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Eco Rover: A Smart Vision Integrated Autonomous System for Sustainable Water Body Rehabilitation

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Abstract

Floating plastic waste has become a serious environmental problem that harms marine ecosystems and affects human health, particularly in coastal regions of Tamil Nadu such as Palk Bay, Pulicat Lake, Muthupet Lagoon, Pichavaram Mangrove Forest, and Thoothukudi, where slow-moving currents cause the accumulation of floating debris on the water surface. Manual cleaning methods are often slow, labor-intensive, and inefficient for large water bodies, highlighting the need for automated and intelligent solutions. This paper presents Eco-Rover, an autonomous robotic system designed for efficient surface-level plastic waste detection and removal while also supporting aquatic ecosystem restoration. The robot employs a catamaran-style floating mechanism with two buoyant pontoons connected by a rectangular platform to ensure stability and balanced load distribution. Dual propeller motors provide propulsion and maneuverability across the water surface. A front-mounted scoop mechanism with serrated edges collects floating plastic debris, which is guided through a 35–40° slanted plate into a load carrier chamber equipped with drain holes for water removal. Inside the chamber, a screw compactor driven by a low-speed, high-torque motor compresses the collected plastic to increase storage efficiency. For intelligent operation, a camera module mounted on a vertical stand captures images for real-time analysis using a Raspberry Pi vision system with the YOLOv8 algorithm, enabling accurate plastic detection. Navigation and obstacle avoidance are managed through an Arduino-controlled propulsion system integrated with ultrasonic sensors. Additionally, a fertilizer storage tank with a mini pump and rear micro-sprinkler system dispenses Liquid Seaweed Extract, an eco-friendly bio-stimulant that helps restore nutrient balance and promote aquatic plant growth after waste removal. By integrating mechanical waste collection, compression mechanisms, AI-based detection, and ecological restoration, the proposed Eco-Rover offers a scalable and sustainable approach for smart water-surface cleaning and environmental management.

Keywords: *Floating Plastic Waste, Autonomous Cleaning Robot, YOLOv8 Detection, Catamaran Floating Mechanism, Sustainable Water Cleanup*

1. Introduction

Water pollution caused by floating plastic waste has become a major environmental issue affecting ecosystems, biodiversity, and human health. Plastics are non-biodegradable and tend to accumulate on the

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surface of lakes, rivers, and coastal regions, leading to long-term ecological damage. Marine organisms often ingest or become entangled in plastic debris, resulting in injury or death. Additionally, plastics degrade into microplastics, which enter the food chain and pose significant health risks to humans. In coastal regions such as Palk Bay, Pulicat Lake, Muthupet, and Pichavaram, the problem is intensified due to slow water currents that trap floating debris. These areas are ecologically sensitive and economically important, supporting fisheries and local communities. Traditional methods of waste removal rely heavily on manual labor, making the process slow, inefficient, and sometimes hazardous. Moreover, these methods lack continuous monitoring and fail to address the restoration of the affected aquatic ecosystem. To overcome these limitations, this work proposes Eco-Rover, a smart autonomous system designed for efficient water surface cleaning and ecological rehabilitation. The system integrates robotics, computer vision, and environmentally sustainable techniques. It is capable of detecting, collecting, and removing plastic waste while also contributing to biological restoration using organic solutions. The combination of automation and eco-friendly design makes Eco-Rover a scalable and effective solution for sustainable water management. [1]

1.1. Challenges in Conventional Water Cleaning Methods

Conventional water cleaning approaches are predominantly manual and labor-intensive. These methods suffer from several limitations such as low efficiency, high operational time, and limited coverage. Workers are often exposed to unsafe and polluted environments, increasing health risks. Additionally, manual systems lack precision in identifying specific types of waste and do not provide real-time monitoring or data analysis. As a result, large-scale implementation becomes impractical, especially in heavily polluted or hard-to-reach areas.

1.2. Need for Smart Autonomous Rehabilitation Systems

With advancements in embedded systems, artificial intelligence, and IoT, there is a growing demand for automated solutions that can efficiently address environmental challenges. Smart autonomous systems can operate continuously with minimal human intervention, ensuring higher efficiency and accuracy. By integrating computer vision for waste detection and sensor-based navigation, such systems can intelligently perform cleaning operations. Furthermore, incorporating eco-friendly restoration techniques helps in improving water quality and supporting aquatic life. This highlights the need for a comprehensive solution like Eco-Rover that combines waste removal with environmental rehabilitation. [2]

2. Methodology

The Eco-Rover system is designed as an autonomous floating robot that performs waste detection, collection, and environmental restoration. The working methodology is divided into the following stages:

- **Waste Detection**

A Raspberry Pi camera module captures real-time images of the water surface. The YOLOv8 algorithm processes these images to identify and classify plastic waste with high accuracy.

- **Navigation and Obstacle Avoidance**

The robot uses ultrasonic sensors to detect obstacles and navigate safely. An Arduino microcontroller controls the propulsion system, enabling smooth movement across the water surface.

- **Waste Collection Mechanism**

A front-mounted scoop collects floating waste efficiently. The collected waste is transferred into an onboard storage container with a perforated base that allows water drainage, maintaining buoyancy.

- **Biological Restoration**

A micro-sprinkler system at the rear dispenses Liquid Seaweed Extract, an organic bio-stimulant. This helps restore nutrient balance and supports the growth of aquatic plants.

- **Monitoring and Data Transmission**

IoT integration allows real-time monitoring of system performance and environmental conditions. Data can

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be transmitted for analysis and future improvements.

Table 1 Components and Use

COMPONENTS	USE
Raspberry Pi	Processes image data and runs the YOLOv8 algorithm for waste detection
Camera Module	Captures real-time images of the water surface
Arduino Microcontroller	Controls motors, sensors, and overall movement of the rover
Ultrasonic Sensors	Detect obstacles and help in navigation
DC Motors / Propellers	Provide movement and propulsion in water
Motor Driver	Controls speed and direction of motors
Front Scoop Mechanism	Collects floating plastic waste
Storage Container	Stores collected waste; perforated for water drainage
Micro-Sprinkler System	Sprays Liquid Seaweed Extract for ecological restoration
Battery / Power Supply	Provides power to all electronic components
IoT Module (Wi-Fi)	Enables real-time data monitoring and communication

2.1.Components

The Eco-Rover system is built using a combination of hardware and software components that work together to achieve autonomous waste detection, collection, and environmental restoration.

- **Raspberry Pi**

This acts as the main processing unit of the system. It handles image processing tasks and runs the YOLOv8 algorithm to identify plastic waste from the captured images. [3]

- **Camera Module**

The camera is used to capture real-time visuals of the water surface. These images are continuously sent to the Raspberry Pi for analysis and waste detection.

- **Arduino Microcontroller**

Arduino is responsible for controlling the movement and operation of the robot. It receives commands from the Raspberry Pi and controls motors and sensors accordingly.

- **Ultrasonic Sensors**

These sensors help in detecting obstacles such as rocks, plants, or other floating objects. This ensures safe navigation by preventing collisions.

- **DC Motors / Propellers**

These components provide propulsion to the Eco-Rover, enabling it to move forward, backward, and change direction on the water surface.

- **Motor Driver**

The motor driver acts as an interface between the Arduino and motors. It controls the speed and direction of the motors based on signals received from the controller.

- **Front Scoop Mechanism**

This is a mechanical structure placed at the front of the rover that collects floating plastic waste efficiently as the robot moves.

- **Storage Container**

The collected waste is stored in this container. It is designed with small holes (perforations) to allow water to drain out, helping maintain the rover's balance and buoyancy.

- **Micro-Sprinkler System**

This system sprays Liquid Seaweed Extract, which is an organic solution that helps restore nutrients in water and supports the growth of aquatic plants.

- **Battery / Power Supply**

This provides the necessary electrical energy to all components of the system, ensuring uninterrupted operation.

- **IoT Module (Wi-Fi)**

The IoT module enables wireless communication. It allows real-time monitoring of the rover's

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performance and helps in data collection and remote control if required.

2.2.Design

The figure shows the Eco-Rover, an autonomous floating robot designed for cleaning water bodies. It consists of a front scoop mechanism with serrated edges to collect floating plastic waste, which is then stored in an onboard container. A camera mounted on top enables real-time waste detection using computer vision. The system uses propellers for movement and sensors for navigation and obstacle avoidance. Additionally, the structure supports eco-friendly restoration features, making it an efficient solution for sustainable water cleaning. [4]

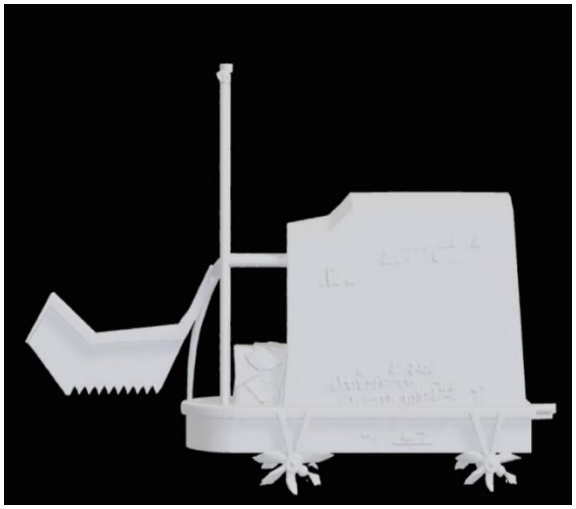

Figure 1 Eco-Rover Autonomous Water Cleaning System

3. Results and Discussion

3.1.Results

The implementation of the Eco-Rover system demonstrates effective performance in detecting and removing floating plastic waste from water bodies. The integration of computer vision using YOLOv8 achieved a high detection accuracy of up to 95%, enabling precise identification of plastic materials in real-time conditions. The autonomous navigation system, supported by ultrasonic sensors, ensured smooth movement and successful obstacle avoidance. The waste collection mechanism efficiently gathered floating debris, while the perforated storage container maintained stability by allowing water drainage. Additionally, the micro-sprinkler system showed positive impact in supporting ecological restoration by dispersing Liquid Seaweed Extract, promoting healthier aquatic conditions. Result Overall, the system proved to be a reliable, scalable, and eco-friendly solution for water body rehabilitation, reducing manual effort and improving cleaning efficiency. [5]

3.2.Discussion

The Eco-Rover system effectively combines robotics and computer vision for efficient water cleaning. The YOLOv8 model ensures accurate waste detection, while autonomous navigation enables smooth and safe operation. The waste collection mechanism improves efficiency compared to manual methods.
A key advantage is its dual function of waste removal and ecological restoration using Liquid Seaweed Extract. However, performance may be affected by weather conditions and battery limitations. Overall, Eco-Rover is a promising, scalable solution for sustainable water body management.

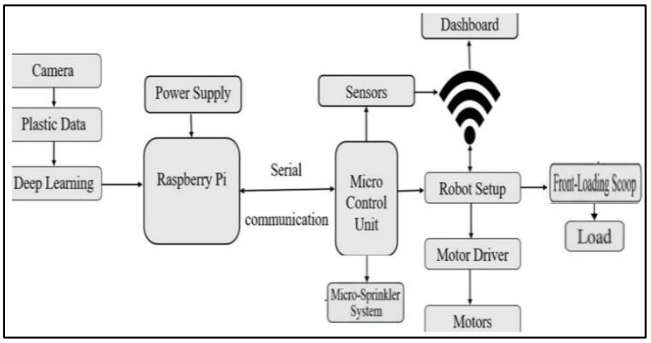

Figure 2 Working Process

Conclusion

The Eco-Rover system provides an efficient and sustainable solution for cleaning polluted water bodies. By integrating computer vision, autonomous navigation, and an effective waste collection mechanism, it significantly reduces manual effort and improves cleaning accuracy. In addition to removing plastic waste, the system promotes ecological

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restoration through the use of eco-friendly bio-stimulants, making it a unique and holistic approach. Despite minor limitations such as environmental dependency and power constraints, Eco-Rover demonstrates strong potential for large-scale implementation. Overall, it contributes to cleaner aquatic environments and supports sustainable development goals for water conservation

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