The Ocean Cleaner

Chapter 1: Introduction

1. General Introduction

This project aims to design and develop a Minimum Viable Product (MVP) of an autonomous boat to clean plastic waste from lakes and oceans. The boat features a dual-hull catamaran design and integrates sensors (LiDAR, GPS, gyroscope, camera), motors, and a Raspberry Pi 4 (8GB RAM) running Ubuntu 20.04 and ROS Noetic for autonomous navigation and waste detection. A virtual simulation using Gazebo 11 validates the design, and a mobile app enables remote monitoring.

Problem Statement

Plastic pollution in aquatic environments threatens marine life and ecosystems. Manual cleanup is labor-intensive and inefficient, necessitating autonomous solutions. The challenge lies in designing a stable, cost-effective boat that can navigate autonomously, detect plastic waste, and operate reliably in diverse water conditions.

Objectives

- Design a mechanically stable dual-hull boat prototype.
- Develop autonomous navigation using LiDAR, GPS, and gyroscope.
- Implement AI-based plastic waste detection using camera feeds.
- Simulate the boat's performance in Gazebo 11 with ROS Noetic.
- Create a mobile app for remote control and monitoring.

2. Existing solutions

Plastic pollution in aquatic environments(rivers, lakes, and oceans)has become a growing global concern. Millions of tons of waste, especially plastic, are dumped into water. Traditional cleanup methods are labor-intensive, costly, and often ineffective in hard-to-reach areas. As a result, there is an urgent need for innovative, automated, and scalable solutions to address this environmental crisis efficiently.

In recent years, projects such as **WasteShark** (Netherlands), **ClearBot** (Asia), and **Jellyfishbot** (France) have emerged.

2.a. WasteShark

Figure 2.a- WasteShark Boat Developed in the Netherlands

WasteShark, developed in the Netherlands, is a compact aquatic drone designed to clean ports and canals.

	WasteShark	Cleaning Boat
Dimensions	L: 1656mm H: 623mm W: 1182mm	L: 630mm H: 400mm W: 757mm
Weight	72Kg	7Kg

Propulsion	2x electric thrusters (4.1 kg f per thruster)	2x electric thrusters (1.3 kg f per thruster)
Mesh container	Located inside its hull	net attached to the back
Price	$25,600	$2,000
Autonomy	Up to 8 hours (in autonomous mode)	1 hour

Table 2.a – Technical Comparison Between WasteShark and Our Cleaning Boat

While WasteShark is a powerful and commercially available solution for cleaning water surfaces, it is designed for industrial use and comes at a high cost. In comparison, our prototype Cleaning Boat is significantly smaller, lighter (7 kg vs. 72 kg), and more affordable (approximately $2,000 vs. $25,600). Unlike WasteShark's internal metal mesh container, our boat uses a simple net attached to the back to collect floating waste as it moves, making it easier to construct and maintain with limited resources.

2.b. Clearbot Fetch(Class1)

ClearBot Fetch(Class 1), developed in Asia, is an AI-powered autonomous boat designed to detect and collect floating waste in coastal and urban waters.

	Clearbot Fetch(Class1)	Cleaning Boat
Dimensions	L: 1300mm W: 750mm H: 680 mm	L: 630mm W: 757mm H: 400mm
Weight	20 - 30Kg	7Kg
Propulsion	2x electric thrusters	2x electric thrusters (1.3 kg f per thruster)
Mesh container	Located inside its hull	net attached to the back
Price	$1,000	$2,000

Autonomy	None	1 hour
Payload Capacity	15Kg	10kg

Table 2.b – Technical Comparison Between ClearBot Fetch and Our Cleaning Boat

ClearBot Fetch (Class 1) is a compact, AI-powered boat designed for detecting and collecting floating waste in urban and coastal waters. It features an internal waste container, basic autonomy, and a lightweight structure of around 20–30 kg. In comparison, our prototype cleaning boat offers a similarly compact design but emphasizes accessibility and modularity. It is equipped with a **LiDAR sensor, camera, GPS, and onboard AI** running on a Raspberry Pi 4 to enable real-time waste detection and autonomous navigation. While ClearBot uses internal waste storage, our boat relies on a **rear-mounted net**, which simplifies the collection mechanism and reduces hardware complexity.

2.c. Jellyfishbot

Developed by **IADYS**, Jellyfishbot is a compact, remotely operated or autonomous surface robot used in marinas, ports, and lakes to collect waste.

	Jellyfishbot	Cleaning Boat

Dimensions	L: 700mm W: 700mm H: 480 mm	L: 630mm W: 757mm H: 400mm
Weight	20Kg	7Kg
Propulsion	3x electric thrusters 250W	2x electric thrusters 130W
Mesh container	net attached to the back	net attached to the back
Price	$15,000- 30,000	$2,000
Autonomy	2 up to 8 hours	1 hour

Table 2.b – Technical Comparison Between Jellyfishbot and Our Cleaning Boat

Jellyfishbot, developed by IADYS, is a compact and robust aquatic robot tailored for professional use in waste collection across ports and marinas. It features three powerful 250W thrusters for precise control and can operate autonomously for up to 8 hours. By comparison, Cleaning boat focuses on affordability, simplicity, and integration with open-source tools. While both boats use a net-based collection system, our prototype is significantly lighter and more compact, optimized for quick deployment and educational use.

Chapter 2: Mechanical Design

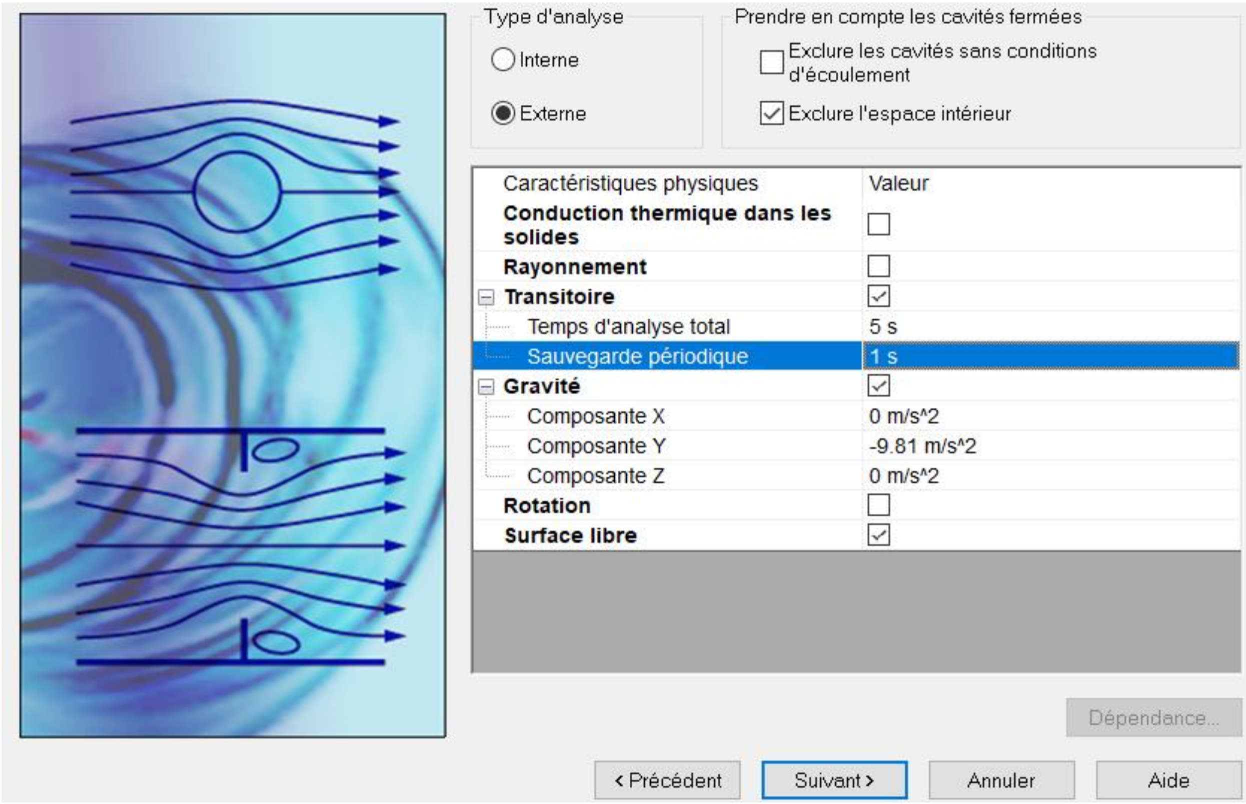
1. Introduction

The mechanical design of my cleaning boat is inspired by the streamlined and stable body of the whale shark. This marine creature, known for its wide and flat shape, served as a natural model to achieve high stability and low hydrodynamic resistance. Based on this inspiration, I designed a **catamaran-style boat** with two hulls, which provides both balance and space to mount electronic components. In this chapter, I present the mechanical choices I made regarding structure, dimensions, materials, and the use of simulation tools.

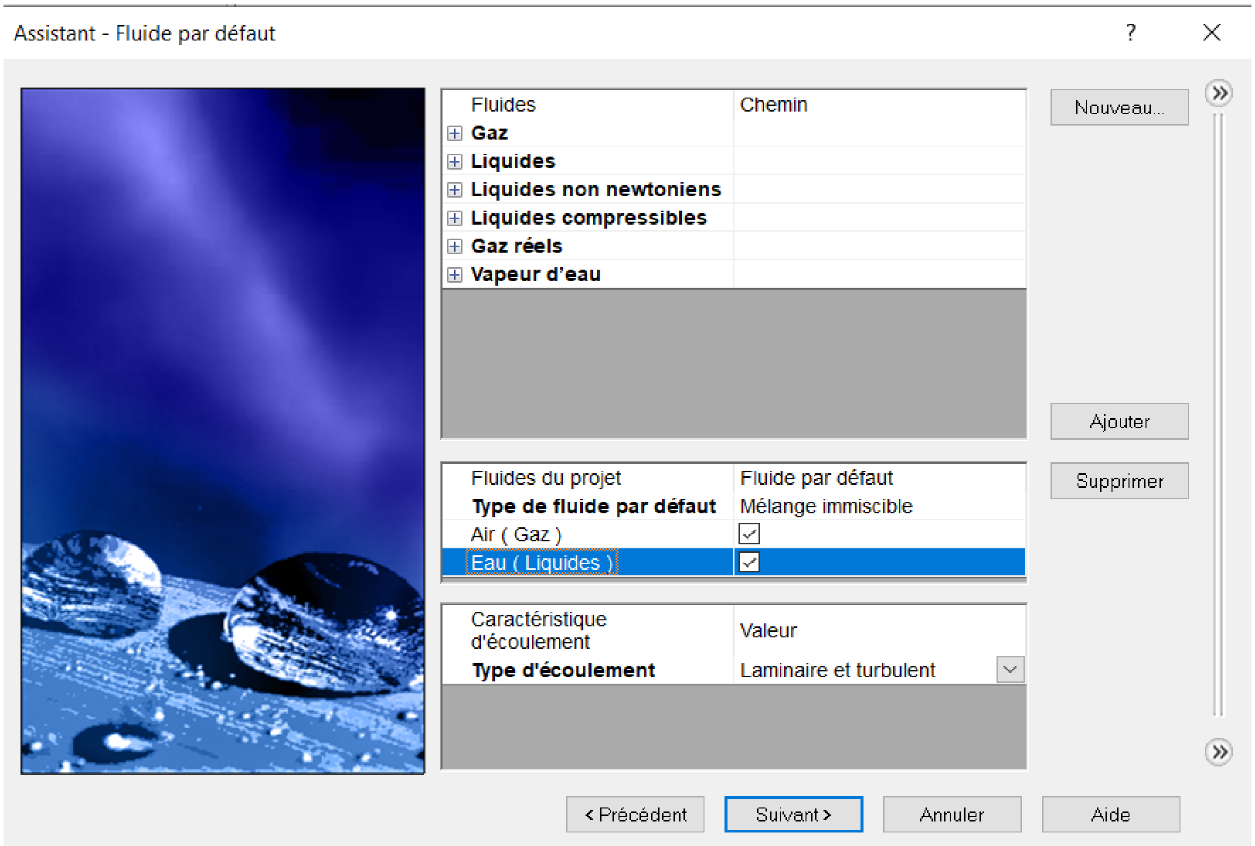
2. Structural Analysis

2.1) F low Simulation Setup

For the external flow analysis of the boat design, I selected **"External"** as the analysis type to focus on the interaction between the boat hull and the surrounding water and air. The **"Exclude internal space"** option was checked to ensure that only the outer geometry was considered in the simulation. Under **Physical Features**, I enabled the **"Transient"** simulation mode with a total analysis time of **10 seconds** and data saved every **2 seconds** to capture dynamic flow behavior over time. **Gravity** was activated with a **Y-component of -9.81 m/s^2**, reflecting standard Earth gravity acting downward, which is appropriate for the boat's orientation. Additionally, I enabled the **"Free Surface"** option to simulate the interface between water and air, which is crucial for accurately representing buoyancy, drag, and wave formation around the boat hull.

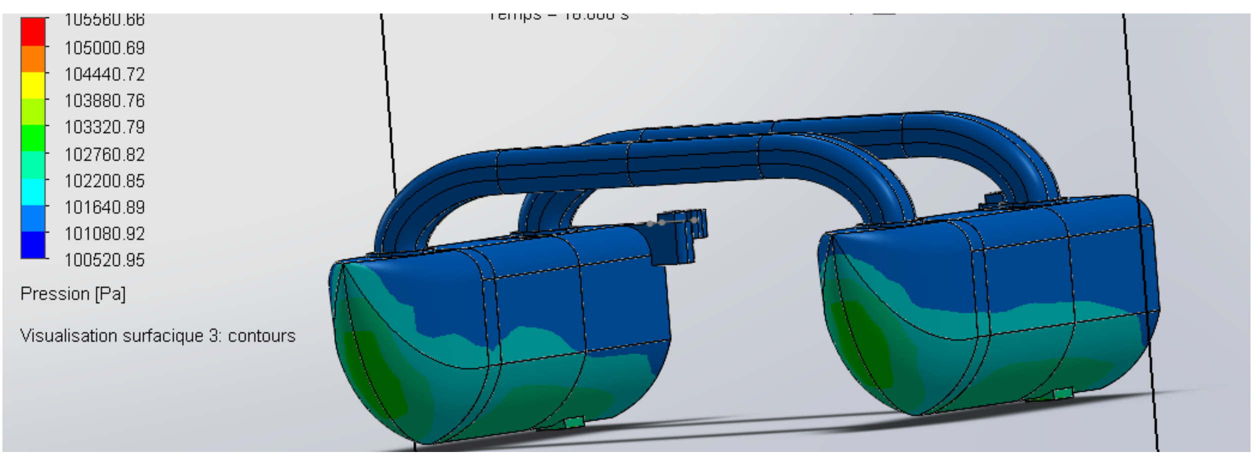


In the **fluid selection** step of the simulation setup, I included both **water and air** to accurately model the real environmental conditions experienced by the boat.



In the flow simulation, I set the **inlet velocity to 4 knots.** This value represents the boat moving at a relatively high operational speed, allowing observation of fluid behavior under dynamic conditions such as high drag and resistance forces.

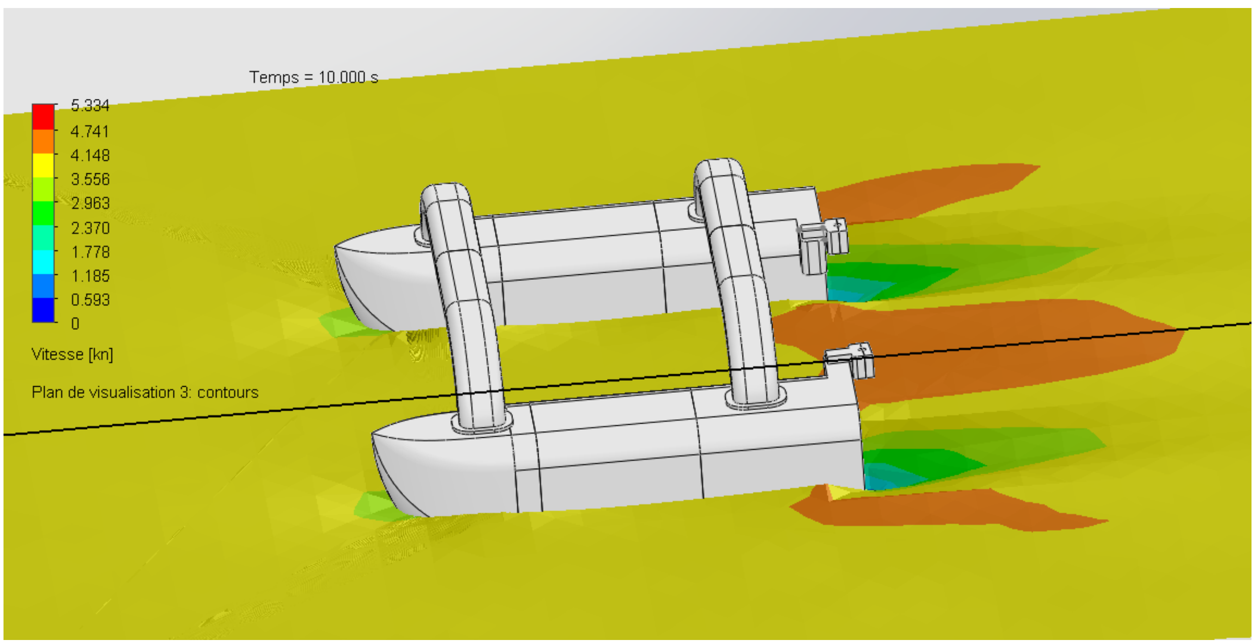
Following the velocity setup, I defined the **calculation domain**, which represents the virtual space around the boat where the simulation takes place



This image illustrates the pressure distribution on the double-hull catamaran during the external flow simulation using SolidWorks Flow Simulation. The simulation was conducted at a velocity of **4 knots (≈2.06 m/s)** with transient analysis over 10 seconds. The color gradient indicates the pressure acting on the surface of the hulls, where:

- **Red areas** represent regions of **high pressure**,
- **Blue to green areas** indicate **lower pressure** zones.

This result helps evaluate the hydrodynamic behavior of the boat design, particularly how water pressure affects the hull structure during movement. The curved, boat-optimized bow shape helps reduce drag and ensures smoother flow, as seen by the pressure gradients.



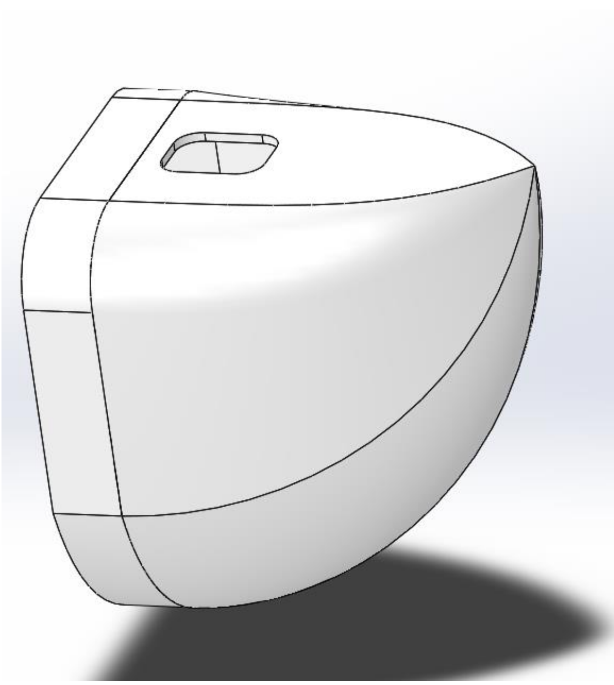
To analyze the flow behavior around the hull, a **Cut Plot – Velocity** was generated using SolidWorks Flow Simulation. This plot visualizes the velocity distribution of the fluid along a selected plane intersecting the boat model. It highlights how the water accelerates around the bow and flows along the hull, offering insight into the hydrodynamic performance of the design. Areas of higher velocity indicate regions of reduced pressure, which are critical for understanding drag forces and optimizing the shape for better flow efficiency. This visualization helps validate the effectiveness of the hull form in reducing resistance and improving movement through water.

3. Pieces Designed

In this part of the mechanical design, the focus is placed on the detailed modeling of the boat's structure, particularly the hulls and their rear sections. Special attention is given to the front of the hull (coque), as its shape plays a crucial role in hydrodynamic performance. The design aims to ensure both stability and smooth water penetration. Several studies have been conducted to refine this form before finalizing the 3D model.

3.1 Hull head

The front part of the hull is meticulously engineered to minimize water resistance and enhance the boat's efficiency in navigating through water. Drawing on principles of streamlined marine structures, the pointed and curved geometry of the bow optimizes hydrodynamic flow, reducing wave-making resistance and minimizing splash, as described by Molland (2011). This design improves stability by maintaining a balanced center of buoyancy and lowers the energy required for propulsion. The 3D model of the boat's bow, developed using SolidWorks, is presented in the figure below

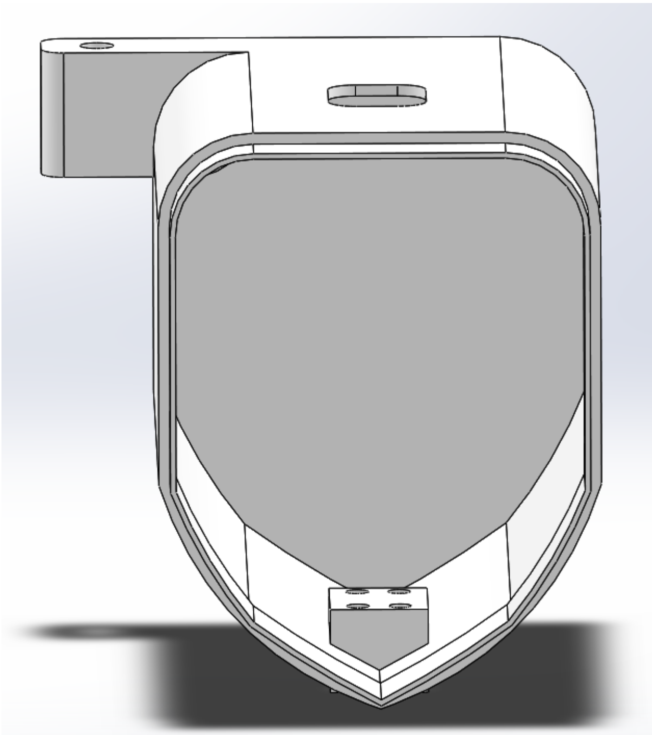


Parameter	Value

Dimension	L=20cm W=15,8cm H=20,8cm
Longitudinal Curvature Radius	18,2cm
Transverse Curvature Radius	29,4cm
Bow length	17cm

3.2 Hull Back

The rear section of the hull is a critical component, engineered to support the net and motor assembly, ensuring operational efficiency and structural integrity. The design features a reinforced platform with a curved trailing edge to optimize water flow and reduce drag during propulsion, while providing a stable mounting surface for the motor. An A-shaped transition, extending from the middle hull, enhances the liaison between the midsection and rear, improving load distribution and hydrodynamic continuity. This configuration supports dynamic loads from the net tension and motor, as validated by the integrated design.



Parameter	Value
Dimension	L=20cm W=15,8cm H=20,8cm
Support motor	4 screw holes(3*4 diameter)
Support net	1 screw hole (8mm diameter)

Fillet position and motor position

4. Material Selection

- **Hulls**: 3D-printed ABS or PLA or EPTG for lightweight, water-resistant properties.
- **Adhesives**: Waterproof epoxy or silicone for assembling printed parts.
- **Mounts**: Aluminum or plastic for sensor and motor housing.

5. Coil Selection

Chapter 3: Virtual Simulation

Simulation Environment

Gazebo 11, integrated with ROS Noetic on Ubuntu 20.04, simulates the boat in a virtual water environment.

Boat Model

- **URDF/XACRO**: Defines the dual-hull structure, sensors (LiDAR, GPS, IMU, camera), and motors.
- **Plugins**: Gazebo plugins for motor propulsion and sensor data.

Navigation Simulation

ROS nodes simulate SLAM or waypoint-based navigation, using LiDAR for obstacle avoidance and GPS for positioning.

Waste Detection Simulation

A mock CNN model processes simulated camera feeds to detect plastic waste, validated in Gazebo.

Performance Metrics

- Navigation accuracy: Path deviation < 10cm.
- Waste detection: >80% precision in identifying plastics.
- Stability: No tipping in simulated currents.

Chapter 4: Hardware Selection

Sensors

- **LiDAR**: RPLIDAR A1 for 360° mapping.
- **GPS**: Ublox NEO-6M for positioning.
- **IMU**: MPU-6050 (gyroscope + accelerometer) for orientation.
- **Camera**: Pi Camera or USB webcam for waste detection.

Processing Unit

Raspberry Pi 4 (8GB RAM) running Ubuntu 20.04 and ROS Noetic for real-time data processing.

Actuators

Two DC motors or thrusters for propulsion and differential steering.

Power System

- **Battery**: 12V LiPo battery with 5000mAh capacity.
- **Regulation**: Voltage regulators for stable power to components.

Environmental Protection

IP67-rated enclosures for electronics; sealed hulls for water resistance.

Chapter 5: Software Development and Integration

ROS Architecture

- **Nodes**: Sensor data (LiDAR, GPS, IMU, camera), navigation, waste detection, motor control.
- **Communication**: ROS topics and services for real-time data exchange.

AI Model Development

A CNN (e.g., YOLOv5) trained on a dataset of plastic waste images for real-time detection.

Navigation Algorithms

- **SLAM**: Cartographer or Hector SLAM for mapping and localization.
- **Path Planning**: A* or DWA for obstacle avoidance and waypoint navigation.

Optimization

Code optimized for Raspberry Pi's limited computational resources, using lightweight libraries.

Chapter 6: Electronic Cabling and Integration

Wiring Diagram

Detailed schematic for connecting Raspberry Pi, sensors, motors, and battery.

PCB Design (Optional)

Custom PCB for compact, reliable connections.

Testing

Validate power delivery, sensor communication, and motor control in wet conditions.

Chapter 7: Mobile Application

Purpose

A mobile app for remote start/stop, camera feed visualization, and sensor data monitoring.

Development

Flutter or React Native for cross-platform compatibility, using ROS bridge for communication.

Features

- Real-time camera feed.
- Manual override for navigation.
- Sensor status dashboard.

Chapter 8: Prototype Realization and Testing

Assembly

Combine mechanical, electronic, and software components into a functional prototype.

Testing

- **Environment**: Controlled water body (pool or lake).
- **Metrics**: Navigation accuracy, waste detection precision, battery life, and durability.
- **Iteration**: Adjust design based on test outcomes.

Chapter 9: Future Improvements and Recommendations

Scalability

- Larger hulls for increased payload.
- Solar panels for extended operation.

Advanced Features

- Multi-boat coordination via ROS.
- Cloud-based data processing for AI model updates.

Challenges

- Battery life in long missions.
- Regulatory compliance for ocean deployment.

Roadmap

Transition from MVP to a fleet of boats for large-scale cleanup.

Bibliography

Molland, A. F. (Ed.). (2011). The Maritime Engineering Reference Book: A Guide to Ship Design, Construction, and Operation. Butterworth-Heinemann.