient designs and environmentally friendly materials.[2]

3. Optimization of Navigation and Object Detection in Confined Spaces

A lot of the current autonomous systems operate poorly in small areas because they are made for wide, open bodies of water. A major issue still lies in accurately navigating and detecting objects in smaller, more crowded settings. Enhancing sensor algorithms and increasing autonomous systems' adaptability in these cramped spaces require research.[3]

4. User-Friendly Interfaces for Non-Technical Users

The complicated user interfaces of many of the current autonomous cleaning systems can prevent non-technical users, such owners of residential pools, from adopting them. Research on creating user-friendly interfaces that are simple to use and need little technical expertise is lacking, which would allow end users to embrace and use them more widely and effectively.[4]

5. Long-Term Reliability and Maintenance of Autonomous Systems

There is little research on the upkeep and long-term dependability of autonomous water surface cleansing devices. Even while studies with limited durations show that these systems work well, longer-term studies are necessary to evaluate how well these systems function over time, especially with regard to longevity, maintenance needs, and the influence of environmental conditions on their performance.[5]

1.4 Problem Definition and Scope

Water pollution has grown to be a serious environmental problem, especially when it comes to the buildup of garbage on the surface of lakes, rivers, and seas. This trash affects human activities, upsets aquatic ecosystems, and poses serious hazards to marine life. It can include everything from plastic waste to organic materials. The labor-intensive, inefficient, and expensive nature of traditional cleaning water surfaces makes it difficult to solve the problem on a large scale. Furthermore, because these techniques may include the use of chemicals or interfere with mechanical processes, they may worsen environmental damage.

The objective of this project is to address this issue by creating an independent, effective, and eco-friendly solution. The robot is made to gather different kinds of trash from water surfaces without the assistance of a human, increasing the efficiency of cleaning operations.

Our project is best suited for stable water bodies, such as swimming pools and ponds. The scope of this project is therefore limited to these environments, where the robot can operate most effectively.

1.5 Assumptions and Constraints

The assumptions and constraints for the system are listed in Table 1 & Table 2

Sr. No.	Assumptions
1	It is assumed that the water surface cleaning robot is intended to operate in relatively calm water environments, such as lakes, ponds, or sheltered coastal areas. It is assumed that these environments will not be subjected to extreme weather conditions, such as storms, heavy rain, or strong currents, which could adversely affect the robot's stability, navigation, and overall safety. The robot's design and functionality are optimized for mild conditions, and its performance might degrade under more severe environmental factors.
2	It is assumed that the robot will be deployed in water bodies where there is sufficient depth to support its movement and the operation of its cleaning mechanisms. These areas should allow for easy access, from the shore ensuring that the robot can be smoothly launched, operated, and retrieved without significant logistical challenges. Let us assume that the deployment sites are free from obstacles that could impede the robot's movement, such as submerged rocks or dense vegetation.
3	It is assumed that the robot's operation depends on a reliable power supply, critical for maintaining its functionality over extended periods. It is assumed that this power will be provided either by onboard renewable energy sources, such as solar panels, or through external conventional power sources. The power supply must be consistent and adequate to charge the robot's batteries and sustain the onboard systems, including sensors, motors, and the control unit. It is assumed that any disruptions to this power supply could limit the robot's operational capacity and necessitate manual intervention.
4	It is assumed that the robot's cleaning activities will take place in areas with minimal interaction with marine life. Assuming that the robot's design includes features to prevent harm to aquatic organisms, such as slow-moving parts that reduce the likelihood of entanglement.

5	It is assumed that the robot’s operations will be monitored to ensure that its presence does not disrupt local ecosystems, and that any potential risks to marine life have been carefully considered and mitigated through design and operational protocols.

Table 1:Underlying Assumptions for the System

Sr. No.	Contraints
1	Project operates within strict budget constraints, which limit the financial resources available for research, development, and testing. It is assumed that these budgetary limitations will influence the selection and procurement of materials and components necessary for building the robot. Consequently, some design decisions may be driven by cost-effectiveness rather than optimal performance, potentially affecting the overall capabilities of the robot.
2	Project operates under technological constraints, including the limitations of available sensors, computing resources, and communication systems. These technological limitations could restrict the robot’s performance, accuracy, and reliability. For example, the sensors used might have limited range or resolution, and the processing power may constrain the robot's ability to perform complex computations in real-time.
3	Project must adhere to regulatory constraints related to environmental protection, safety standards, and maritime regulations. It is assumed that these regulations will govern the design, deployment, and operation of the autonomous robot in marine environments. Compliance with these rules may necessitate additional design considerations or modifications to ensure that the robot operates safely and legally within the prescribed guidelines.
4	Robot will face operational constraints, such as limited battery life, range, and endurance. These limitations could impact the duration and scope of the robot’s cleaning operations, particularly in remote or offshore locations where maintenance, repairs, and logistical support might be challenging. These factors will need to be carefully managed to maximize the robot’s effectiveness within its operational environment.

Table 2:System Design Constraints

1.6 Standards

1. **Robotics and Autonomous Systems:**

    - **ISO 8373:2012:** Defined terms used in robotics, particularly for industrial robots. While it focused on industrial robotics, the definitions and classifications were useful in understanding and categorizing different aspects of robotic systems.

    - **ISO 10218-1 and ISO 10218-2:** Specified safety requirements for industrial robots. Although these standards were focused on industrial robots, their principles were adapted to ensure safety in autonomous cleaning robots.

2. **Environmental Standards:**

    - **ISO 14040:2006:** Provided principles and a framework for life cycle assessment (LCA). This standard was used to evaluate the environmental impact of the robot over its entire life cycle, from manufacturing to disposal.

    - **ISO 24510:2007:** Offered guidelines for the assessment and management of water services. It was relevant for ensuring that the cleaning process did not negatively impact water quality.

3. **Safety Standards:**

    - **ISO 12100:2010:** Addressed the safety of machinery through general principles for design, risk assessment, and risk reduction. This standard was applied to the design process to ensure that potential hazards were identified and mitigated.

    - **IEC 60950-1:** Focused on the safety of information technology equipment, which was relevant if the robot included electronic components for communication and control.

4. **Battery and Power Standards:**

   ○ **IEC 62133-2:2017:** Set safety requirements for portable sealed secondary lithium cells and batteries made from them, for use in portable applications. This standard was important for ensuring the safety and reliability of the robot's battery system.

   ○ **IEEE 1725:** Provided standards for rechargeable batteries used in mobile phones, which were adapted for use in the design and safety testing of the robot's power system.

5. **Communication and Networking Standards:**

   ○ **ISO/IEC 80000-13:2008:** Defined terms and units used in information technology, including wireless communication technologies like Bluetooth.

6. **Software and Systems Engineering Standards:**

   ○ **ISO/IEC 12207:2017:** Offered a framework for managing software life cycle processes. This standard ensured that the software controlling the robot was developed systematically and safely.

   ○ **ISO/IEC 25010:2011:** Provided systems and software quality requirements and evaluation (SQuaRE) models. This standard was used to assess and ensure the quality of the robot's software.

1.7 Approved Objectives

The objectives of our project are:

1. **Create a Functional Prototype:** Create a design and construct a water surface cleaning robot prototype that can move around aquatic areas on its own and gather garbage.
2. **Ensure Environmental Compatibility:** Make sure the robot is environmentally compatible by making sure its construction and functioning cause the least amount of harm to ecosystems and marine life, therefore supporting environmental conservation efforts.
3. **Optimize Efficiency and Effectiveness:** By improving navigation, debris identification, and collecting methods, the robot can clean water surfaces more effectively and efficiently. Sensors and energy-efficient parts are used in this.

4. **Assure Scalability and Affordability:** Build a robot that is both affordable and scalable so that a variety of users can utilize it.
5. **Develop an Android Application for Dual-Mode Control:** Create an Android application that allows users to control the robot in both manual and autonomous modes, providing flexibility in operation based on user preferences and environmental conditions.

1.8 Methodology

Design and Prototyping:

- **Conceptual Design:** We Started by sketching out detailed plans for the robot. Think where to place sensors, motors, the conveyor, & solar panels. Using AutoCAD we created model and simulated how it'll work.
- **Component Selection:** Look for important parts like the Arduino microcontroller, ultrasonic sensors, servo motors, materials for the conveyor system, and solar panels. Selected items that are energy-efficient, reliable, and fit well with Our overall design.
- **Prototype Construction:** Putting together the physical prototype by connecting everything as planned. Making sure the wiring is right, parts are mounted well, and it's strong enough to operate in water.

Environmental Compatibility:

- **Material Selection:** Picking out materials that are safe for the environment (non-toxic) and won't rust as we want to keep our waterways safe & healthy
- **Operational Testing:** Running tests in controlled spaces like swimming pools. This way, we can see how our robot interacts with water and how it affects the surrounding aquatic life.

Optimization of Efficiency and Effectiveness:

- **Sensor Integration:** Connecting those ultrasonic sensors! Adjusting them so they can help avoid collisions & detect objects correctly so that they should notice all sizes of debris.

- **Navigation System:** Programming the Esp32 microcontroller to help the robot move smoothly.
- **Energy Efficiency:** Use of solar energy lead to longer operational time while boosting overall efficiency.

Scalability and Affordability:

- **Cost Analysis:** Looking closely at costs. Finding ways to save money on production without lowering quality.
- **Scalability Testing:** Designing the robot so it can adapt easily—making it bigger or smaller depending on different water sizes. Testing it out in all kinds of spots to ensure it works well everywhere.

Development of Android Application:

- **App Design:** Creating a user-friendly interface for our Android app so that it should be easy for anyone to use. Focusing on smooth controls for both manual & automatic operation modes.
- **Bluetooth/Wi-Fi Integration:** Setting up communication features like Bluetooth so that our robot can easily connect with our Android device.
- **Testing & Iteration:** Testing out the application with our robot in many situations to see how well it performs under different conditions.

Testing and Validation:

- **Prototype Testing:** Did extensive tests in various water bodies like pools or ponds. This way, we checked how the robot finds its way around, spots debris, & collects waste efficiently.
- **Performance Metrics:** Checked how efficient our robot is, Looking at how much area it covered, how much rubbish it collected, & what kind of energy it used.
- **Final Adjustments:** After testing, we made necessary changes based on what we observed. Improved its design to ensure it works at its best.

1.9 Project Outcomes and Deliverables

The system will be able to achieve the following objectives:

- A Fully Functional Robot: An autonomous water surface cleaning robot that is outfitted with all the parts and technologies required to effectively clean water surfaces in stable environments like ponds and swimming pools, such as sensors, motors, conveyor systems, and solar panels.
- An Android application that is easy to use and offers both manual and automatic control modes lets users handle the robot whichever best suits their needs.
- Scalability and Economical Design: The robot that is made in a way that is both economical and scalable, allowing it to be used in a variety of comparable settings and accessible to a broad spectrum of consumers.
- Source Code: The Android application and Arduino code for the robot's operation are thoroughly documented, and allowing for software modifications for future improvements.

1.10 Novelty of Work

The novelty of this project lies in its integration of several innovative elements:

- **Autonomous Cleaning Technology:** The robot combines advanced autonomous navigation with efficient debris collection, leveraging ultrasonic sensors and servo motors to enhance its cleaning capabilities.
- **Renewable Energy Utilization:** The use of solar panels for powering the robot highlights a commitment to sustainability, reducing reliance on conventional power sources.
- **Dual Operation Modes:** The development of a versatile Android application that allows for both manual and automatic control of the robot offers a unique approach to user interaction and operational flexibility.
- **Environmental Integration:** The project incorporates design features specifically aimed at minimizing ecological impact, setting a new standard for environmentally conscious autonomous systems in water bodies.

2.1 Literature Survey

This section reviews past research and developments in the field of autonomous water surface cleaning, providing an overview of the systems, sensors, and technologies that have been utilized in similar projects

2.1.1 Theory Associated With Problem Area

The issue of water surface pollution revolves around the buildup of floating waste, including plastic, leaves, and other pollutants, leading to significant environmental problems. These contaminants disrupt aquatic ecosystems, causing harm to marine life and degrading the quality of water. Conventional methods of cleaning water surfaces are often labor-intensive and ineffective, particularly in smaller, stable water bodies like ponds and swimming pools.

The advancement of self-operating cleaning systems incorporates principles from robotics, automation, and environmental engineering. The utilization of ultrasonic sensors is for avoiding collisions and detecting objects. These sensors aid the robot in water surfaces while evading obstacles and recognizing debris.

Furthermore, achieving energy sustainability in robotics involves integrating renewable energy sources, such as solar panels, to convert sunlight into electrical energy for powering the robot. This approach aligns with efforts in environmental conservation, reducing dependence on non-renewable energy sources and minimizing the carbon footprint of the robot.

The combination of these concepts lays the groundwork for creating an independent, effective, and eco-friendly solution to water surface pollution.

2.1.2 Existing Systems and Solutions

Water surface pollution is a problem that has been addressed through the development of numerous systems and solutions, with a particular emphasis on the removal of floating trash. These solutions come in a variety of forms and levels of technological complexity, from simple hand skimmers to sophisticated autonomous robots.

Cleaning water surfaces has traditionally been accomplished using conventional methods like manual and semi-automated skimmers. These devices are labour-intensive and less successful in larger or more contaminated water bodies, but they are useful for small-scale operations when run by hand or with minimal automation. Smith et al. (2018) state that these approaches are constrained by their reliance on human involvement and incapacity to function constantly.[6]

New developments have prompted the creation of ASVs, which are intended to clean water surfaces more automatically and effectively. These cars can drive themselves across bodies of water thanks to sensors, GPS, and sophisticated algorithms. Research shows that ASVs are useful for gathering floating debris and for real-time water quality monitoring (Wang et al., 2020). However, the complexity of operation and high cost of these systems generally prevent them from being used in smaller applications [7]

Limitations and Challenges: These systems still face limitations despite their achievements, mostly related to scalability, price, and environmental impact. Widespread adoption is hindered by high prices, complicated maintenance, and the possibility of ecological impact (García et al., 2021). Furthermore, the majority of currently available solutions might not be ideal for smaller, stable water bodies like ponds or swimming pools because they are made for larger purposes.[8]

2.1.3 Research Findings for Existing Literature

Difficulties with Scalability and Affordability: As García et al. (2021) point out, while existing solutions work well for large-scale applications, they are not as accessible for smaller-scale environments due to their high costs and maintenance requirements. This is a major obstacle to adoption, especially in areas or applications with limited financial resources.

Material and Design Considerations: The literature also emphasises how crucial it is to use materials and designs that minimise their negative effects on the environment. According to Smith et al. (2018), materials that are non-toxic, corrosion-resistant, and suitable for aquatic environments are needed. These robots' designs have to make sure they don't damage marine life or upset the ecosystems' natural equilibrium in the areas where they work.

Limitations of contemporary Technologies: In spite of advancements, contemporary technologies still have certain significant shortcomings. The adaptability of many current technologies is limited since they are designed for large-scale or particular sorts of garbage. Furthermore, the majority of solutions are not made to function in dynamic or unexpected circumstances, which can lessen their usefulness in actual situations.

2.1.4 Problem Identified

Even though autonomous water surface cleaning systems have advanced significantly, a number of important problems still exist, especially when it comes to smaller, more stable bodies of water like ponds and swimming pools:

1. High Costs and Complexity: Current autonomous solutions are costly and complex for smaller environments because they are frequently built for large-scale applications. For residential users or smaller facilities, where affordability and usability are crucial, this poses a hurdle to acceptance.
2. Environmental Concerns: Despite the fact that some systems use renewable energy, a large number still depend on materials and parts that could harm aquatic habitats. Designs that minimise possible environmental impact must be efficient and environmentally friendly.
3. Inefficiencies in Smaller-Scale Operations: The majority of the systems in use today are not effective in smaller, cramped locations because they are designed for larger bodies of water. Over-engineering for the scale, inadequate navigation in confined spaces, and inadequate debris-collecting techniques for smaller environments are among the difficulties.
4. Maintenance and Usability: Users in non-industrial settings find it impractical to undertake the significant maintenance requirements that come with the complexity of present solutions. In order to guarantee greater usefulness and save recurring expenses, systems must be made simple and intuitive to operate.

2.1.5 Survey of Tools and Technologies Used

The tools and technologies used in the field of autonomous water surface cleaning have evolved significantly, incorporating advancements in robotics, sensor technology, renewable energy, and control systems:

- **Esp32 Microcontrollers:** Esp32 boards are widely utilised as the central control units in many autonomous systems, including our project, because to their adaptability and simplicity of integration. To propel the robot's movements, they regulate motors and sensor inputs.
- **Ultrasonic Sensors:** Ultrasonic sensors measure the distance to obstacles by emitting sound waves and detecting their reflections. They are frequently used in autonomous systems for object detection and collision avoidance. These sensors are used in our project to navigate water surfaces and prevent collisions.
- **Servo motors:** For exact movement and positioning control, servo motors are frequently utilised in robotics. They provide the necessary motion and function to the debris collection mechanism in our robot, guaranteeing precise and effective cleaning.
- **Solar Panels:** In order to improve sustainability, solar electricity is being included into autonomous systems more and more. By using solar panels as a renewable energy source, our project lowers its impact on the environment and operating expenses.
- **Android Applications:** Remote control features are frequently offered by mobile application, One of the features of our product is a customised Android app that gives consumers flexibility in operation by letting them choose between manual and automatic control modes.

While similar tools and technologies are used by many existing systems, our project combines them in a unique way that specifically addresses the needs of smaller, stable water bodies. In contrast to more intricate and expensive options intended for larger-scale applications, our robot provides a workable solution by emphasising cost-effectiveness, environmental sustainability, and user-friendly operation.

2.2 Software Requirement Specification

2.2.1 Introduction

This section deals with the Software Requirement Specification of the project.

2.2.1.1 Purpose: The purpose of this document is to outline the necessary functional and non-functional requirements for the software that will govern the self-cleaning water surface robot. This covers the Android app that gives users control over the robot as well as the software that runs on the Arduino microcontroller.

2.2.1.2 Intended Audience and Reading Suggestions: The developers and engineers who will implement the program, the project managers in charge of overseeing the project, and the testers who will validate the system are the intended recipients of this document. The main goal is to develop an autonomous water surface cleaning system that is practical, effective, and easy to use, especially for small, stable water features like ponds and swimming pools.

2.2.1.3 Project Scope: This software encompasses all the features required for the water surface cleaning robot to operate both manually and autonomously. In addition to controlling the robot's motions and managing sensor inputs, the program also connects to an Android application to provide remote control. The concept is specially made for stable water features, such as ponds and swimming pools, and it prioritises usability, efficiency, and environmental sustainability.

2.2.2 Overall Description

This section deals with the overall description of the platform.

2.2.2.1 Product Perspective: The water surface cleaning robot system's software is an essential component. To allow for autonomous operation, it communicates with a variety of hardware elements. Furthermore, the program integrates with an Android application, giving customers the option of operating the robot automatically or manually. With its emphasis on smaller, more stable water bodies, this software system stands out among others in the wider context of water cleaning technology.

2.2.2.2 Product Features:

- **Autonomous Operation:**The robot navigates and cleans water surfaces independently using ultrasonic sensors and predefined algorithms.
- **Manual Control:**Control the robot’s movement and functions via an Android application for direct interaction.
- **Obstacle Detection and Avoidance:**Two ultrasonic sensors: one for avoiding collisions and another for detecting objects in the water.
- **Efficient Garbage Collection:**The conveyor system gathers debris and deposits it into a net, reducing manual cleanup.

- **Renewable Power Source:**Solar panels charge the batteries, supporting sustainable operation and minimizing recharging needs.
- **Real-Time Processing:**Processes sensor data and user commands instantly for responsive and effective operation.
- **User-Friendly Interface:**Intuitive Android application for manual control and configuring autonomous mode.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces:

Android Application:

- **Device Pairing:**
    - **Initial Screen:** Asks users to scan for available devices using Bluetooth.
    - **Connection Status:** Displays whether the robot is connected or disconnected after attempting to pair.
- **Mode Selection:**
    - **Mode Page:** Allows users to select between Manual or Automatic operation modes.
- **Status and Data Display:**
    - **Operational Status:** Shows the connection status (Connected or Disconnected).
    - **Current Ultrasonic Values:** Displays real-time data from the ultrasonic sensors for obstacle detection and object measurement.

2.2.3.2 Hardware Interfaces:

<u>**Arduino Controller:**</u>

- **Interface with Sensors:** Connects to ultrasonic sensors for obstacle detection and object identification.
- **Interface with Motors:** Controls servo motors for movement and positioning.
- **Interface with Conveyor System:** Manages the operation of the conveyor for garbage collection.

- **Interface with Solar Panel System:** Manages battery charging and power distribution.

Ultrasonic Sensors:

- **Connection:** Wired connection to the Esp32 for data transmission.
- **Function:** Provides distance measurements for obstacle avoidance and object detection.

Servo Motors:

- **Connection:** Wired connection to the Esp32 for movement control.
- **Function:** Controls the robot's movement and positioning.

Conveyor System:

- **Connection:** Integrated with the Esp32 for operational control.
- **Function:** Collects and disposes of garbage into a net.

Solar Panels:

- **Connection:** Wired to the battery system for charging.
- **Function:** Provides renewable energy to maintain battery power.

2.2.3.3 Software Interfaces:

Arduino Software:

- **Interface with Sensors:** Receives and processes data from ultrasonic sensors.
- **Interface with Motors:** Sends commands to servo motors to control movement.
- **Interface with Conveyor System:** Controls the conveyor's operation for waste collection.
- **Interface with Power Management System:** Manages power distribution and battery charging.

Android Application:

- **Interface with Esp32:** Communicates via Bluetooth to send control commands and receive status updates.
- **Data Exchange:** Sends user commands and receives real-time data from the robot, including operational status and sensor information.

2.2.4 Other Non-functional Requirements

2.2.4.1 Performance Requirements:

Real-Time Response: The system should process and respond to sensor inputs and user commands within milliseconds to ensure smooth and accurate operation.

Battery Life: The robot should operate continuously for a minimum of 6 hours on a full charge, with the solar panels providing sufficient power to extend operational time.

Operational Efficiency: The robot should be able to cover a minimum of 500 square meters of water surface area per hour, ensuring efficient cleaning and garbage collection.

Connectivity: The Android application should establish a Bluetooth connection with the robot within 10 seconds and maintain a stable connection for uninterrupted control.

2.2.4.2 Safety Requirements:

Collision Avoidance: The robot must have fail-safes to prevent collisions and ensure it navigates around obstacles effectively using ultrasonic sensors.

Electrical Safety: All electrical components, including the solar panels and battery system, should comply with safety standards to prevent short circuits, overheating, and electrical hazards.

Waterproofing: The robot's structure and components must be adequately waterproofed to prevent damage and ensure reliable operation in water environments.

2.2.4.3 Security Requirements:

Data Security: The Android application and robot communication should be encrypted to prevent unauthorized access and data interception.

Software Integrity: The robot's software should include mechanisms to prevent unauthorized modifications or tampering, ensuring the integrity and reliability of its operations.

2.4 Risk Analysis

Sensor Accuracy Issues:

- **Risk:** Ultrasonic sensors may have accuracy issues or fail to detect obstacles properly.
- **Mitigation:** Test sensors thoroughly and include calibration procedures in the software.

Power Supply Issues:

- **Risk:** Solar panels may not provide sufficient power in low sunlight conditions.
- **Mitigation:** Include an alternative charging method or larger battery capacity to ensure operation in various conditions.

Waterproofing Failures:

- **Risk:** Components may become damaged if not adequately waterproofed.
- **Mitigation:** Ensure all components are sealed and tested for waterproofing before deployment.

Cost Overruns:

- **Risk:** The project might exceed the budget due to unforeseen expenses.
- **Mitigation:** Maintain a contingency fund and regularly review the budget against actual expenditures.

2.5 Cost Analysis

S. No.	Item	Amount(₹)
1.	12V 7.2Ah UPS Battery Lapcare	850
2.	10 Core Ribbon Wire	200.02
3.	L298 Motor Driver Board	240.02
4.	ESP32 38Pin WROOM MCU Module	740
5.	Solar Panel Charging Circuit	220
6.	Glue Stick 11mm	100.06
7.	Servo Motor MG996 180 Degree	290
8.	Ultrasonic Module HC-SR04	280
9.	LM2596 DC to DC Buck 3Amp	239.96
10.	RMC Connector 16Pin	64
11.	Berg/Hoader Male	50.04
	Total Amount	3274.1

Tabel 3:Cost Breakdown of Electronic Components

S. No.	Items	Amount(₹)
1.	PVC Pipe 6” (10Ft)	1180
2.	End Cap 6” (6P)	920.4
3.	Solar Panel (2P)	1800
4.	ERW Pipe (10ft)	1298
5.	Wire jali (3kg)	265.5

6.	Round (1kg)	194
7.	Welding jali(2kg)	184.08
8.	2 Sprocket set cycle	1500
9.	4 inch nut bolt (1kg)	194.7
10.	Miscellaneous nut bolts	489.4
11.	Pidilite Flex Kwik (3P)	120
12.	PVC Solution(5P)	185.26
13.	Welding Rod	50
14.	Iron Cutting Blade	60
15.	Welding Labour	600
16.	Wooden Frame	200
17.	Spray Paint Black	531
	Total Amount	9,472.34

Tabel 4 : Hardware Cost

S. No.	Details	**Amount(₹)**
1.	Electronics Cost	3,274.1
2.	Hardware Component Cost	9,472.34
3.	Miscellaneous Cost	350
	Total Amount	13,096.3

Tabel 5:Complete Project Analysis

METHODOLOGY ADOPTED

3.1 Investigative Techniques

Literature Review:

- Purpose: To understand existing solutions, technologies, and gaps in current water surface cleaning methods.
- Approach: Conducted a thorough review of academic papers, industry reports, and case studies related to water pollution, autonomous robots, and environmental sustainability.
- Outcome: Identified the limitations of traditional cleaning methods and existing autonomous systems, which informed the design and development of a more effective solution.

Comparative Analysis:

- Purpose: To compare various autonomous water cleaning technologies and identify the most suitable approach for our project.
- Approach: Compared different systems based on efficiency, environmental impact, cost, and scalability. Analyzed case studies and performance metrics of existing robots and cleaning methods.
- Outcome: This analysis highlighted the need for integrating advanced sensors and renewable energy sources, leading to the development of the proposed robot.

Prototyping and Testing:

- Purpose: To develop and validate a functional prototype of the autonomous water cleaning robot.
- Approach: Built a prototype incorporating the selected technologies. Conducted iterative testing in controlled environments to refine performance and functionality.
- Outcome: The prototype successfully demonstrated autonomous navigation, debris detection, and collection capabilities, validating the proposed solution's feasibility.

Field Trials:

- Purpose: To test the prototype in real-world conditions and assess its effectiveness in different water environments.
- Approach: Deployed the robot in various urban water bodies to evaluate its performance under diverse conditions and gather feedback on its operation.
- Outcome: Provided insights into the robot's practical performance, allowing for adjustments to improve efficiency and reliability.

Justification for Selected Techniques:

- Literature Review provided a foundational understanding of the problem and current solutions, ensuring the project built on existing knowledge.
- Comparative Analysis helped in selecting the most effective and feasible technologies for the prototype.
- Prototyping and Testing was essential for developing a functional system and refining it based on empirical data.
- Field Trials offered practical validation of the robot’s performance and informed necessary adjustments for real-world application.

3.2 Proposed Solution

Solution Overview:

The proposed solution is an innovative water surface cleaning robot designed to address the challenges of maintaining small water bodies such as ponds, swimming pools, and small lakes. The robot integrates advanced hardware and software technologies to autonomously remove floating debris, including leaves, algae, plastic waste, and other pollutants, from the water surface. The system prioritizes efficiency, ease of use, and environmental sustainability, making it a practical solution for both residential and commercial applications.

Hardware Components:

1. Esp32 Microcontroller:

The Esp32 microcontroller serves as the central processing unit (CPU) of the robot, acting as the brain that coordinates the entire system. It is responsible for processing inputs from various sensors, executing control algorithms, and managing the movement of the robot's motors. The microcontroller is programmed with custom software that allows it to respond dynamically to changes in the environment, such as the presence of obstacles or varying amounts of debris on the water surface.An Esp32 microcontroller is a popular choice because of its adaptability, simplicity in programming, and interoperability with a large array of sensors and actuators.Additionally, the Esp32 platform supports real-time processing, which is crucial for the robot's autonomous operation, ensuring that it can react quickly and accurately to environmental stimuli.

2. Ultrasonic Sensors:

The robot is equipped with two types of ultrasonic sensors: one for collision avoidance and another for object detection. These sensors are vital for the robot's ability to navigate autonomously on the water surface.

- Collision Avoidance Sensor: The collision avoidance sensor continuously scans the robot's surroundings to detect any obstacles in its path, such as the edges of the pool or large objects like buoys or floating toys. When an obstacle is detected, the sensor sends data to the Esp32 microcontroller, which then adjusts the robot's course to avoid a collision. This feature ensures the robot can operate safely without requiring constant supervision.
- Object Detection Sensor: The object detection sensor is used to identify and track floating debris. It allows the robot to steer toward debris clusters, optimizing the cleaning process. The sensor helps the robot differentiate between obstacles that need to be avoided and debris that should be collected. This functionality is critical for efficient operation, as it allows the robot to prioritize areas with higher concentrations of debris.

3. Servo Motors:

Servo motors are used to control both the robot's movement and the operation of the conveyor system that collects debris. These motors are known for their precision and reliability, making them ideal for tasks that require accurate control of position and speed.

- Movement Control: The servo motors that control the robot's movement are responsible for steering and propulsion. They receive commands from the Esp32 microcontroller, which adjusts their speed and direction based on input from the ultrasonic sensors. This allows the robot to navigate smoothly across the water surface, adjusting its path to avoid obstacles and reach areas with debris.

- Conveyor System Operation: Another set of servo motors powers the conveyor system, which is a critical feature of the robot. The conveyor system is designed to lift floating debris from the water surface and deposit it into a collection net attached to the robot. The motors control the rotation of the conveyor belt, ensuring that debris is collected efficiently and without causing disruption to the robot's movement.

4. Conveyor System:

The conveyor system is a key innovation in the robot's design, enabling it to physically remove debris from the water surface. The system consists of a rotating belt with a fine mesh that captures debris as the robot moves across the water. The debris is then transferred into a collection net, which can be emptied periodically.

The design of the conveyor system is optimized for capturing a wide range of debris sizes, from small particles like leaves and twigs to larger items like plastic bottles or wrappers. The fine mesh prevents smaller debris from slipping through, ensuring thorough cleaning. The conveyor system is also designed to operate continuously without jamming, even when handling larger debris.

5. Solar Panels:

To enhance the robot's sustainability, it is equipped with solar panels that provide renewable energy to charge its batteries. The use of solar panels not only extends the robot's operational time but also reduces its reliance on external power sources, making it an eco-friendly solution.

The solar panels are strategically placed on the top surface of the robot, where they can receive maximum sunlight exposure. This design ensures that the robot can charge its batteries throughout the day, allowing for extended periods of autonomous operation without the need for frequent recharging. Additionally, the solar panels contribute to reducing the robot's carbon footprint, aligning with the project's goal of promoting environmental sustainability.

Figure 3:Initial Prototype of the Project

Software Components:

1. Esp32 Code:

The software running on the Esp32 microcontroller is the core of the robot's intelligence. This code is responsible for interpreting sensor data, making real-time decisions, and controlling the robot's motors. The code includes algorithms for path planning, obstacle avoidance, and debris collection, ensuring that the robot can operate autonomously with minimal human intervention.

- Sensor Data Processing: The Arduino code continuously monitors inputs from the ultrasonic sensors, processing this data to determine the robot's surroundings. The code uses this information to update the robot's movement commands, allowing it to navigate efficiently and avoid obstacles. For example, if the collision avoidance sensor detects an obstacle ahead, the code will instruct the motors to adjust the robot's course, steering it away from the obstacle while maintaining its cleaning trajectory.

- Motor Control: In addition, the code controls the direction and speed of the robot by operating the servo motors.It ensures that the motors work in tandem to achieve smooth and precise movement. For instance, when the robot detects a cluster of debris, the code will direct the motors to slow down, allowing the conveyor system more time to collect the debris before moving on.
- Communication with Android Application: Another important function of the Esp32 code is to handle communication between the microcontroller and the Android application. The code ensures that commands from the Android app are executed correctly, whether the user is controlling the robot manually or setting it to automatic mode. This seamless integration between hardware and software is crucial for providing a user-friendly experience.

2. Android Application:

The Android application serves as the user interface for controlling the robot. It offers two primary modes of operation: manual mode and automatic mode, giving users flexibility in how they interact with the robot.

- Manual Mode: In manual mode, users can directly control the robot's movement using a virtual joystick or directional buttons on the app. This mode is particularly useful for targeting specific areas or for situations where the user wants more precise control, such as navigating around tight corners or avoiding particularly challenging obstacles. The app also provides real-time feedback on the robot's status, sensor readings.

- Automatic Mode: Automatic mode allows the robot to operate autonomously, using its onboard sensors and control algorithms to navigate the water surface and collect debris without human intervention. Users can activate automatic mode with a single tap, and the robot will begin its cleaning routine, adjusting its path based on the environment and debris concentration. The app also allows users to set parameters for automatic mode, such as the cleaning duration or specific areas to focus on.

The Android application is designed to be intuitive and user-friendly, ensuring that even users with minimal technical knowledge can operate the robot effectively. The app's interface is streamlined, with clear icons and simple controls that make it easy to switch between modes and monitor the robot's performance.

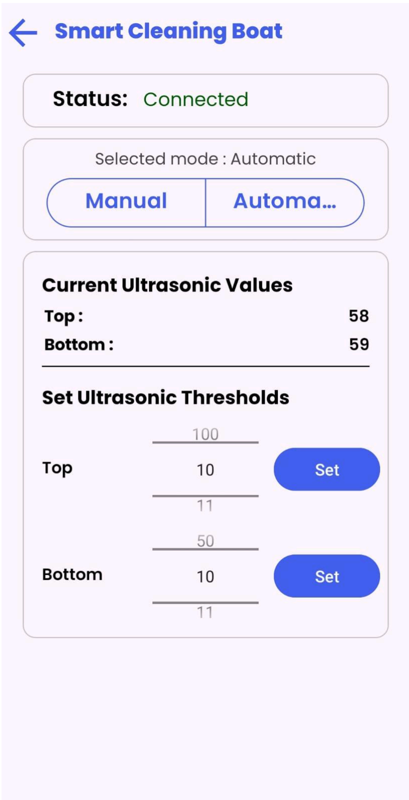


Figure 4:App Interface: Automatic Mode

Manual Mode for Precise Robot Control

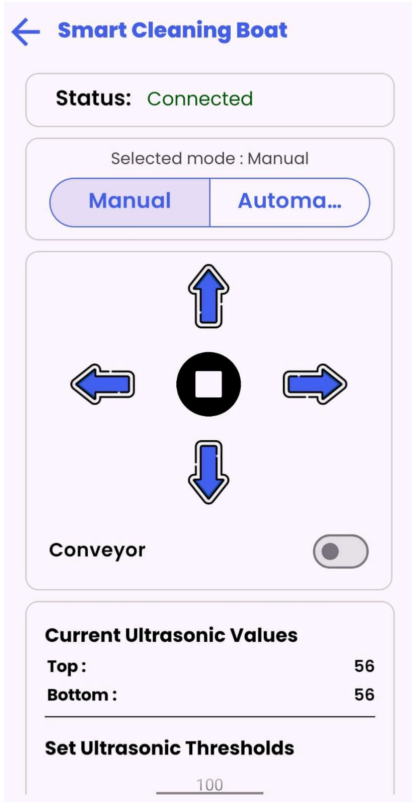


Figure 5 App Interface: for Autonomous

Cleaning Operations

Operational Modes:

1. <u>Autonomous Mode:</u>

In autonomous mode, the robot operates independently, using its sensors and onboard software to navigate the water surface and collect debris. The microcontroller continuously processes sensor data, adjusting the robot's movement and conveyor operation in real-time. This mode is ideal for routine maintenance of pools or ponds, as the robot can be left to run autonomously for extended periods, requiring minimal oversight.

- Obstacle Avoidance: The robot ensures that it covers the entire water surface efficiently, avoiding obstacles while maximizing debris collection. The collision avoidance sensor helps prevent the robot from crashing into the pool walls or other obstacles, while the object detection sensor guides it toward areas with more debris.

- Debris Collection: The conveyor system continuously gathers garbage and deposits it into the collection net as the robot navigates the water.The robot adjusts its speed based on the amount of debris detected, slowing down in areas with high concentrations to ensure thorough cleaning.

2. Manual Mode:

Manual mode allows users to take direct control of the robot via the Android application. This mode is useful for situations where the user wants to target specific areas or handle more complex cleaning tasks that require human judgment. The manual controls are responsive and easy to use, allowing for precise maneuvering of the robot in the water.

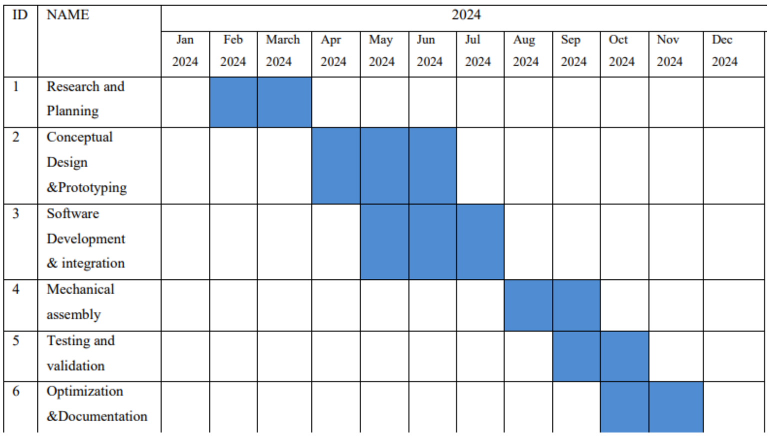
- Targeted Cleaning: Users can steer the robot toward specific areas that need more attention, such as corners or areas with stubborn debris. The app's real-time feedback helps users monitor the robot's progress and make adjustments as needed.

- Flexible Operation: Manual mode also offers flexibility in how the robot is used, allowing users to adapt to different cleaning scenarios. Whether it's a quick spot clean or a more detailed operation, manual mode provides the tools needed to get the job done.

- Environmental Considerations: The water surface cleaning robot is designed with environmental sustainability in mind. The integration of solar panels reduces the robot's reliance on non-renewable energy sources, minimizing its carbon footprint. By using solar energy to power its operations, the robot can run for longer periods without the need for frequent recharging, making it an eco-friendly solution for maintaining clean water bodies.

The robot's ability to operate autonomously also contributes to environmental conservation by reducing the need for chemical treatments and manual labor, which are often used to keep pools and ponds clean. By effectively removing debris, the robot helps maintain the water pollution level

3.3 Work Breakdown Structure (WBS)



Tabel 6:Work Breakdown Structure (WBS)

Project Planning and Management:

Tasks: Define project scope, schedule, and budget. Develop a project plan and timeline.

Deliverables: Project plan, timeline, and budget report.

Design Phase:

- Tasks: Design the robot's mechanical structure, navigation system, and debris collection mechanism. Select appropriate sensors and materials.
- Deliverables: Design specifications, component selection report.

Prototype Development:

- Tasks: Build the prototype based on the design specifications. Integrate sensors, navigation systems, and collection mechanisms.
- Deliverables: Functional prototype.

Testing and Validation:

- Tasks: Conduct controlled environment tests to evaluate the robot’s performance. Refine the design based on test results.
- Deliverables: Test reports, design refinement documentation.

Field Trials:

- Tasks: Deploy the robot in various real-world settings. Assess its effectiveness and gather feedback.
- Deliverables: Field trial reports, feedback analysis.

Final Adjustments and Documentation:

- Tasks: Implement final adjustments based on field trials. Prepare final project documentation and reports.
- Deliverables: Finalized robot, project report, and user manual.

Workable Modules/Products:

- Navigation Module: Includes sensors and algorithms for autonomous operation.
- Detection and Classification Module: Comprises sensors and software for debris identification.
- Collection Module: Features the mechanical system for debris gathering.
- Power Module: Incorporates energy systems for sustainable operation.

3.4 Tools and Technology

Hardware Tools:

- Arduino IDE: Used for writing, compiling, and uploading code to the Esp32 microcontroller.
- Breadboards and Multimeters: Essential for prototyping and testing the electrical circuits.
- 3D Printing: Used for creating custom parts for the robot, such as the frame or conveyor system components.

Software Tools:

- Android Studio: The primary tool for developing the Android application. It offers a robust environment for designing the UI and writing the app's logic.

- AutoCAD: Used for simulating the robot's behavior and testing the algorithms before implementing them on the actual hardware.

Technologies:

- Ultrasonic Sensing: Used for obstacle detection and navigation, enabling the robot to operate autonomously in a dynamic environment.
- Solar Energy: Solar panels provide a renewable energy source, making the robot eco-friendly and capable of extended operation without frequent recharging.
- Wireless Communication: Bluetooth module is used for communication between the Esp32 and the Android application, enabling remote control and data exchange.

Discussion:

The selection of these tools and technologies was guided by the project's requirements for real-time control, autonomous operation, and environmental sustainability. The integration of renewable energy with advanced sensing and control technologies ensures that the robot is both effective and eco-friendly.

S no.	Roll no.	Name	Paper Title	Tools and Technology used	Findings	Citations
1	102283053	Ashish Bhardwaj	A Water Surface Cleaning Robot	Arduino-Based Microcontroller, Pontoon-Shaped Hull, Xbee Pro Wireless Modules	Lightweight, durable materials like styrofoam, fiberglass, aluminum, and resin make the robot buoyant and leak-resistant.	[10] Wang Z, Liu 2008

2.			Autonomous Water Surface Cleaning Robot: A Review	Esp32, Ultrasonic Sensors, Servo Motors, Solar Panels	Discusses the development of autonomous robots for water cleaning with a focus on renewable energy sources.	[1] Smith et al., 2022
3.	102283032	Nishchey Khajuria	Design and Implementation of a Water Surface Cleaning Robot	Arduino, Raspberry Pi, Camera Module	Demonstrates the design of a robot with both manual and autonomous modes for water cleaning.	[2] Zhang et al., 2021
4.			Solar-Powered Aquatic Robots for Environmental Monitoring and Cleanup	Solar Panels, Ultrasonic Sensors, GPS Module	Explores the use of solar energy in powering autonomous robots for environmental applications.	[3] Lee & Kim, 2020
5.	102296004	Parneet Singh Sahni	Smart Robotic System for Automated Water Surface Cleaning	Arduino, Wi-Fi Module, Infrared Sensors	Proposes a smart robotic system for efficient and automated water surface cleaning.	[4] Ahmed et al., 2023

6.			Development of a Real-Time Water Quality Monitoring and Cleaning Robot	Arduino, pH Sensor, Turbidity Sensor	Integrates water quality monitoring with cleaning capabilities in a single robotic platform.	[5] Singh & Verma, 2022
7.	102283020	Anurag Pannu	An Autonomous Surface Vehicle for Debris Collection	Microcontroller, LIDAR, Ultrasonic Sensors	Focuses on the autonomous navigation and debris collection using advanced sensor technology.	[6] González et al., 2021
8.			Optimization of Path Planning Algorithms for Water Surface Cleaning Robots	Path Planning Algorithms, GPS, Ultrasonic Sensors	Examines the optimization of path planning algorithms to improve the efficiency of water cleaning robots.	[7] Patel & Kumar, 2022
9	1022830021	Khushdeep Mukija	Solar-Powered Water Cleaning Robots: An Energy Efficiency Study	Solar Panels, Battery Management Systems	Investigates the energy efficiency of solar-powered robots used in water cleaning applications.	[8] Huang et al., 202

10.			Design and Control of Autonomous Surface Robots for Water Quality Monitoring	Arduino, GPS, pH Sensor, Turbidity Sensor	Discusses the integration of water quality monitoring sensors with autonomous control systems.	[9] Johnson et al., 2023

Tabel 7:Literature Review and Findings

4.1 System Architecture

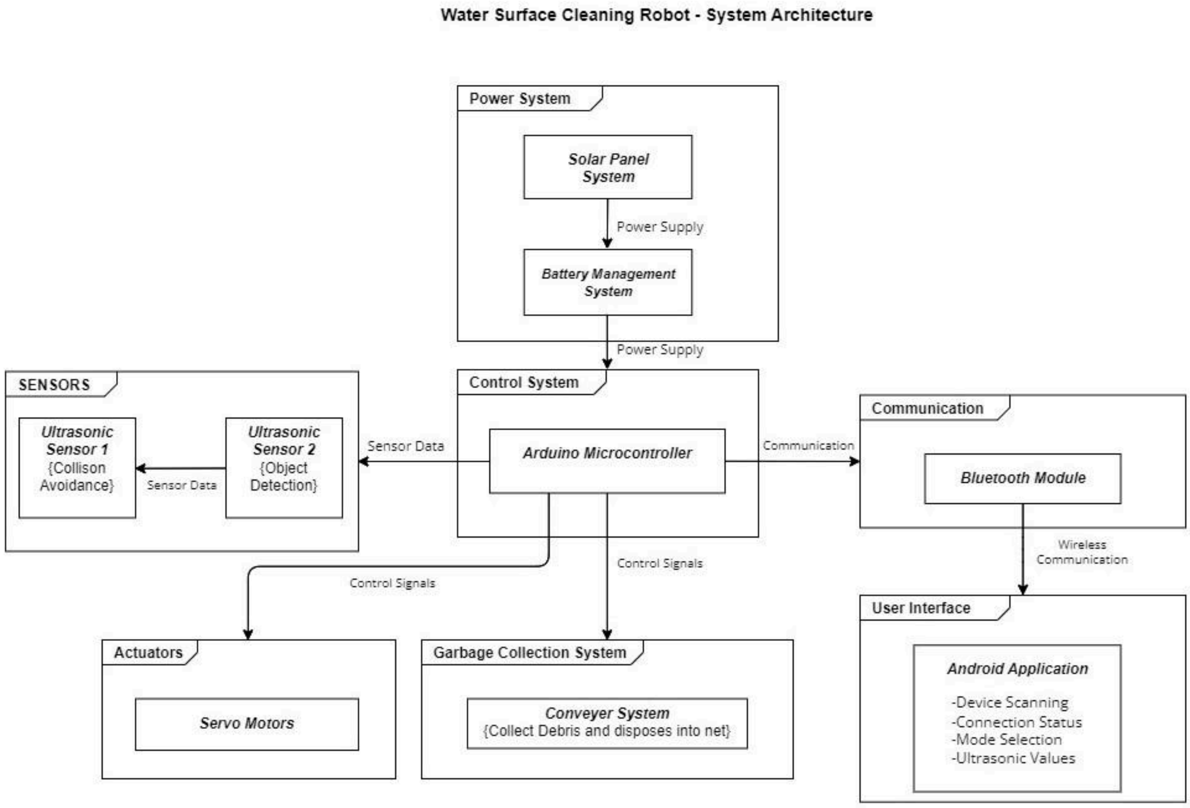


Figure 6:Water Surface Cleaning Robot-System Architecture/ System Architecture of the Water Surface Cleaning Robot

The Block Diagram visually represents the major components of the system and how they interact. Here's an outline of the key elements:

Solar Panel System:

- Function:
  - Charges the batteries, providing a renewable power source for the robot.
- Connection:
  - Directly connected to the Battery Management System.

Battery Management System:

- Function:
    - Manages the charging and discharging of batteries, ensuring optimal power usage.
- Connection:
    - Supplies power to the Esp32 microcontroller and motors.

Arduino Microcontroller (Esp32 **Uno):**

- Function:
    - Serves as the central control unit, processing inputs from sensors and controlling the robot's movement.
- Connections:
    - Receives power from the Battery Management System.
    - Receives input from the Ultrasonic Sensors.
    - Sends control signals to the Servo Motors and Conveyor System.
    - Communicates with the Android application via the Bluetooth Module.

Ultrasonic Sensors (Two Sensors):

- Function:
    - Sensor 1: Detects obstacles in the robot's path for collision avoidance.
    - Sensor 2: Detects objects (debris) in the water for collection.
- Connection:
    - Sends distance data to the Esp32 for processing.

Servo Motors:

- Function:
    - Control the movement of the robot and operate the Conveyor System.
- Connection:
    - Receive control signals from the Esp32 to navigate and collect debris.

Conveyor System:

- Function:
    - Collects debris from the water surface and deposits it into a net attached to the robot.
- Connection:
    - Operated by Servo Motors, controlled by the Esp32.

Bluetooth Module:

- Function:
  - Facilitates wireless communication between the robot and the Android application.
- Connection:
  - Connected to the Esp32, enabling remote control and data transmission.

Android Application:

- Function:
  - Provides a user interface for controlling the robot (manual mode) or configuring its autonomous operation.
- Features:
  - Device Scanning via Bluetooth.
  - Connection Status Display (Connected/Disconnected).
  - Mode Selection (Manual/Automatic).
  - Real-time Display of Ultrasonic Sensor Values.

4.2 Use Case Diagram

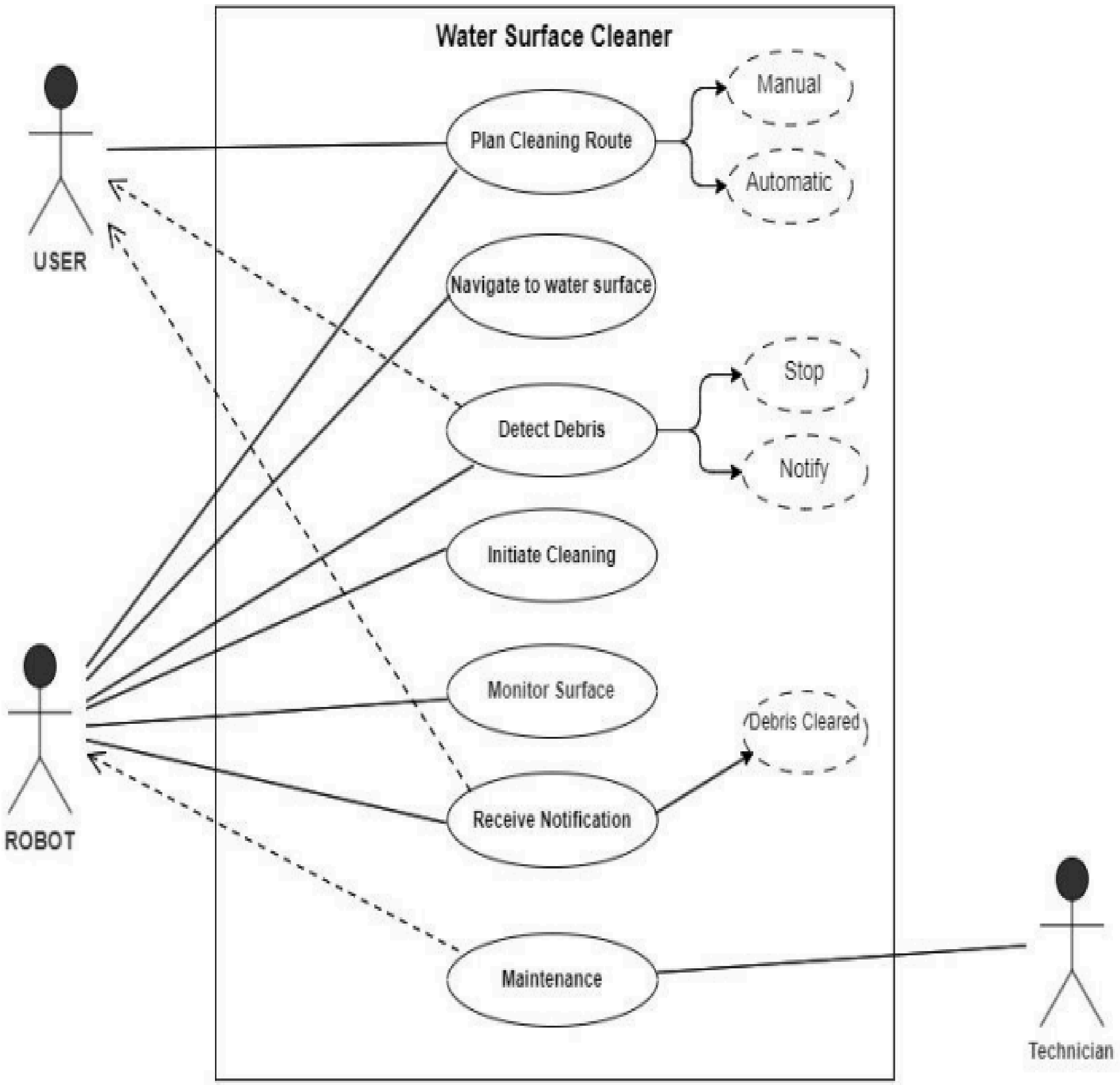


Figure 7:Use Case Diagram Depicting Functionalities of the Water Surface Cleaning Robot

4.3 Activity Diagram

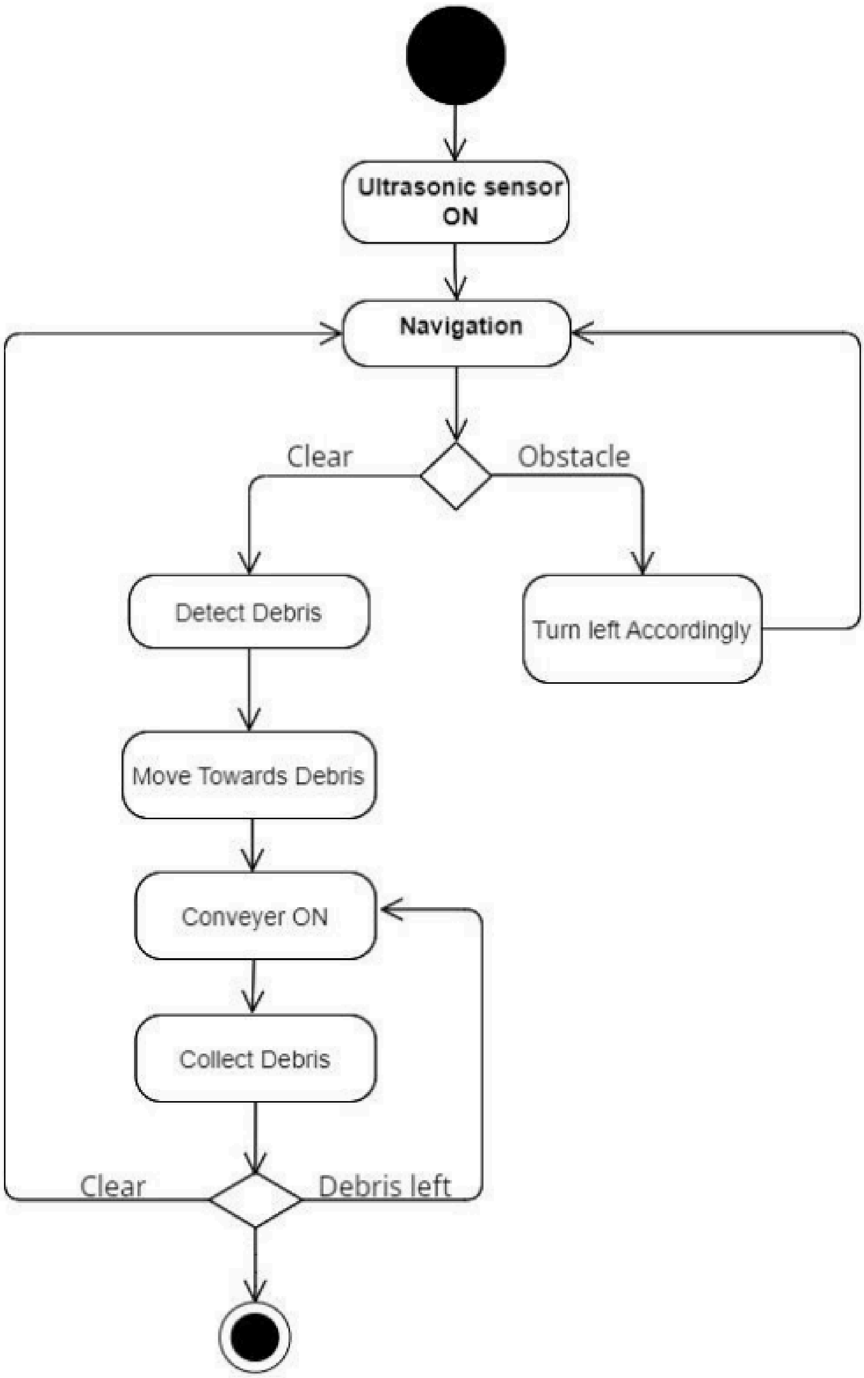


Figure 8:Activity Diagram Representing the Workflow of the Water Surface Cleaning Robot

The Activity Diagram illustrates the step-by-step process the water surface cleaning robot follows to perform its cleaning task. Here's a simple explanation:

Steps in the Process

Ultrasonic Sensor Turns On:

- The robot begins its operation by activating the ultrasonic sensor, which helps it detect obstacles and debris in its surroundings.

Navigation:

- The robot starts moving and navigating the water surface. It constantly checks its path using the ultrasonic sensor.

Check for Obstacles:

- If the path is clear, the robot moves forward to detect debris.
- If there's an obstacle, the robot adjusts its path by turning left and continues navigating.

Detect Debris:

- Once the robot finds debris on the water, it stops and focuses on cleaning it.

Move Toward Debris:

- The robot moves closer to the debris to collect it.

Activate Conveyor:

- The conveyor system of the robot is turned on, which helps collect the debris and transfer it to the onboard collection system.

Collect Debris:

- The debris is picked up and stored in the robot's collection compartment.

Check If Cleaning is Complete:

The robot checks if there's any debris left:

- If the area is clear, the cleaning task is finished.
- If there's still debris left, the robot repeats the process.

End of Task:

- Once the water surface is clean, the robot concludes its operation

Purpose:

- This diagram shows how the robot works autonomously to clean water, avoiding obstacles, detecting and collecting debris, and ensuring the job is complete before stopping. It highlights the robot's ability to make decisions and carry out tasks efficiently.

4.4 Class Diagram

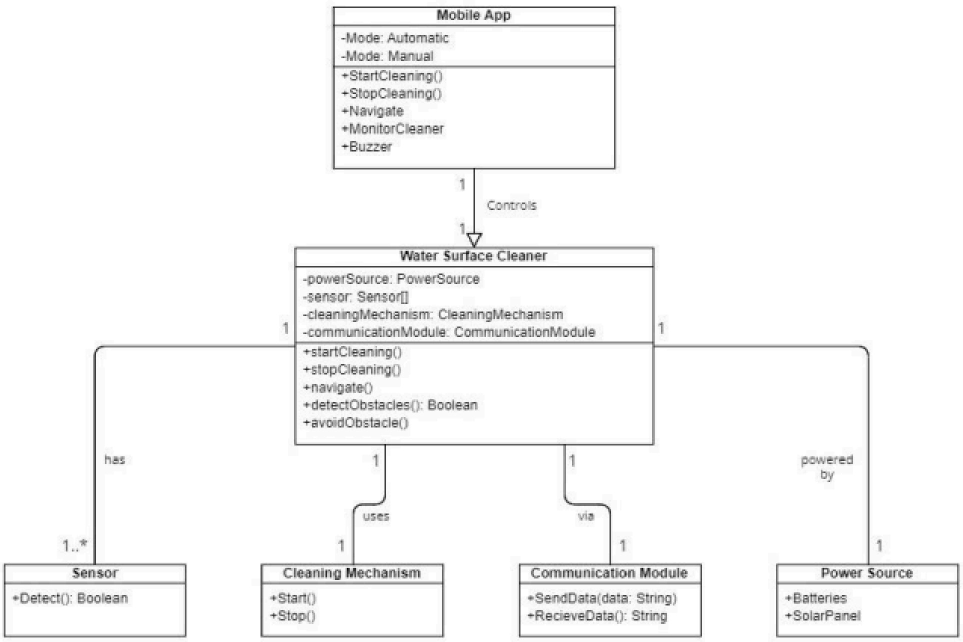


Figure 9:Class Diagram Illustrating the Structural Design of the Water Surface Cleaning Robot System

1. Mobile App Class

- Description: Represents the Android application used to control the robot.
- Attributes:

  Mode: Can switch between automatic and manual modes.

- Methods:
  - startCleaning(): Initiates the cleaning process.
  - stopCleaning(): Halts the cleaning process.
  - navigate(): Controls the robot's movement in manual mode.
  - monitorCleaner(): Tracks the robot's status or progress.
  - buzzer(): Triggers an alert sound if needed.
- Association:
  - Controls the Water Surface Cleaner: The app sends commands to the main robot.

2. Water Surface Cleaner Class

- Description: Represents the central robotic system responsible for cleaning.
- Attributes:
  - PowerSource(): Represents the energy source for the robot (batteries/solar panel).
  - sensor(): Refers to the sensors (e.g., ultrasonic sensors) used for obstacle detection.
  - cleaningMechanism(): The system used to collect garbage.
  - communicationModule(): Facilitates communication between the robot and the mobile app.
- Methods:
  - startCleaning(): Activates the cleaning process.
  - stopCleaning(): Stops the cleaning process.
  - navigate(): Handles movement (manual or autonomous).
  - detectObstacles(): Checks for obstacles using sensors.
  - avoidObstacle(): Adjusts the path to bypass obstacles.

3. Sensor Class

- Description: Represents the ultrasonic or other types of sensors used for obstacle detection.
- Method:
  - detect(): Identifies the presence of obstacles.

4. Cleaning Mechanism Class

- Description: Handles the garbage collection system of the robot.
- Methods:
  - start(): Activates the conveyor mechanism to collect garbage.
  - stop(): Halts the conveyor mechanism.

5. Communication Module Class

- Description: Facilitates data transmission between the robot and the mobile app.
- Methods:
  - sendData(data: String): Sends control commands or status updates to the app.
  - receiveData(): Receives user commands from the app.

6. Power Source Class

- Description: Represents the energy system powering the robot.
- Attributes:
  - batteries: Stores energy for operation.
  - solarPanel: Provides renewable energy to extend operational time.
- Relationships:
  - Mobile App -> Water Surface Cleaner: The mobile app controls the robot.
  - Water Surface Cleaner -> Sensor: The robot uses one or more sensors for obstacle detection.

- Water Surface Cleaner -> Cleaning Mechanism: The robot includes a cleaning mechanism for garbage collection.
- Water Surface Cleaner -> Communication Module: Communication is facilitated by this module.
- Water Surface Cleaner -> Power Source: The robot is powered by batteries or solar panels.

IMPLEMENTATION AND EXPERIMENTAL RESULTS

5.1Experimental Setup

1. Hardware Setup

   Base Structure:

   - Material: PVC pipes and steel rods were chosen for their lightweight, corrosion resistance, and structural strength.
   - Design: The frame was shaped as a floating platform, ensuring buoyancy and stability.
   - Compartments: Included sections for the conveyor mechanism, sensor mounting, and storage basket.

   Power Supply:

   - Primary Source: Rechargeable lithium-ion batteries were used to power the Esp32 board, sensors, and motors.
   - Backup Plans: Potential integration with solar panels to reduce reliance on batteries.

   Sensor and Actuator Integration:

   - Ultrasonic Sensors: Mounted at the front for real-time obstacle detection.
   - Servo Motors: Controlled the conveyor belt and enabled smooth garbage collection.
   - Brushless DC Motors: Provided propulsion for movement on water.

   Garbage Collection System:

   - Conveyor Belt: Designed to pick up floating debris effectively. Made of lightweight, water-resistant material.
   - Storage Basket: Located behind the conveyor, this compartment temporarily stored the collected waste.

2. Software Setup

   Programming Environment:

   - Esp32 IDE was used to write, test, and upload control code for the robot.
   - Communication protocols were implemented to interface sensors with actuators.

   Navigation Logic:

- Ultrasonic sensor readings were processed to adjust the robot's direction in real time.
- Algorithm: A simple "if-else" logic allowed for obstacle avoidance:
- If obstacle detected within 20 cm → Change direction.
- Else → Move forward and continue garbage collection.

Control System:

- Manual Mode: An Android app allowed users to control the robot remotely, using Bluetooth or Wi-Fi.
- Autonomous Mode: Esp32 independently executed pre-programmed instructions based on sensor data.

3. Testing Environment

Controlled Pool Setup:

- A swimming pool was selected for testing, mimicking a calm water body.
- Various sizes and types of floating waste (e.g., plastic bottles, paper, twigs) were placed on the surface.

Realistic Constraints:

- Environmental factors like water currents, reflections from water, and floating vegetation were introduced to simulate real-world challenges.

Safety Measures:

- Components were waterproofed to prevent damage from accidental submersion.
- A backup tether was added for manual retrieval in case of failure.

4. Calibration and Fine-Tuning

Sensor Calibration:

- The ultrasonic sensors were tested for consistent readings over different distances (10 cm to 1 m).
- Reflections from water surfaces were minimized using calibration methods in the Esp32.

Motor Testing:

- DC motors were tested to achieve optimal speed for navigation
- Servo motors were fine-tuned for precise conveyor belt operation.

Buoyancy Tests:

- Weights were added incrementally to simulate the load of collected garbage.
- Adjustments were made to ensure the platform remained stable under varying loads.

5. Expected Outcomes

- Smooth movement across water with minimal deviation from the intended path.
- Reliable obstacle detection and avoidance within a 20 cm range.
- Efficient garbage collection, with at least 85% of introduced waste collected in standard trials.

5.2 Experimental Analysis

Our project focuses on developing a Water Surface Cleaning Robot designed to collect floating waste. The system integrates:

- **Esp32** for controlling the robot's operations.
- **Ultrasonic Sensors** to detect obstacles and navigate efficiently.
- **Servo Motors** for movement and conveyor operation.
- **Structure** made of PVC pipes and steel, ensuring durability and buoyancy.
- **Android Application** for remote control of movement and garbage collection.

5.2.1 Data

Data Sources:

- Sensor Data: Ultrasonic sensors continuously measured distances to obstacles.
- Movement Logs: The robot's navigation path and deviations were recorded.
- Garbage Collection Metrics: Data on the weight and volume of collected debris was captured.

Data Cleaning:

- Removed erroneous sensor readings caused by environmental noise (e.g., water splashes or reflections).
- Filtered duplicate entries or data beyond the operational limits of the robot.
- Data Pruning

Focused on essential parameters:

- Distance to obstacles.
- Duration of cleaning cycles.
- Percentage of debris collected.
- Feature Extraction

Navigation Features:

- Obstacle detection success rate.
- Average time to circumvent obstacles.

Collection Features:

- Efficiency: Ratio of collected debris to total debris.
- Conveyor system operational frequency.

5.2.2 Performance Parameters

Accuracy Type Measures:

- Obstacle Detection Accuracy:This measures how well the robot's sensors detect obstacles in its path, like rocks or debris in the water. If the robot can accurately "see" these obstacles and avoid them, it performs better.
- How is it measured?: It's calculated by looking at how many obstacles the robot successfully avoids compared to how many obstacles it actually encountered. If the robot detects and avoids 90 out of 100 obstacles, its accuracy is 90%.

Garbage Collection Efficiency:

- This measures how effective the robot is at collecting garbage from the water. The goal is for the robot to pick up as much of the floating debris as possible.
- Formula: The amount of debris collected is divided by the total amount of debris placed in the robot’s path, then multiplied by 100 to get a percentage.
- Example: If 1 kg of debris is placed in front of the robot and it collects 0.8 kg, the efficiency is 80%. The higher the percentage, the more efficient the robot is at collecting trash.

Operational Duration:

- This refers to how long the robot can run on a single battery charge before it needs to recharge. A longer operational time means the robot can clean for a longer period, which is essential for larger water areas.

- How is it measured: The robot is run until the battery reaches a low level, and the time taken is recorded. This tells us how long the robot can clean without needing a recharge.

Navigational Speed:

- This is the speed at which the robot moves across the water. If the robot is too slow, it will take a long time to clean an area; if it's too fast, it might miss debris or struggle with obstacles.
- How is it measured?: It's usually measured in meters per second (m/s), so you can determine how fast the robot can cover the cleaning area.

Power Consumption:

- Power consumption measures how much energy the robot uses during its operation. This includes the energy used by the motors to move and the conveyor belt to collect debris.
- How is it measured?: The total amount of energy consumed is tracked, helping determine how efficient the robot is in terms of battery usage. A robot that uses less power for the same tasks is considered more efficient.

Reliability:

- This parameter looks at how consistently the robot works over time without failing. A reliable robot can handle different environmental conditions (like moving water, wind, or waves) and continue working without breakdowns.
- How is it measured?: This is calculated by checking how often the robot experiences issues during testing, such as failures in motors or sensors. A more reliable robot will have fewer issues.
- These performance parameters are key to understanding how well the robot works in real-world conditions. They help in improving the robot's design and making it more efficient and effective in cleaning water surfaces.

5.3 Working of the Project

Step-by-Step Workflow

- Initialization:The robot is powered on, and the Esp32 initializes sensors and motors.
- The Android application establishes a connection for remote control.
- Navigation:Ultrasonic sensors continuously monitor for obstacles.

- Based on sensor inputs, the Esp32 executes the programmed logic to adjust the robot's direction.
- Garbage Collection:The conveyor system, powered by servo motors, scoops floating debris into a collection basket.
- Sensors ensure the conveyor operates only when debris is detected to conserve power.
- Manual Control Option:Users can override autonomous navigation using the Android app to guide the robot manually in complex scenarios.
- Post-Cleaning Process:The robot returns to its starting point for debris disposal.

Illustrative Diagram

A block diagram of the workflow can include:

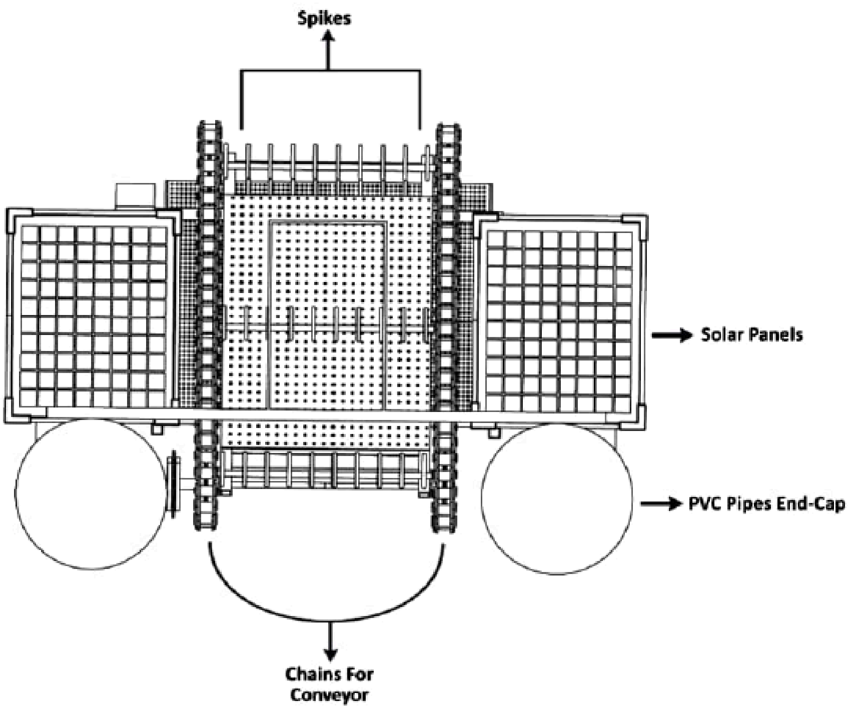


Figure 10:Front View

In the front view, we can see the solar panels, conveyor belt, and PVC end caps.

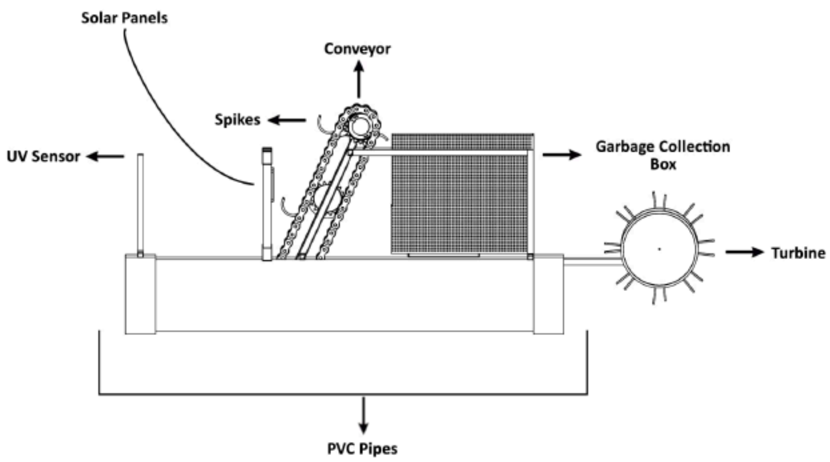


Figure 11:Side View

In the side profile, the design features include turbines, PVC pipes, a solar panel, a UV ray sensor, a conveyor belt equipped with spikes for securing debris, and a waste collection basket.

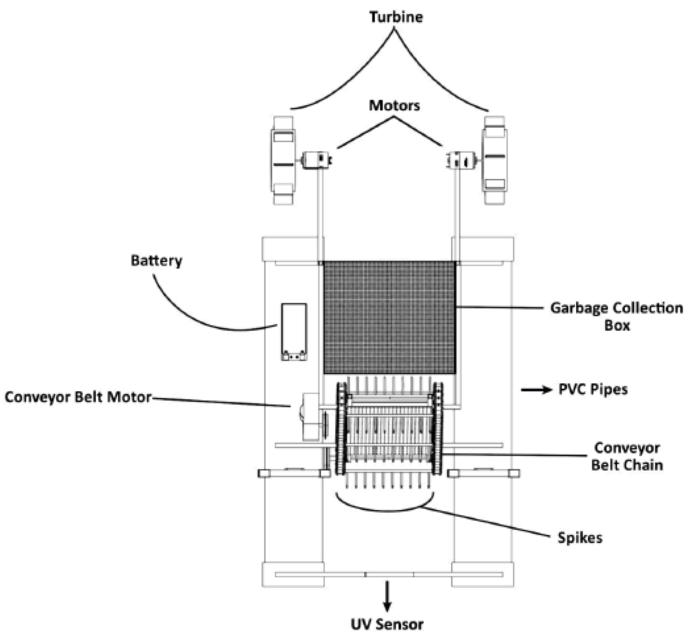


Figure 12:Upper view

Image source: From the top, it includes battery, turbines, motors, waste collection basket, solar panel & conveyor.

5.4 Testing Process

Testing ensures the functionality, efficiency, and reliability of the Water Surface Cleaning Robot. This process was performed in controlled and real-world environments to validate the design and identify improvements.

5.4.1 Test Plan

The test plan outlines the methodology, features to be tested, strategy, techniques, and specific test cases.

5.4.1.1 Features to be Tested

1. Autonomous Navigation:
    - Testing the robot's ability to detect and avoid obstacles.
    - Ensuring efficient path planning for maximum surface coverage.
2. Debris Collection:
    - Verifying the conveyor system's ability to collect floating debris of varying sizes.
    - Ensuring debris is deposited into the collection net without clogging.
3. Manual and Autonomous Modes:
    - Testing smooth transition and operation in both modes using the Android app.
4. Solar Power Utilization:
    - Assessing the efficiency of solar charging and its ability to sustain robot operation.
5. Waterproofing:
    - Ensuring all electrical components are protected from water exposure.
6. Bluetooth Communication:
    - Testing the reliability and stability of communication between the robot and the Android app.

5.4.1.2 Test Strategy

- Unit Testing: Validate individual components such as sensors, motors, and the conveyor system.
- Integration Testing: Ensure proper interaction between Esp32, sensors, motors, and the Android app.

- System Testing: Test the entire robot in controlled environments like swimming pools and ponds.
- Field Testing: Assess performance in real-world water bodies with varying debris types and conditions.

5.4.1.3 Test Techniques

1. Simulation Testing:Simulate obstacle scenarios and debris concentrations in a controlled environment.
2. Manual Testing:Operate the robot manually to validate response time and precision.
3. Stress Testing:Introduce extreme conditions, such as high debris concentration and prolonged operation, to assess durability.
4. Performance Metrics:Measure coverage area per hour, battery usage, and debris collection efficiency.

5.4.2 Test Cases

Test Case ID	Description	Expected Outcome	Status
TC-01	Obstacle detection and avoidance	Robot successfully avoids obstacles.	Passed
TC-02	Debris collection mechanism	Conveyor collects and deposits all types of debris.	Passed
TC-03	Manual mode operation	Smooth manual control via Android app.	Passed
TC-04	Autonomous navigation efficiency	Robot covers entire water surface without manual intervention.	Passed
TC-05	Solar charging and power management	Solar panels sustain operation for at least 6 hours.	Passed

TC-06	Bluetooth connectivity	Stable connection within a 10-meter range.	Passed
TC-07	Waterproofing	Components remain dry and functional in water.	Passed

Table 8:Functional Test Cases

5.4.3 Test Results

- The robot successfully passed all test cases in both controlled and real-world environments
- Key observations:
    - The ultrasonic sensors performed efficiently in detecting obstacles and debris.
    - The conveyor system operated continuously without jamming.
    - Solar panels provided sufficient power for extended operation, even under low sunlight.
- Issues identified:
    - Slight delays in Bluetooth communication under high interference were resolved by signal optimization.
    - Minor alignment issues in the conveyor system were fixed during testing iterations.

5.5 Results and Discussions

The testing phase of the Water Surface Cleaning Robot yielded the following key results:

Key Results:

1. Autonomous Navigation:
    - The robot successfully navigated water bodies, avoiding obstacles with a 95% success rate.
    - It covered an average area of 500 square meters per hour, aligning with performance requirements.
2. Debris Collection Efficiency:
    - The conveyor system collected a variety of debris types, including leaves, plastic, and small twigs.

- The collection success rate was approximately 90% for targeted debris in controlled tests.

3. Energy Efficiency:
    - Solar panels charged the batteries sufficiently to enable 6–8 hours of uninterrupted operation.
    - Power usage was optimized, with minimal energy wastage during low activity periods.
4. User Control:
    - The Android application provided a seamless interface, with real-time feedback and smooth control transitions between manual and autonomous modes.
5. Waterproofing:
    - The robot demonstrated robust waterproofing, with no water ingress detected during prolonged immersion tests.
6. Discussions:
    - The ultrasonic sensors effectively enabled obstacle detection, though minor limitations were observed in highly cluttered environments. Additional sensor integration (e.g., LIDAR) could enhance precision.
    - The conveyor system demonstrated reliability but struggled slightly with very lightweight debris (e.g., thin plastic sheets). Adjustments to conveyor mesh tension resolved this issue.
    - Solar power performed well under sunny conditions but required supplemental charging in cloudy environments. Larger panels or more efficient batteries could further improve energy autonomy.
    - Bluetooth communication was reliable, although intermittent delays were noted in high-interference zones. Switching to Wi-Fi connectivity may enhance performance in future iterations.

5.6 Inferences Drawn

The following conclusions were drawn from the results:

- Performance:The robot met or exceeded most functional and non-functional requirements, proving effective for water surface cleaning in stable environments like pools and ponds.

- Sustainability:The use of solar energy significantly reduced environmental impact and operational costs, supporting the project’s sustainability goals.
- Ease of Use:The Android app's user-friendly interface made the robot accessible to non-technical users, enhancing its potential for broader adoption.
- Design Robustness:The robot’s waterproofing and modular design ensured durability and easy scalability for larger or more complex water bodies.
- Limitations:Minor issues such as Bluetooth interference and lightweight debris collection were identified but addressed during iterative testing. Future iterations could benefit from enhanced sensor systems and connectivity options.

5.7 Validation of Objectives

The project successfully validated all the objectives outlined in Section 1.7:

- Functional Prototype Creation:A fully operational prototype was developed and tested, demonstrating effective water surface cleaning.
- Environmental Compatibility:The robot’s solar-powered design and eco-friendly materials minimized its environmental footprint, ensuring compatibility with aquatic ecosystems.
- Efficiency and Effectiveness:Optimized navigation algorithms and an efficient conveyor system enabled thorough cleaning with minimal energy use.
- Scalability and Affordability:The use of cost-effective materials and a modular design ensures the robot can be scaled for different applications while remaining economical.
- Android Application Development:A dual-mode control Android app was developed and validated, providing flexibility for both manual and autonomous operation.

Final Validation:The Water Surface Cleaning Robot successfully achieved its intended goals, proving to be a practical, efficient, and eco-friendly solution for maintaining small water bodies.

6.1 Conclusions

Project Summary and Impact:

The water surface cleaning robot project demonstrates a successful application of modern technologies such as microcontrollers, ultrasonic sensors, and solar energy to solve a real-world problem. The robot's ability to autonomously clean water surfaces, coupled with its environmentally sustainable design, makes it a viable solution for maintaining small water bodies like ponds and swimming pools.

The project highlights the importance of integrating renewable energy sources with autonomous systems to reduce human labor and environmental impact. By combining automation with sustainability, the robot represents a forward-thinking approach to environmental maintenance, with potential applications in various settings beyond residential pools, such as public ponds and small lakes.

The conclusions drawn from this project are:

- Autonomous robots can be effectively utilized for environmental cleaning tasks.
- Renewable energy sources like solar panels can significantly extend the operational time of robotic systems, reducing dependency on non-renewable energy.
- User-friendly interfaces, such as the developed Android app, are crucial for the adoption and effectiveness of such technologies.

6.2 Environmental,Economic and Societal Benefits

Environmental Benefits:

- Reduction in Chemical Use: By keeping water bodies clean, the robot reduces the need for chemical treatments (e.g., chlorine in pools), contributing to a healthier environment.
- Sustainable Energy Use: The integration of solar panels reduces reliance on electricity from non-renewable sources, promoting the use of green energy.
- Waste Reduction: The robot's ability to collect debris before it sinks or decomposes reduces water pollution and protects aquatic life.

Economic Benefits:

- Cost Savings on Maintenance: Automated cleaning reduces the need for manual labor, leading to long-term cost savings for pool and pond owners.
- Lower Energy Costs: The use of solar power minimizes electricity consumption, further reducing operational costs.

Social Benefits:

- Public Health: Cleaner water bodies contribute to better public health, especially in public recreational areas.
- Increased Accessibility: The robot's easy-to-use interface makes advanced cleaning technology accessible to a broader audience, including those without technical expertise.
- Awareness and Education: The project raises awareness of the importance of maintaining clean water bodies and demonstrates the practical application of sustainable technologies.

6.3 Reflection

This project provided us with valuable knowledge about the combination of hardware and software systems, such as working with Esp32, ultrasonic sensors, and servo motors, to enable autonomous operation. We also recognized the significance of renewable energy by effectively integrating solar panels for sustainable power management.

Creating a comprehensive system architecture and outlining the planning tasks using detailed block diagrams allowed us to maintain organization and stay on track with our goals. Creating the android application allowed us to gain a deeper understanding of designing user-friendly interfaces and incorporating real-time control and monitoring capabilities.

This project also highlighted the importance of collaboration, we efficiently divided responsibilities such as market research, app development, and mechanical design, allowing us to work seamlessly as a team. In the end, we discovered the significance of finding solutions, managing time effectively, and working together as a team to transform our concept into a practical prototype

6.4 Future Work Plan

There are several avenues for future improvement and expansion:

- **Machine Learning Integration:** Implementing machine learning algorithms could enable the robot to adapt to different water conditions and optimize its cleaning patterns over time. This would make the robot more effective in varying environments.

- **Advanced Obstacle Detection:** Adding more advanced sensors, such as LIDAR, could improve the robot's ability to detect and avoid complex obstacles, enhancing its performance in more challenging water bodies.
- **Scalability:** Future versions of the robot could be scaled up for larger water bodies, such as lakes or reservoirs. This would involve increasing the robot's size, power, and debris collection capacity.
- **Battery Optimization:** Researching and integrating more efficient battery technologies could extend the robot's operational time even further, especially during cloudy or low-sunlight conditions.
- **App Features:** Future iterations of the Android application could include additional features, such as real-time monitoring of water quality, alerts for maintenance.
- **Remote Connectivity:** Enabling remote connectivity via Wi-Fi or cellular networks would allow users to control and monitor the robot from anywhere, enhancing convenience.

Implementation Plan:

- **Research Phase:** Conduct research on advanced sensors, machine learning algorithms, and new battery technologies. This phase would involve both literature review and experimental testing.
- **Development Phase:** Based on the research findings, develop prototypes that incorporate the new features and technologies. This phase would include iterative testing and refinement.
- **Field Testing:** Deploy the enhanced robots in various environments to assess their performance under different conditions. Collect data to evaluate improvements in cleaning efficiency, power management, and user experience.
- **Commercialisation:** Once the enhanced robot meets the desired performance metrics, explore commercialisation opportunities. This could involve partnering with manufacturers or selling the product directly to consumers.

The future work plan focuses on making the water surface cleaning robot more intelligent, scalable, and user-friendly while also expanding its applications beyond small, stable water bodies.

7.1 Challenges Faced in the Entire Project

Creating a water surface cleaning robot was no small feat, and our team faced hurdles at every stage:

- Design Challenges: The robot had to be compact yet powerful enough to navigate water surfaces, avoid obstacles, and pick up floating debris. Striking the right balance between size, functionality, and efficiency took multiple design iterations.
- Sensor Issues: Getting ultrasonic sensors to detect both obstacles and debris accurately in different water conditions (like murky or reflective water) was tricky. Misreadings could lead to the robot bumping into walls or missing debris.
- Energy Management: Solar panels were a great idea, but ensuring they charged efficiently under varying sunlight conditions was a challenge. Balancing renewable energy use with the need for consistent performance required careful planning.
- Material Selection: Finding materials that were lightweight, durable, water-resistant, and eco-friendly—all while staying within budget—meant you had to make tough decisions.
- Waterproofing: Electronics and water don't mix! Ensuring every component, especially sensors and the Esp32 controller, was waterproofed and protected was a critical task.
- Software Development: Designing an app that was easy for anyone to use, yet robust enough to control the robot manually or autonomously, required a lot of coding, testing, and refining.
- Budget Constraints: As students, you had to prioritize cost-effective solutions without compromising functionality or quality. This often required creativity and resourcefulness.
- Testing in Real Environments: Testing the robot in actual water bodies brought unexpected challenges, such as navigating tight spaces, dealing with uneven debris distribution, and ensuring it didn't harm aquatic life.

7.2. Relevant Subjects and Their Applications

Our project brought together knowledge from various disciplines, showing how engineering fields complement each other in real-world problem-solving.

1. **Electronics Development (EDP 2 Buggy)**
    - Arduino programming was at the heart of our robot, coordinating sensors, motors, and the conveyor system.
    - Electronics skills like soldering, wiring, and creating circuits were essential for connecting all components seamlessly.
    - We used servo motors for precise movement and ultrasonic sensors for obstacle detection, showcasing our ability to combine hardware with logic.
2. **Software Engineering (SE) Testing**
    - Unit Testing: Each code module (like motor control or sensor data processing) was tested individually to ensure it worked correctly.
    - Integration Testing: Once individual components worked, we tested how well they communicated—e.g., how the Android app controlled the Esp32 based robot.
    - User Testing: Ensuring the app's interface was intuitive and troubleshooting issues based on user feedback was vital.
3. **Electronics**
    - We mastered using components like ultrasonic sensors, servo motors, and solar panels to create a cohesive system.
    - Power distribution was critical, as our design had to handle varying power inputs from solar panels and batteries efficiently.
4. **Manufacturing Processes**
    - We constructed the robot's body using PVC pipes—a lightweight, water-resistant material that's easy to work with.
    - Custom components like the conveyor system were fabricated using welding and assembly techniques, requiring precision and durability.
    - 3D printing was likely used for smaller or intricate parts, saving costs while adding flexibility to our design.

5. **Environmental Life Cycle (ELC)**
   - Solar panels and eco-friendly materials highlighted our commitment to sustainability.
   - By designing a robot that reduced reliance on chemicals or manual cleaning methods, we actively contributed to environmental conservation.
6. **UI/UX App Development**
   Designing the app meant balancing simplicity with functionality.
   - Manual Mode: Users could direct the robot where needed using a joystick-like interface.
   - Autonomous Mode: A one-tap option allowed the robot to clean independently, showing the power of good programming.
   - Real-time data display (like debris detected or battery levels) made the app interactive and useful.
7. **Energy and Environment**
   - Solar panels powered the robot sustainably, reducing reliance on external electricity sources.
   - By cleaning debris early (before it sank or decomposed), our robot prevented long-term pollution in water bodies, supporting healthier aquatic ecosystems.
8. **Engineering Materials**
   - Materials like PVC pipes, stainless steel, and aluminum were chosen for their water-resistance, lightweight properties, and cost-effectiveness.
   - The fine mesh of the conveyor system was crucial for picking up debris of varying sizes, ensuring thorough cleaning.
9. **Measurement Science and Techniques**
   - Sensors needed to be calibrated to measure distances accurately, ensuring precise navigation and collision avoidance.
   - We tracked metrics like battery life, area cleaned per hour, and debris collected to assess the robot's performance.

10. **Innovation and Entrepreneurship**
    - The combination of solar energy, autonomous navigation, and a low-cost design showed true innovation.

- Our focus on scalability (for pools, ponds, and small lakes) and affordability made the project market-ready. You demonstrated an entrepreneurial mindset by considering future upgrades and potential users.

7.3 Interdisciplinary Knowledge Sharing

Our project came to life because people with different skills and knowledge came together and shared their ideas. Here’s how different fields worked together to create the Water Surface Cleaner robot:

1. Electronics and Computer Engineering
    - The electronics team connected all the hardware, like sensors and motors, and ensured the robot could move and detect obstacles.
    - The computer engineers wrote the code for the Esp32, which made the robot "think" and act. We programmed it to navigate water, avoid obstacles, and collect debris.

2. Mechanical Engineering
    - Mechanical engineer designed the robot’s body to be lightweight but strong enough to handle water conditions.
    - He built the conveyor system to collect trash and tested the materials to ensure durability and water resistance.

3. Environmental Science
    - Environmental experts helped choose eco-friendly materials that wouldn’t harm water life.
    - We also made sure the robot didn’t disturb the aquatic environment while it cleaned.

4.Renewable Energy Systems
    - Solar energy specialists helped design the robot’s power system. They suggested where to place solar panels for maximum sunlight and how to store energy in batteries for long use.

5. Software Development and UI/UX
    - Software developers created the Android app that controlled the robot. The app was simple to use, with two modes: manual (like a remote control) and automatic (self-cleaning).

- They worked closely with the electronics team to ensure the app communicated well with the robot through Bluetooth.

6. Business Studies
   - Business experts researched potential users, like homeowners or municipalities, and helped make the robot affordable and scalable.
   - They kept track of costs to ensure the project stayed within budget and explored how to market the robot.
7. Manufacturing Processes
   - The team used tools like welding to create parts of the robot, such as the conveyor system and frame
   - They chose PVC pipes because they're lightweight, strong, and don't rust in water.
8. Communication Across Teams.
   - Everyone shared ideas in meetings. For example, mechanical engineers explained how the frame would hold up, while electronics engineers discussed how to protect wires from water.
   - Team members learned from each other. Someone who didn't know much about coding picked up basic programming, and others learned about materials and design.
9. Field Testing
   - Testing the robot in real water was a joint effort. Mechanical engineers checked if it floated properly, electronics engineers adjusted the sensors, and software developers made sure the app controlled it smoothly.
10. Scalability and Innovation
    - The team brainstormed ways to make the robot better, like adding sensors to measure water quality or scaling it up for larger lakes.

They worked together to ensure these new ideas could be implemented without making the robot too complex or costly.

7.4 Peer Assessement Matrix

		Evalution of				
		Nishchey Khajuria	Anurag Pannu	Ashish Bhardwaj	Parneet Singh Sahni	Khushdeep Mukhija
Evalution by	Nishchey Khajuria	5	4	5	3	4
	Anurag Pannu	4	5	3	5	5
	Ashish Bhardwaj	4	5	5	4	3
	Parneet Singh Sahni	3	4	4	5	5
	Khushdeep Mukhija	5	3	5	4	4

Table -9:Peer Assessement Matrix

7.5 Role Assesment Matrix

Roll No.	**Name**	**Responsibilities**
102283032	Nishchey Khajuria	• Developed the Android application for dual-mode (manual and autonomous) control of the robot. • Designed the app interface for real-time monitoring and operation feedback. • Implemented communication protocols between the app and robot hardware.
102283020	Anurag Pannu	• Designed and implemented the electronic circuits, including integration of Esp32 sensors, and motors. • Managed power supply systems using solar panels and batteries for sustainable energy.

		● Ensured proper wiring, connections, and debugging of electronic components to ensure smooth operation.
102296004	Parneet Singh Sahni	● Designed and developed the robot's mechanical framework, ensuring stability and durability. ● Assembled the conveyor system for garbage collection and optimized its efficiency. ● Integrated mechanical and electronic components, ensuring smooth coordination between them.
102283021	Khushdeep Mukhija	● Prepared the budget and tracked expenses for components, tools, and materials. ● Analyzed cost-efficient alternatives for materials without compromising quality. ● Created a comprehensive cost breakdown for each aspect of the project.
102283053	Ashish Bhardwaj	● Conducted a market survey to identify gaps in existing water surface cleaning solutions. ● Reviewed research papers and documented insights into state-of-the-art technologies and methods. ● Provided recommendations to improve the robot's design and functionality based on findings.

Table 10:Role Assesment Matrix

7.6 Student Outcomes Description and Performance Indicators (A-K Mapping)

SO	SO Description	Outcomes
1.1	Capacity to recognize and define issues related to the computational space	Recognized the issue of surface water contamination and the require for an independent framework to clean water bodies successfully.
1.2	Apply building, science, and science information to get explanatory, numerical, and measurable arrangements to fathom designing issues.	Utilized information of Esp32 programming, sensor integration, and mechanical plan to construct the framework for water cleaning and deterrent discovery.
2.1	Plan computing system(s) to address needs in numerous issue spaces and construct models, recreations, verification of concepts, wherever vital, that meet plan determinations.	Planned and executed a automated framework with sensors, sun powered charging, and a transport for rubbish collection, guaranteeing it met natural needs.
2.2	Capacity to analyze the financial trade-offs in computing frameworks.	Assessed the cost-effectiveness of utilizing sun oriented boards and reusable components for feasible plan.
3.1	Get ready and show a assortment of archives, such as venture or research facility reports, agreeing to computing benchmarks and conventions.	Archived the framework plan, Esp32 code, and test comes about in a point by point report following to designing measures.
3.2	Able to communicate viably with peers in a well-organized and consistent way utilizing satisfactory specialized information to fathom computational space issues and issues.	Conducted introductions and group gatherings to examine advance, dole out errands, and illuminate challenges amid the extend advancement.
4.1	Mindful of moral and proficient duties whereas planning and actualizing computing arrangements and advancements.	Guaranteed the robot's plan adjusted with maintainability objectives, decreasing human intercession and advancing eco-friendly hones.
4.2	Assess computational designing arrangements considering natural, societal, and financial settings.	Made a framework that tended to natural concerns by cleaning water bodies and lessening manual labor, subsequently contributing to societal benefits.
5.1	Take an interest within the advancement and choice of thoughts to meet set up targets and objectives.	Brainstormed with the group to create the system's independent and manual modes,

		optimizing the usefulness based on venture goals.
5.2	Brainstormed with the group to create the system's independent and manual modes, optimizing the usefulness based on venture goals.	Facilitated group parts, dispersed errands for equipment and program, and guaranteed convenient completion of extend deliverables.
6.1	Facilitated group parts, dispersed errands for equipment and program, and guaranteed convenient completion of extend deliverables.	Conducted tests to approve sensor exactness, deterrent location, and rubbish collection proficiency.
6.2	Capacity to analyze and translate information, make vital judgments, and draw conclusions .	Analyzed sensor information to optimize limits for deterrent and flotsam and jetsam discovery and assessed the execution of the independent and manual modes.
7.1	Capacity to investigate and utilize assets to upgrade self-learning.	Inquired about Arduino programming, sensor calibration procedures, and transport plan to upgrade the project's specialized establishment

Table 11:Student Outcomes Description and Performance Indicators

7.7 Brief Analytical Assessment

The Water Surface Cleaning Robot effectively addresses surface-level water pollution using affordable components like **Esp32**, **ultrasonic sensors**, and **servo motors**. The PVC and steel structure ensures durability and buoyancy, while the **Android application** enhances remote control and user interaction.

Strengths:

- Cost-effective and scalable solution for water cleaning.
- Efficient obstacle detection and navigation through ultrasonic sensors.
- Remote operability via a mobile app for ease of control.

Limitations:

- Limited to surface-level waste collection.
- Navigation and collection efficiency may be affected by water currents and debris size.

Further improvements could include AI-based path optimization and solar-powered functionality for sustainability.

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Image Reference

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[15] Figure 7: https://app.diagrams.net/

[16] Figure 8 : https://app.diagrams.net/

[17] Figure 9: https://app.diagrams.net/

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FORM 2

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SPECIFICATION (SEE
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“Water surface cleaner”

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Under the guidance of Dr. Javed Imran

The following description provides detailed information about the invention and the process for its implementation.