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River Cleaning Robot Using Solar Power

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Abstract- River pollution caused by floating waste is a critical environmental issue. Manual cleanup is time-consuming, expensive, and often ineffective for large water bodies. This study presents a solar-powered robotic system designed to collect floating debris from river surfaces. The robot operates using renewable energy and includes a conveyor mechanism for waste collection, DC motors for propulsion, and Bluetooth for remote control. The prototype demonstrates an eco-friendly, low-cost solution for continuous surface waste management in rivers. Future versions aim to incorporate autonomous navigation and AI-based classification to avoid harming aquatic life.

Keywords: River pollution, robotic cleaner, solar energy, Arduino Uno, conveyor mechanism, sustainable technology.

I. INTRODUCTION

The accumulation of floating waste in rivers has become a growing environmental concern, particularly in urban and industrial areas. Conventional cleaning *methods often rely on manual labor, which can be inefficient, costly, and hazardous* to workers exposed to polluted water. Moreover, these approaches typically lack scalability and sustainability.

With the advancement of embedded systems and automation technologies, there is an increasing opportunity to address this issue using smart, eco-friendly solutions. Robotic systems offer the ability to perform repetitive cleaning tasks while reducing the need for human intervention. When powered by renewable energy, such systems become even more suitable for long-term deployment in natural environments.

This project introduces a river-cleaning robot powered by solar energy and controlled remotely using Bluetooth. It incorporates a conveyor mechanism for collecting waste from the water surface and features live video streaming via an ESP32-CAM module for enhanced user control. The goal is to develop a reliable, energy-efficient, and user-friendly system that contributes to cleaner waterways and promotes sustainable environmental practices.

II. LITERATURE REVIEW

Akash Shahu [1] proposed a remote-controlled river cleaning robot that emphasized reducing manual involvement and promoting safer operation in polluted environments. Kshitija A. Ingle [2] developed a similar floating robot that focused on minimizing human effort by using embedded control systems, though it lacked autonomous feedback capabilities. Dr. B. Mabu Sarif [3] presented a semi-autonomous prototype and discussed future enhancements with renewable energy integration.

Savitha H.S [4] emphasized mechanical automation with rotating collectors and conveyor mechanisms, laying the groundwork for efficient debris collection. M. Mohamed Idhris et al. [5] contributed a sewage cleaning robot, which, although intended for drains, provided insight into scalable mechanisms suitable for rivers. Abhijeet Ballade et al. [6] focused on cost-effective design strategies using readily available components, aiding resource-limited implementations. Finally, P. M. Sirsat et al. [7] developed a motorized waste collection system, which influenced modern design thinking for paddle-based river robots.

Building on these foundations, this project integrates solar charging via BMS, live-streaming through ESP32-CAM, and Bluetooth-controlled mobility, providing an energy-efficient and scalable river cleaning solution.

III. SYSTEM HARDWARE

Arduino UNO

The Arduino Uno is an open-source microcontroller board built around the ATmega328P. It serves as the central processing unit for the river cleaning robot. With 14 digital I/O pins and 6 analog inputs, it provides enough flexibility to control multiple devices such as motors, sensors, and communication modules. Its ease of programming through the Arduino IDE and compatibility with various libraries makes it suitable for beginners and experts alike. In this project, the Arduino Uno receives input from the Bluetooth module and controls the L298N motor drivers to manage both propulsion and the waste-collecting conveyor mechanism in real time.

Figure1: Arduino UNO

L298N Driver

The L298N is a dual H-Bridge motor driver module that allows bidirectional control of two DC motors or one stepper motor. It can handle up to 2A current per channel and is ideal for robotics applications. In the river cleaning robot, two L298N modules are used—one for controlling the boat's motion and the other for the conveyor belt that collects floating waste. The driver receives PWM signals from the Arduino Uno and manages motor direction and speed accordingly. The built-in heatsink helps with thermal management, and it also includes enable pins for precise speed control using PWM techniques.

Figure2: L298N Driver

Bluetooth module (HC-05)

The HC-05 Bluetooth module is used for establishing wireless communication between the Arduino Uno and a mobile device. It operates via UART interface, supporting master or slave modes, which allows the robot to receive navigation and operational commands remotely. Its compatibility with Android-based control apps makes it ideal for this application, enabling manual guidance of the robot in real time with minimal latency.

Figure3: Bluetooth Module (HC-05)

ESP32-CAM Module

The ESP32-CAM is a low-cost microcontroller board featuring an ESP32-S module integrated with an OV2640 camera. It supports both Wi-Fi and Bluetooth connectivity, making it suitable for wireless image streaming and AI-based vision tasks. In this project, the ESP32-CAM captures real-time video of floating debris and runs a lightweight AI model to distinguish between living organisms and inanimate waste. The board can be programmed using the Arduino IDE and supports TensorFlow Lite for Microcontrollers. Its compact size and onboard microSD slot make it ideal for embedding in robotics projects where live feedback and basic object recognition are required.

Figure4: ESP32-CAM Module

FTDI Programmer

The FTDI programmer is a USB-to-Serial adapter that allows communication between a PC and serial devices like the ESP32-CAM. Since the ESP32-CAM lacks a native USB port, the FTDI adapter is essential for uploading code, flashing firmware, and debugging. It uses the FT232RL chip and provides reliable 3.3V and 5V output options. The programmer connects to the ESP32-CAM's TX, RX, GND, and VCC pins, and a button or jumper can be used to enable flashing mode. In this project, the FTDI programmer is used during development to upload the object detection model and configure the ESP32-CAM's settings before deployment.

Figure5: FTDI Programmer.

BO (Battery Operated) Motor

BO motors are small, low-cost DC motors commonly used in DIY and educational robotics projects. They typically operate between 3V to 12V and provide enough torque for small robotic applications. These motors are lightweight and efficient, making them ideal for mobile platforms like the river cleaning robot. In this system, two BO motors are used to drive the robot forward and backward, while two additional motors rotate the conveyor belt to collect waste. Their compatibility with L298N motor drivers and ease of mounting contribute to simple yet effective mechanical integration. Despite their simplicity, they are sufficient for the intended task.

Figure6: BO Motor

IV. SOFTWARE SPECIATION

Arduino IDE

The Arduino Integrated Development Environment (IDE) is a freely available software platform that simplifies programming for Arduino microcontrollers. Designed to run across different operating systems, it combines a straightforward text editor for writing code with a built-in compiler that prepares the code for uploading to Arduino boards [13]. Programs created within this environment, commonly known as "sketches," are written in a simplified version of C/C++. Once uploaded, the microcontroller interprets these instructions to carry out specific tasks. Thanks to its clean interface and beginner-friendly design, the Arduino IDE has become a popular tool in both educational settings and rapid prototyping, helping users bridge the gap between software and hardware development.

Figure7: A default Arduino IDE window.

V. WORKING

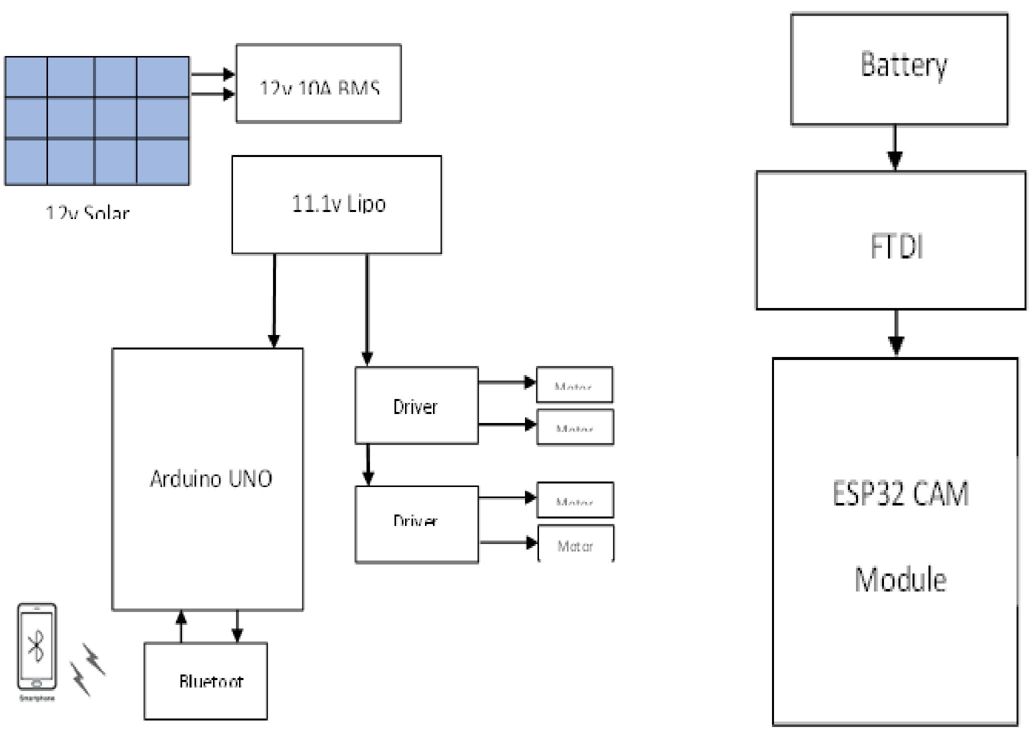


Figure8: Block diagram of the robot

Figure9: Circuit Diagram of Robot Control

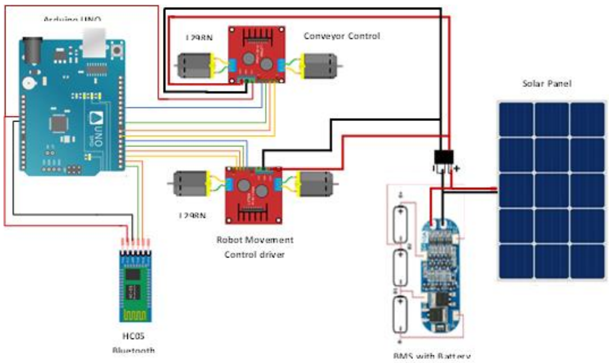
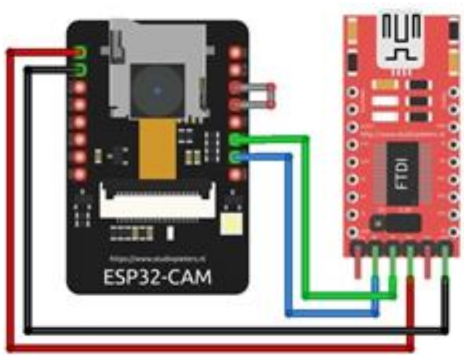


Figure10: Circuit Diagram of Video Streaming



The river-cleaning robot operates as a solar-powered, semi-automated system for collecting floating waste from water surfaces. Power is supplied by an 11.1V 3S LiPo battery, which is charged through a solar panel connected via a Battery Management System (BMS). This ensures safe charging, discharging, and protection against overcurrent or short circuits.

The system uses two L298N motor drivers: one dedicated to propelling the robot using two BO motors (for forward, backward, and turning movements), and the other to operate a front-mounted conveyor belt that scoops floating waste into a storage bin. All movement and conveyor actions are controlled by an Arduino Uno, which receives user inputs wirelessly through the HC-05 Bluetooth module.

In addition, an ESP32-CAM module is mounted at the front of the robot for live video streaming, enabling remote monitoring of the robot’s operation in real-time. This enhances situational awareness and allows the user to visually guide the robot as it cleans the river surface, combining efficiency with environmental safety.

Result

The prototype of the river-cleaning robot was successfully developed and tested in a controlled water environment such as a small pond. The system operated continuously for over 2.5 hours on a fully charged 11.1V 3S LiPo battery, charged using a solar panel through a Battery Management System (BMS). The BO motors provided reliable movement over water, and the conveyor mechanism effectively collected various types of floating debris such as leaves, plastic wrappers, and foam pieces.

The robot responded accurately to commands sent via Bluetooth through the HC-05 module, with minimal delay. The live video streaming feature powered by the ESP32-CAM module functioned smoothly within a range of 10–15 meters, allowing real-time remote monitoring and manual navigation.

VII. CONCLUSION

This project presents a cost-effective, eco-friendly river-cleaning robot powered by solar energy and designed to remove floating waste from water surfaces. By integrating an Arduino Uno, L298N motor drivers, and BO motors, the system effectively performs cleaning operations while being controlled remotely through Bluetooth. The addition of a Battery Management System (BMS) ensures safe and efficient solar charging of the 11.1V LiPo battery, supporting extended operation without manual intervention.

Furthermore, the inclusion of the ESP32-CAM module enables live video streaming, enhancing user awareness and control during operation. The robot performed reliably during field tests, demonstrating its potential for real-world deployment in small-scale water bodies.

Overall, the system contributes to sustainable environmental practices by combining renewable energy with robotics. With further improvements such as autonomous navigation and AI-based object classification, the robot can evolve into a fully automated solution for large-scale river and lake cleaning applications.

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