

# SOLAR-BASED RIVER GARBAGE CLEANING ROBOT

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**Abstract:** The Solar-Based River Garbage Cleaning Robot is an environmentally focused, automated system developed to remove floating waste from rivers, lakes, and similar water bodies. The project addresses the rising challenge of water pollution caused by plastic debris, organic waste, and human activities. By integrating solar energy with robotic collection mechanisms, the system operates independently without the need for external power sources, making it suitable for remote and energy-restricted regions. Equipped with sensors, motorized collectors, and an onboard control architecture, the robot identifies, gathers, and stores waste efficiently. The proposed solution enhances water quality, minimizes human involvement in hazardous cleaning tasks, and promotes long-term ecological conservation.

## INTRODUCTION

Rivers are among the most essential natural resources, supporting human life, agriculture, industry, and countless ecological systems. However, in recent decades, rapid urbanization, industrial growth, and improper waste management practices have led to a dramatic increase in pollution levels in many rivers around the world. A significant portion of this pollution consists of floating solid waste such as plastics, bottles, food wrappers, leaves, and organic debris, which accumulates on the water surface and disrupts the natural ecosystem. This floating waste poses severe environmental challenges, including the degradation of water quality, harm to aquatic organisms, obstruction of natural water flow, and negative impacts on nearby communities who depend on river water for daily activities.[1]

Conventional river cleaning methodologies rely heavily on manual labor, where workers use boats or nets to collect waste. While effective on a small scale, these methods are highly time-consuming, strenuous, and lack the efficiency needed to manage pollution in larger river systems. Additionally, manual operations involve human risk and require continuous financial and labor investment. These limitations highlight the need for sustainable, automated, and energy-efficient solutions capable of operating for extended durations with minimal human intervention.[4]

To address these challenges, the concept of a solar-based river garbage cleaning robot has gained significant attention. This system integrates renewable solar energy with autonomous robotic mechanisms to provide an environmentally friendly and cost-effective solution for surface waste collection.[1] By utilizing solar panels, the robot can continuously recharge and operate without dependency on external power sources or fossil fuels, making it both sustainable and economical. The use of solar power also enables the system to function in remote or underdeveloped areas where electricity supply is limited.

The robot typically consists of a floating platform equipped with propulsion motors, waste-collection mechanisms such as conveyor belts or scooping systems, and control electronics for autonomous or semi-autonomous operation. Solar panels mounted on the structure provide energy for movement and waste-handling components.[9] Depending on the design, additional sensors, cameras, or microcontrollers can be integrated to improve navigation, detect obstacles, and enhance the efficiency

## LITERATURE REVIEW

Recent research on water surface and river waste cleaning robots emphasizes sustainable, low-cost, and autonomous solutions to mitigate floating waste pollution in aquatic environments. **S. Sowndeswari et al. (2025)** proposed *SOLNIX*, a solar-powered water surface cleaning robot that integrates photovoltaic panels with onboard batteries to drive propulsion and debris collection, highlighting renewable energy adoption for reduced human intervention.[1] Studies by **Xiaohong Gao and Xijin Fu (2021)** focus on miniature unmanned surface vehicles designed for confined water bodies, emphasizing compact structures, lightweight platforms, and simple mechanical skimming mechanisms.[2] Advancements in intelligence and autonomy are addressed by **T. Meenambal (2022)**, who introduced AI-enhanced detection and decision-making frameworks to overcome limitations of sensor-based navigation and improve waste identification accuracy.[3]

Sustainable robotic design is further explored by **V. Abhiram (2024)** through the Surface Water Cleaning Robot (SWCR), which combines embedded controllers with mechanical collection systems to reduce labour-intensive cleaning while maintaining cost efficiency.[4] Vision-based tracking and real-time object detection using Raspberry Pi and OpenCV were demonstrated by **Sruthy Vidiyala (2023)**,[5] highlighting the role of computer vision in autonomous navigation. Foundational contributions to image processing were provided by **J. S. Duncan (2003)**, establishing analytical frameworks applicable to modern vision-based robotic systems. [6] Energy storage considerations for photovoltaic systems were analysed by **M. Glavin (2023)**, emphasizing battery selection and charging challenges in solar-powered applications.[7] Educational and implementation feasibility of embedded image processing using Raspberry Pi was presented by **\*\*Marot and Bourennane (2024)**. [8] Machine learning-based image recognition techniques using Python were discussed by **Manish Kumar (2019)**, demonstrating efficient feature-based classification methods.

[9] Finally, **M. Mohammadha Hussaini et al. (2021)** validated the feasibility of solar-powered debris collection systems using relay-controlled motors and mechanical collectors, reinforcing sustainability as a key design objective.[10]

**SYSTEM OVERVIEW**

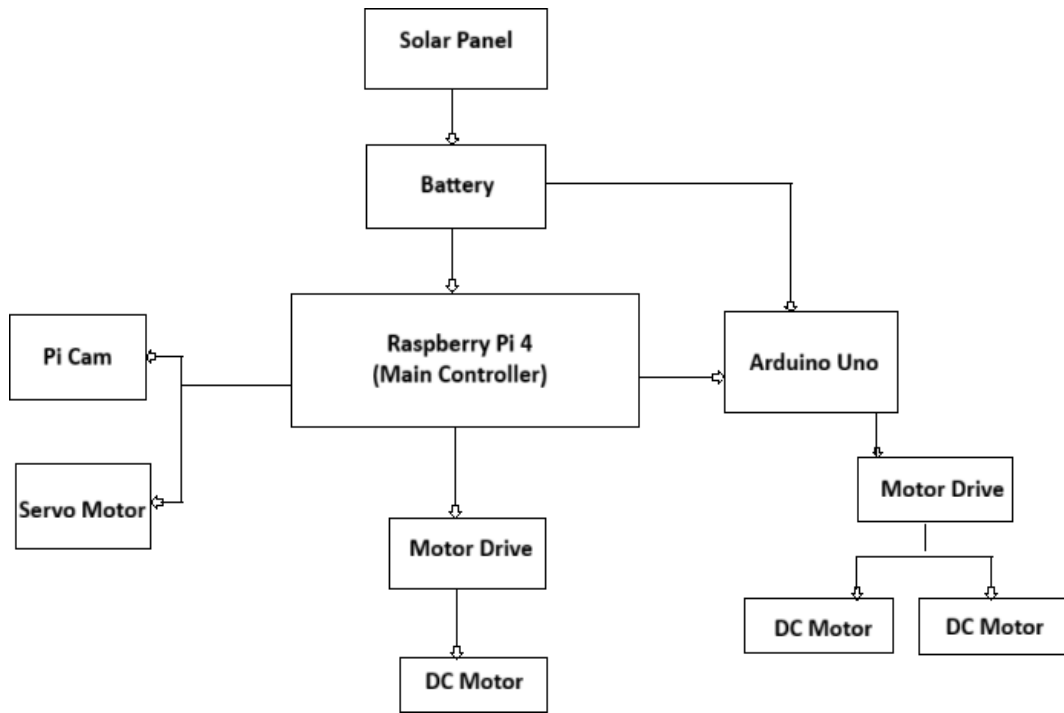


Figure 1. Block diagram

The proposed system architecture of the solar-based river garbage cleaning robot integrates renewable energy, embedded control, vision sensing, and actuation to enable autonomous surface-level waste collection. The system is powered by a solar panel that converts sunlight into electrical energy, which is stored in a rechargeable battery to ensure continuous operation even under low-light conditions. The battery supplies regulated power to all electronic modules, including the Raspberry Pi 4 and the Arduino Uno, thereby providing a stable and reliable power source for the entire system.

The Raspberry Pi 4 functions as the main controller and is responsible for high-level processing and decision-making. A Pi Camera is interfaced with the Raspberry Pi to capture real-time images of the water surface, which are processed using image processing and computer vision techniques to detect the presence and location of floating garbage. Based on the visual analysis, the Raspberry Pi generates appropriate navigation and control commands. A servo motor connected to the Raspberry Pi is used for precise positioning tasks, such as adjusting the camera orientation or aligning the garbage collection mechanism for accurate operation.

To improve real-time motor control and reduce computational load on the Raspberry Pi, an Arduino Uno is employed as a secondary controller. The Arduino receives movement and actuation commands from the Raspberry Pi through serial communication. It primarily handles low-level control of the DC motors via motor driver circuits, ensuring smooth and responsive movement of the robot. Motor drivers act as an interface between the controllers and the DC motors, providing the necessary current and voltage amplification required for propulsion and garbage collection mechanisms.

Overall, the coordinated operation of the solar power unit, Raspberry Pi-based vision system, Arduino-controlled actuation, and mechanical cleaning components enables efficient and autonomous garbage collection from water surfaces. This architecture minimizes human intervention, promotes sustainable energy usage, and enhances the reliability and scalability of the river cleaning robot for real-world environmental applications.

## EXPERIMENTAL SETUP

This design highlights a sustainable, solar-powered solution for surface water cleaning. By combining renewable energy, simple mechanical structures, and automated control, the robot aims to reduce water pollution while minimizing operational cost and environmental impact.

### 1. Hardware Configuration

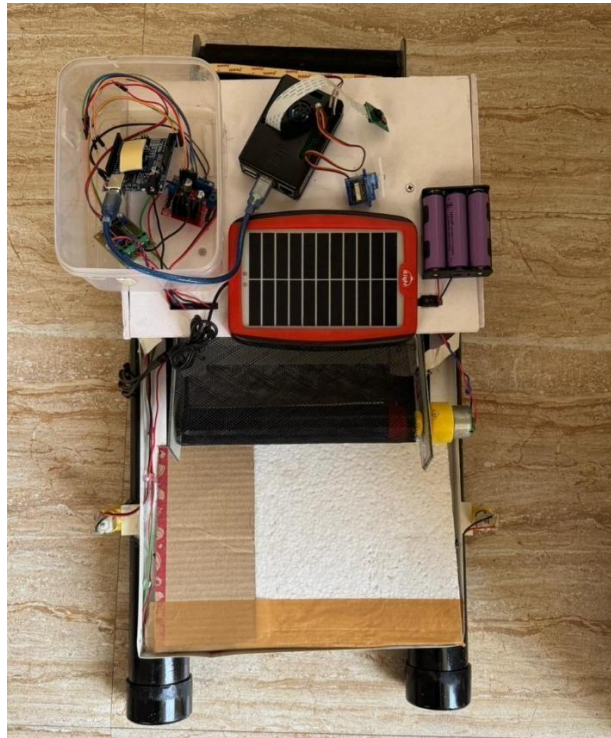


Figure 2. Hardware Connections

The hardware body of the proposed solar-based river garbage cleaning robot is designed to provide buoyancy, stability, and structural support for all onboard electronic and mechanical components while operating on the water surface. The robot is built on a lightweight yet rigid floating platform, typically fabricated using corrosion-resistant materials such as PVC sheets, acrylic, aluminium framing, or sealed pharmacol pontoons. These materials are selected to withstand prolonged exposure to water, prevent rusting, and ensure long operational life in river and lake environments. The symmetrical design of the floating body helps maintain balance and minimizes tilting during movement and garbage collection.

The upper section of the robot houses the solar panel, which is mounted on a rigid frame at an optimal angle to maximize sunlight absorption. Beneath the solar panel, a protected enclosure is provided for the rechargeable battery, Raspberry Pi 4, Arduino Uno, and associated power regulation circuits. This enclosure is waterproof and dustproof, ensuring the safety of sensitive electronic components from splashes, humidity, and debris. Proper ventilation and cable management are incorporated to avoid overheating and short circuits while maintaining ease of maintenance.

The propulsion system is integrated into the lower portion of the hardware body, where DC motors with paddle wheels are mounted on either side of the floating platform. This configuration enables forward, backward, and directional movement of the robot across the water surface. Motor mounts are firmly secured to the chassis to reduce vibration and mechanical stress. A separate DC motor is used for the garbage collection mechanism, which may consist of a conveyor belt positioned at the front of the robot to lift floating waste onto a collection tray.

A Pi Camera is mounted at the front or top of the robot body using a servo motor arrangement, allowing dynamic adjustment of the camera's viewing angle for effective garbage detection. The camera mount is designed to provide an unobstructed field of view while remaining stable during motion. Overall, the hardware body of the robot combines mechanical robustness, waterproof protection, and modular design, enabling reliable operation, easy component replacement, and scalability for future enhancements such as additional sensors or increased waste capacity.

## 2. Software configuration

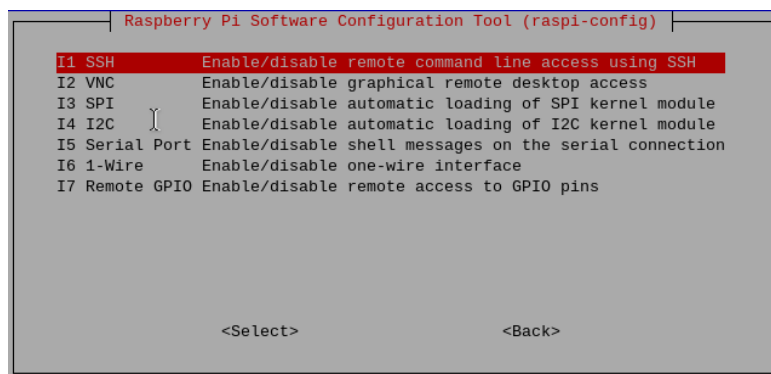


Figure 3 Software Configuration

This figure illustrates the terminal-based software setup on Raspberry Pi 4, which is a crucial stage in configuring the control and vision system of the solar-based river garbage cleaning robot. It demonstrates system update commands, installation of Python and OpenCV libraries for image processing, camera verification using bicameral, and serial communication setup with the Arduino Uno for motor control. The command prompt interface highlights the Linux-based environment used to integrate vision algorithms, hardware interfacing, and control logic in an embedded platform.

The software implementation of the proposed solar-based river garbage cleaning robot is divided into two coordinated modules: high-level processing on the Raspberry Pi and low-level motor control on the Arduino Uno. The Raspberry Pi code is developed in Python and is primarily responsible for image acquisition, garbage detection, decision-making, and command generation. Using a camera interface, real-time images of the water surface are continuously captured and processed with computer vision techniques such as frame resizing, colour conversion, thresholding, and contour detection to identify floating waste. Once garbage is detected, the relative position of the object within the frame is analysed to determine the required navigation direction (left, right, forward, or stop). Based on this analysis, corresponding control commands are transmitted to the Arduino Uno through serial communication.

The Arduino Uno code is written in Embedded C/C++ and focuses on real-time motor actuation. It continuously monitors serial input from the Raspberry Pi and decodes the received commands. Depending on the instruction, the Arduino activates the appropriate motor driver pins to control the propulsion motors for movement and the collection motor for garbage pickup. Pulse Width Modulation (PWM) is used to regulate motor speed, enabling smooth and controlled motion of the robot on the water surface. This division of tasks improves system efficiency by reducing the computational burden on the Raspberry Pi while ensuring precise and responsive motor control through the Arduino.

Overall, the coordinated software architecture enables autonomous detection, navigation, and collection of floating garbage with minimal human intervention. The modular structure of the code allows easy debugging, scalability, and future enhancements such as advanced object classification, GPS-based navigation, or wireless monitoring, making the system suitable for real-world environmental applications.

## 3. Image processing concept



Figure 4 Visual Data Capturing

Image processing involves analyzing visual data captured by the camera to extract useful information. In this project, the camera continuously captures images of the river surface. These images are processed to identify garbage based on visual features such as shape, size, and contrast.

The image-processing pipeline generally includes:

1. Image acquisition
2. Image preprocessing
3. Object detection
4. Decision making

### FLOWCHART FOR ROBOT OPERATIONS

The flowchart represents the complete operational logic of the proposed solar-based river garbage cleaning robot, illustrating the interaction between sensing, decision-making, actuation, and power management modules. The process begins with system initialization, where the Raspberry Pi 4, Arduino Uno, camera module, motors, and other peripheral devices are configured and prepared for operation. Once initialization is completed, the robot enters its main control loop.

#### 1. System Architecture Coordination

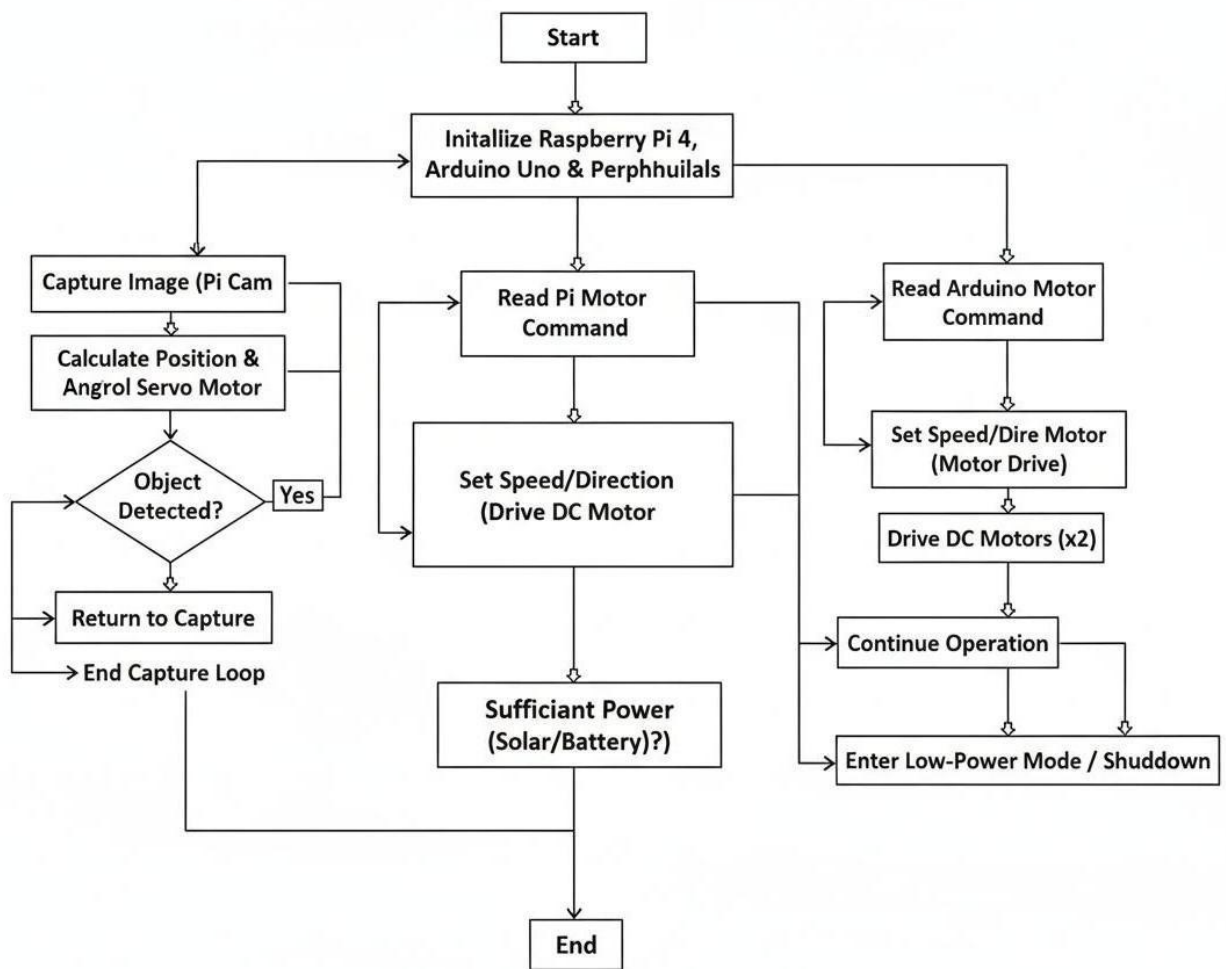


Figure 3. High-Level Architecture Diagram

In the sensing stage, the Pi Camera continuously captures images of the water surface. These images are processed by the Raspberry Pi to estimate the position of floating objects. Based on the calculated position, the servo motor is adjusted to align the camera or collection mechanism for better targeting. The system then evaluates whether an object has been detected. If no garbage is identified, the robot returns to the image capture stage, maintaining continuous monitoring of the environment.

When garbage is successfully detected, the Raspberry Pi generates appropriate motion commands and forwards them to the motor control logic. The speed and direction of the DC motor connected to the Raspberry Pi are set to guide the robot toward the detected waste. Simultaneously, control signals are transmitted to the Arduino Uno, which interprets the received commands and activates the motor driver to operate the dual propulsion motors. This coordinated control ensures smooth navigation and effective positioning of the robot on the water surface.

The flowchart also incorporates energy management as a critical decision stage. The system continuously checks the availability of sufficient power from the solar panel and battery unit. If adequate power is available, the robot continues normal operation and repeats the detection and cleaning cycle. In contrast, when the battery level drops below a safe threshold, the system transitions into a low-power mode or performs a controlled shutdown to protect the hardware and conserve energy

## RESULTS AND DISCUSSION



Figure5. Solar Based River Garbage Cleaning Robot

The developed solar-based garbage cleaning robot was tested under controlled and semi-realistic water surface conditions to evaluate its performance, energy efficiency, and operational reliability. The system successfully operated using solar energy as the primary power source, demonstrating the feasibility of renewable energy integration for water surface cleaning applications.

## CONCLUSION

The solar-based garbage cleaning robot developed in this project demonstrates a practical and sustainable approach to addressing surface water pollution. By integrating renewable solar energy with automated waste collection mechanisms, the system effectively reduces dependency on conventional power sources and minimizes human involvement in hazardous cleaning operations.

The experimental implementation confirms that the robot can successfully navigate water surfaces, identify floating waste, and collect garbage in an efficient manner. The use of solar power ensures extended operational time while promoting eco-friendly practices. Coordination between the Raspberry Pi and Arduino enables reliable control, smooth motor operation, and accurate execution of garbage collection tasks. The project highlights the feasibility of using autonomous robotic systems for environmental protection, particularly in rivers, lakes, and ponds where manual cleaning is inefficient or unsafe. Although the current prototype has certain limitations related to lighting conditions, waste weight, and water turbulence, these challenges provide valuable insights for further enhancement.

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