Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 47 No. 2 (2026)

Automatic Solar Powered Surveillance Boat With Waste Segregator

T.J. Bharambe[1*], O.P.Yadav[2], Gauri Kishor Khandagale[3], Vishakha Ranu Bhagyawnant[4] , Pratiksha Minanath Mhalaskar[5], Bhavesh Anil Wani[6]

[1,2]Assistant Professor, Electrical Engineering, Sandip Institute of Technology & Research Centre, Nashik, Maharashtra, India

[3,4,5,6] Students, Electrical Engineering, Sandip Institute of Technology & Research Centre, Nashik, Maharashtra, India

Abstract

In today's time, rivers & lakes are becoming more polluted. Day by day it increasing due to plastic waste, floating materials, improper disposal of waste & soluble impurities also. This problem becomes more serious during big spiritual events like Mahakumbh or other Utsav's, where so many peoples are gathered & huge amount waste is generated in huge amount. To solve this problem, we have designed an automatic solar power surveillance boat with waste segregator which works on Sun's energy i.e., solar energy (sunlight). The boat has a solar panel, so overall system works on it. It also collects floating waste from the rivers or any other water surface & store it in a container which is mounted on the boat. In Addition to this, the main Feature of this project is waste segregation, where waste is Seperateded on the basic of Biodegradable & non- Biodegradable Materials. Our project mainly addresses the improper disposal of waste, illegal dumping, reduce the human involvement & improve durability. It Merges, conveyor Mechanism, Segregation unit, Bluetooth Control & Microcontroller – Based Automation for Efficient Waste Management. The Boat is Controlled using Arduino .it can work in both automatic & remote mode. the main aim of our project is to clean & Sort Water bodies & promote renewable energy & facilitate renewable purchase obligations.

Keywords: Solar Power, Waste Segregation, Arduino, Cleaning & sorting, renewable energy, Mahakumbh.

1. INTRODUCTION

Currently, Waste Management has become a huge challenge, specially in rivers & lakes. & Public areas also. A lot of people throw plastic or garbage in the water bodies , which causes pollution & it badly affects the aquatic life.

In India, rivers like Ganga are facing serious pollution hurdles. cleaning them management takes a lot of time. also it is not only risky but also difficult.

To solve this problem, people are now using new technologies. Some projects like "Swachh Hush" have shown that robots can be used to collect waste from water, but many of these systems are not fully automatic & do not separate the waste properly.

In this project we have made an automatic solar powered surveillance boat with waste segregator. This boat works using solar power, so it is eco-friendly & does not need external power.

It collects floating waste from the water surface using conveyor belt & also segregates it into containers. The boat can move in any direction (360°) due to use of Arduino which controls the boat.

We also used camera module for live checking & added weight sensor to measure how much waste is collected. We can control the system using Bluetooth. We also used pH level sensor for detection of soluble impurities. This helps to reduce time, human effort & makes process faster

Fig.1: Floating Waste in Water

Fig.2: Manual River waste Collection

2. PROPOSED SYSTEM

2.1 System Overview

As we observe nowadays, waste in water bodies is increasing due to improper disposal. This not only affects the environment but also creates health problems.

To deal with this issue, we designed a solar-powered waste collection robot. The system uses simple components and focuses on practical implementation.

The energy required for the system is generated using solar panels and stored in a battery. This makes the system independent and eco-friendly.

A microcontroller is used to control all operations. Motors are used for movement, and sensors help in detecting obstacles. A camera is also added so that waste can be monitored properly.

The conveyor mechanism collects waste, and the segregation unit separates it into different types. The system can work automatically or can be controlled manually using Bluetooth.

From our testing, we observed that the system is able to move easily and collect waste effectively, even in small are.

2.2 SYSTEM ARCHITECTURE

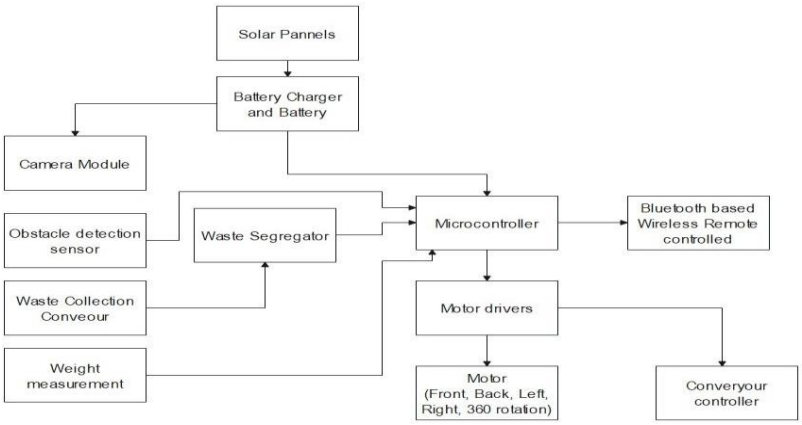

Fig .3 Block Diagram

1. Solar Panels

Function: it is Converts solar energy into electrical energy.

Purpose: Solar energy is one of the best renewable energy sources available. It is free and does not cause pollution. Solar panels convert sunlight into electrical energy, which is used to run the system.

The generated energy is stored in the Battery Charger and Battery for continuous operation 2. Battery Charger and Battery

1. Battery:

Function: Stores the power generated from the solar panels and supplies regulated voltage to all components.

Purpose: Ensures uninterrupted power supply even in the absence of sunlight.

Supplies power to the Camera Module, Microcontroller, Motors, and other sensors.

3. Camera Module

Function: Captures images or video of the waste material.

Purpose: Helps in identifying the type of waste (biodegradable, non-biodegradable, metallic, etc.) for segregation.

The image data is processed by the Microcontroller and Waste Segregator.

4. Obstacle Detection Sensor

Function: Detects obstacles in the movement path of the system.

Purpose: Prevents collisions by sending signals to the microcontroller to stop or change direction.

Examples: Ultrasonic or Infrared sensors.

5. Waste Segregator

This part of the system is used to separate the collected waste into different categories like plastic, metal, and organic materials. The main idea is to make the sorting process automatic so that no manual effort is needed. It works together with the microcontroller and the conveyor system to identify and separate the waste properly.

6. Waste Collection Conveyor

The conveyor plays an important role in moving the waste from one place to another. After the waste is collected and segregated, it is transferred to the correct storage bin using this conveyor. This makes the whole process faster and reduces human work. The conveyor is controlled by a controller unit and runs with the help of motor drivers.

7. Weight Measurement

A weight sensor is used to measure how much waste has been collected. This helps in keeping track of the total waste and also gives an idea when the storage bin is getting full. Based on this, alerts can be generated if needed.

8. Microcontroller

The microcontroller acts like the brain of the whole system. It receives signals from different sensors like the camera, obstacle sensor, and weight sensor. After processing the data, it sends commands to the motors and conveyor to perform the required actions. It also manages Bluetooth communication for wireless control.

9. Bluetooth-Based Wireless Remote Control

This feature allows the user to control the system manually using a mobile phone or remote device. It is useful when manual operation is required. The commands are sent through Bluetooth to the microcontroller, which then controls the movement and working of the system.

10. Motor Drivers

Function: Interface between the microcontroller and motors.

Purpose: Amplifies control signals to drive the motors in various directions.

Controls the movement motors and the conveyor motor.

11. Motors (Front, Back, Left, Right, 360° Rotation)

Function: Provides motion to the entire system.

Purpose: Enables movement in all directions for flexible navigation during waste collection.

12. Conveyor Controller

Function: Controls the operation of the conveyor belt (start, stop, direction).

Purpose: Ensures the waste is transported efficiently for segregation or disposal.

2.3 HARDWARE COMPONENMTS

1. Solar Panel

The sources of conventional and non-renewable energy such as coal, petrol, diesel, etc., are continuously depleting on Earth, and their formation takes a very long time. Hence, the need for alternative energy sources such as wind energy, bio-energy, and solar energy has increased. These are known as non-conventional or renewable energy sources.

Among these, solar energy is the most abundant, freely available, and widely used source. Solar energy is obtained with the help of solar cells. These cells convert sunlight into electrical energy based on the photovoltaic effect.

TP4056 Charger Module

This module is used for charging the battery safely. It protects the battery from overcharging and ensures proper functioning.

Technical Specifications:

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{CC}	Input Supply Voltage		●	4.0	5	8.0	V
I_{CC}	Input Supply Current	Charge Mode, R_{PROG} = 1.2k StandbyMode(Charge Terminated) Shutdown Mode (R_{PROG} Not Connected, V_{CC} < V_{BAT}, or V_{CC} < V_{UV})	● ● ●		150 55 55	500 100 100	μA μA μA
V_{FLOAL}	Regulated Output (Float) Voltage	0℃≤T_A≤85℃, I_{BAT}=40mA		4.137	4.2	4.263	V
I_{BAT}	BAT Pin Current Text condition:VBAT=4.0V	R_{PROG} = 2.4k, Current Mode R_{PROG} = 1.2k, Current Mode Standby Mode, V_{BAT} = 4.2V	● ● ●	450 950 0	500 1000 −2.5	550 1050 −6	mA mA μA
I_{TRIKL}	Trickle Charge Current	V_{BAT}<V_{TRIKL}, R_{PROG}=1.2K	●	120	130	140	mA
V_{TRIKL}	Trickle Charge Threshold Voltage	R_{PROG}=1.2K, V_{BAT} Rising		2.8	2.9	3.0	V
V_{TRHYS}	Trickle Charge Hysteresis Voltage	R_{PROG}=1.2K		60	80	100	mV
T_{LIM}	Junction Temperature in Constant Temperature Mode				145		℃

Absolute Maximum Ratings

Input Supply Voltage (VCC)-0.3 to 8V

TEMP：-0.3V to 10V

BAT Short-Circuit Duration continuous

BAT Pin Current：1200mA

PROG Pin Current：1200uA

Maximum Junction Temperature：145℃

Operating Ambient Temperature Range：-40℃ to 85℃

Lead Temp. (Soldering, 10sec) ：260℃

2. 18650 Battery

Fig. 5: 18650 Battery

Size and Dimensions of the battery:

The 18650 battery is a commonly used rechargeable lithium-ion battery. It has a cylindrical shape with an approximate diameter of 18 mm and a length of 65 mm, which is why it is called “18650”.
It works on lithium-ion (Li-ion) chemistry, which is known for providing good energy density and better efficiency compared to many other battery types. The battery has a nominal voltage of around 3.7V, and when it is fully charged, it can reach up to 4.2V. The capacity of this battery usually ranges between 1200 mAh to 3000 mAh depending on the model and quality. One important advantage of this battery is that it is rechargeable. However, it should always be charged using a proper charging module like TP4056 to ensure safety and longer battery life. These batteries are widely used in devices such as flashlights, power banks, and other portable electronic gadgets

because of their reliability and compact size. While using this battery, some safety precautions should be followed. Overcharging and deep discharging should be avoided, as they can damage the battery. It is also important to use proper charging circuits and handle the battery carefully to prevent any kind of damage or risk.

3. **ESP8266 NodeMCU**

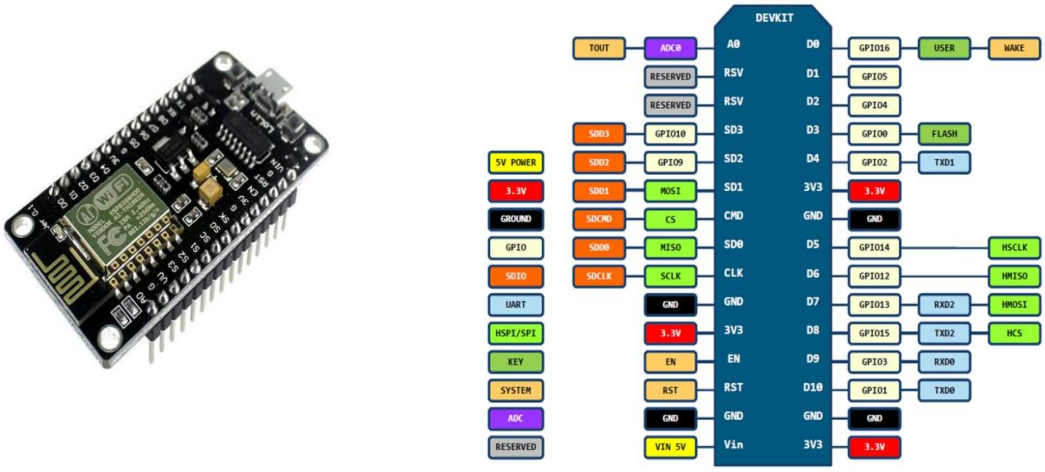

Fig. 6: ESP8266 NodeMCU

The ESP8266 NodeMCU is a microcontroller board developed by Espressif Systems. It comes with an inbuilt Wi-Fi feature, which makes it useful for connecting devices to the internet and running different applications. One of the main advantages of this board is that it is easy to use and program. It has a built-in USB port, so it can be directly connected to a computer for coding and uploading programs. It also provides multiple GPIO pins, which makes it simple to connect sensors, motors, and other components in the system. Because of its compact size and useful features, it is widely used in many IoT-based. Using a micro-USB cable, it can be directly connected to a laptop and programmed easily, similar to Arduino. It is widely used in IoT-based projects due to its low cost and built-in Wi-Fi capability.

4. **Relay Module**

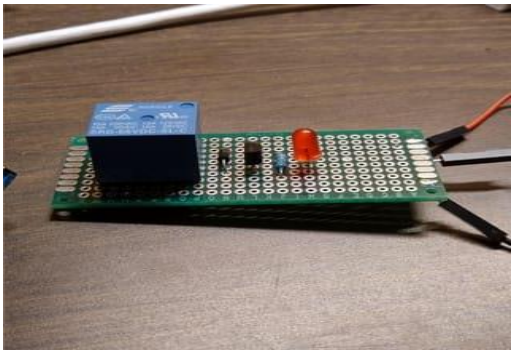

Fig. 7: Relay Module

A relay module is an electronic device used to control high-voltage or high-current devices using low-voltage signals from a microcontroller.

3. LITERATURE REVIEW

In recent years, many researchers have worked on water pollution monitoring and cleaning systems. Different technologies like IoT, robotics, and renewable energy are being used to solve this problem. In this section, we have discussed some previous work and also their limitations.

3.1 Portable Water Pollution Monitoring Device (2021)

This study shows a portable device that is used to check the quality of water. It measures different important parameters such as pH level, temperature, turbidity, conductivity, and dissolved oxygen.

The system is useful because it helps in monitoring water conditions in real time. It is small in size and easy to use, which makes it practical for different locations.

However, the system mainly focuses only on monitoring water quality. It does not include any method for cleaning the water or removing waste. Because of this, it cannot solve the complete problem of water pollution.

3.2 Solar Energy Based Water Cleaning Robot (2023)

This paper describes a solar-powered robot designed to collect floating waste from water bodies. The system uses Arduino, DC motors, and a conveyor belt to collect waste. It is controlled manually using a mobile phone through Bluetooth.

The main limitation is that the system is not fully automatic. It does not include features like obstacle detection, intelligent decision-making, or IoT integration.

3.3 In-Water Surface Cleaning Robot (2013)

This research is about a robot that is specially designed to clean surfaces under water. The robot is made in such a way that it can move easily on underwater surfaces and perform cleaning tasks.

The main focus of this system is on its mechanical design and movement. It does not include advanced features like AI, sensors, or automation. Also, the testing results mentioned in the paper are quite limited.

Still, this study is helpful because it gives a basic idea about how robots can move and work on underwater surfaces.

3.4 Swachh Hasth – Water Cleaning Robot (2020)

In this study, a semi-automatic water cleaning robot is developed using Arduino. The system uses sensors like ultrasonic and PIR to detect obstacles and objects present in water.

The robot can be controlled using a mobile application through Bluetooth, which makes it easy to operate. However, the system is not fully automatic and does not include advanced technologies like IoT or intelligent decision-making.

Also, most of the testing is done only in simulation, not in real conditions. Even then, this paper is useful because it shows how sensors can improve the working of cleaning systems.

3.5 Automation and Robotics in Hydroponics and Aquaponics (2025)

This paper mainly focuses on the use of automation, IoT, robotics, and AI in modern farming systems like hydroponics and aquaponics. These technologies help in improving efficiency and reducing the need for manual work.

However, there are still some challenges, such as high cost, more energy consumption, and difficulty in creating fully integrated systems.

From this study, we can understand how automation can be used in large-scale applications and why sustainable solutions are important in today's time.

4. METHODOLOGY

In this project, the methodology explains how we designed, built, and tested the solar-powered waste segregation system. It includes basic calculations, system setup, and the steps followed during testing. The main focus was to make the system simple and practical.

4.1 Analytical & Mathematical Design

To understand how the system will perform, we did some basic calculations like power requirement, battery backup, motor selection, and sensor working.

1. Solar Power Estimation

We assumed the average solar irradiance to be around 1000 W/m², and the efficiency of the solar panel is about 18%.

Using the formula:

Power = Irradiance × Area × Efficiency

We got approximately 45 W power from one panel. Since we used two panels, the total power comes out to be around 90 W, which is enough to run motors, sensors, and other components.

2. Battery Backup

We used a 12V, 7Ah battery in our system. So, the total energy stored is around 84 Wh.

If the system consumes around 25W, then the battery can run the system for nearly 3 hours. This is useful when there is no sunlight.

3. Motor Torque Calculation

For movement, we calculated the torque required for the motor.

We considered the wheel radius as 0.05 m and required force as 5 N.

Using the formula: Torque = Force × Radius

The required torque comes out to be around 0.25 N·m. So, we selected motors with at least this rating to ensure proper movement.

4. Sensor Response and Range

For obstacle detection, we used an ultrasonic sensor. It calculates distance using sound waves.

The detection formula is based on time and speed of sound. It works accurately up to around 4 meters.

The camera module also processes images quickly, with a delay of less than 200 ms, which is acceptable for real-time use.

5. Waste Weight Measurement

A load cell is used to measure the weight of collected waste. It works by detecting small changes in resistance and converting them into voltage. This helps in monitoring how much waste is collected.

4.2 Experimental Design

Setup

In our setup, the solar panel charges the battery through a charge controller. The stored energy is then used to run the system.

The microcontroller (ESP32 or Arduino) controls all components like motors, sensors, and communication modules (Bluetooth/Wi-Fi).

4.3 Testing Environment

We tested the system in a controlled environment, like a small water tank or shallow water area. Floating plastic waste and small obstacles were placed to check the working of the system.

4.4 Procedure

The working process of the system is as follows:

Step 1: The system is powered using solar energy

Step 2: The camera detects and identifies waste

Step 3: Sensors detect obstacles and adjust movement

Step 4: The conveyor collects waste and sends it to the segregation unit

Step 5: Waste is separated into different categories

Step 6: Weight sensor measures collected waste and data is sent through Bluetooth.

5. RESULTS AND DISCUSSION

We tested the developed solar-powered system in a controlled environment, and from our observation, it was working properly under normal sunlight conditions. The solar panels were able to generate enough power to run all components like motors, sensors, and the control unit without any major issue. The battery backup supported the system for around 3 hours, which is useful when sunlight is not available or during cloudy conditions. It takes nearly 5 hours to fully charge the battery using solar energy. The motors worked smoothly, and the system was able to move and collect waste without any mechanical problems. The ultrasonic sensor performed well in detecting obstacles, and in most cases, the system was able to avoid collisions. This improved the safety of the robot and reduced the chances of damage. The Bluetooth control also worked properly and allowed us to control the system manually whenever required. The camera module helped in identifying different types of waste, which improved the segregation process. However, we noticed a small delay sometimes, especially in low light conditions. Still, overall performance was satisfactory. The load cell gave proper weight readings, and alerts were generated when the bin was full. The system mainly focuses on collecting floating solid waste. It also helps in improving water condition by removing visible waste. It cannot completely remove dissolved impurities, but it can help in monitoring them. The segregation accuracy was quite good, with very few errors observed. Power consumption was also within the expected limit, and the system worked efficiently using solar energy. The overall efficiency of the system was around 82–86%, which is acceptable for practical use. We did notice some small issues like reduced performance in low light and slight delay in image processing, but these did not affect the overall working of the system in a major way. Overall, the system performed well and proved to be useful for waste collection and segregation. It reduces manual effort and helps in keeping the environment clean, especially in areas where manual cleaning is difficult.

CONCLUSION

In this project, we developed a solar-powered automatic waste collection and segregation system. From our testing and observations, it is clear that the system works effectively and can help in reducing water pollution. All the components like solar panel, microcontroller, sensors, motors, conveyor, and Bluetooth module work together to perform the required operations. The use of solar energy makes the system eco-friendly and reduces dependency on electricity. The robot is capable of moving in different directions and collecting waste while avoiding obstacles. The conveyor system helps in collecting waste, and the segregation unit separates it into different categories, which is useful for recycling. The system can also help in monitoring water quality to some extent, although it cannot completely remove dissolved impurities. The microcontroller manages all operations, and Bluetooth control gives flexibility for manual operation. Overall, this project shows that a simple combination of automation and renewable energy can provide a practical solution for waste management. It reduces human effort and helps in maintaining cleanliness in water bodies and surrounding areas

FUTURE SCOPE

There are many improvements that can be made to this system in the future.

One of the main improvements is adding Artificial Intelligence (AI). With AI, the system can become smarter in identifying different types of waste more accurately and improve its performance over time.
Another improvement is adding GPS-based navigation. This will help the robot move automatically to specific locations and cover larger areas like rivers, lakes, and cities.

The waste segregation process can also be improved using machine learning and image processing techniques. This will increase the accuracy of waste classification.
In future, a hydraulic or automatic dumping system can be added so that the robot can unload waste without human help. This will make the system more practical.
Battery capacity can also be increased to improve working time, especially in low sunlight or night conditions.
The system can also be modified for underwater cleaning with proper design changes. This will help in cleaning both surface and underwater waste.
Another improvement is connecting the system with IoT. This will allow remote monitoring and control using mobile apps, where users can check system status and performance.
Multiple robots can also be used together for faster cleaning in large areas. These robots can work in coordination and divide tasks among themselves.
In future, this system can be used in smart cities and connected with waste management systems for better planning and control.
Overall, this project has a wide future scope and can be improved further to make it more efficient, intelligent, and suitable for real-world applications.

It has the potential to significantly contribute to environmental protection and sustainable development.

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