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# AI-ENABLED SOLAR-POWERED BEACH CLEANING ROBOT

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**Abstract -** *Beach pollution, especially due to plastic waste, has become a major environmental concern affecting marine life and coastal ecosystems. This project presents the design and development of an AI-based Beach Cleaning Robot that automates the process of waste detection, collection, and segregation. The system integrates a Raspberry Pi 4 Model B, Arduino Uno , USB camera, and motor control mechanisms to perform intelligent cleaning operations. The camera captures real-time images of the beach surface, and the system uses ONNX Runtime to detect both plastic and metal waste using a trained machine learning model. The robot classifies waste into recyclable plastic and non-recyclable categories, where metal and other non-recyclable waste are deposited together .The Arduino controls motors and actuators, enabling movement and waste collection. The system is designed to reduce human effort, improve cleaning efficiency, and support environmental sustainability. This project demonstrates the effective use of artificial intelligence, embedded systems, and robotics for smart waste management in coastal areas.*

***Key Words*: Raspberry Pi, Arduino Uno, ONNX Runtime, Beach Cleaning Robot, AI, Plastic Detection.**

## 1. INTRODUCTION

Plastic pollution on beaches has become a serious environmental issue, affecting marine ecosystems, tourism, and human health. Traditional beach cleaning methods rely heavily on manual labor, which is time-consuming, inefficient, and labor-intensive. To overcome these limitations, this project proposes an automated beach cleaning robot that uses artificial intelligence and embedded systems for efficient waste management

The system combines Raspberry Pi 4 Model B and Arduino Uno to create a hybrid control architecture. The Raspberry Pi acts as the main processing unit, handling image processing and AI-based waste detection using ONNX Runtime, while the Arduino controls motors, sensors, and mechanical components. A USB camera captures images of the beach, and the system identifies plastic waste objects such as bottles and wrappers. The system uses a USB camera along with ONNX Runtime to detect both plastic and metal waste through image processing, enabling basic waste segregation. The robot moves on the beach using DC gear motors and collects waste using a mechanical conveyor system. Recyclable plastic waste is directed to a shredding mechanism, while non-recyclable waste is separated into a different bin. This integrated system enhances cleaning efficiency, reduces human effort, and supports sustainable waste management practices. The project highlights the importance of combining robotics and AI for environmental protection

## 2. WORKING PRINCIPLE

The working of the beach cleaning robot is based on the integration of artificial intelligence, and embedded control systems. When the system is powered ON, the Raspberry Pi 4 Model B and Arduino Uno are initialized, and the robot starts moving forward using DC motors. A USB camera captures images of the waste present on the beach surface, which are processed using ONNX Runtime to identify plastic and metal objects. Based on the classification results, the system activates the collection mechanism and separates waste into two categories: recyclable plastic and non-recyclable waste including metal. The Arduino controls the motors and actuators, while the Raspberry Pi handles image processing and decision-making. The robot continuously performs detection, classification, and collection, ensuring efficient and automated beach cleaning.

## 3. BLOCK DIAGRAM

The USB camera collect information about the beach environment and the waste present on the surface. This information is sent to the Arduino Uno for initial processing. The Arduino Uno processes this data and may also send it to the Raspberry Pi 4 Model B for more complex processing such as image analysis. Based on the processed information, the Arduino Uno controls the motor drivers to move the robot and operates the servo motor for waste segregation. It also controls the conveyor belt and shredding mechanism for waste collection and processing. The system can also send information to a web application for monitoring and control.

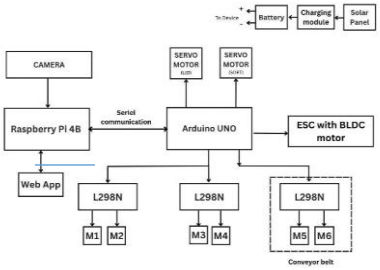


*Figure 3 Block Diagram*

### 3.1 Arduino Uno

The Arduino Uno acts as the main controller for sensors and actuators. It receives input from sensors, processes basic data, and controls motors, servo mechanisms, and other hardware components for robot movement and waste collection..

Fig 3.1 Arduino Uno

### 3.2 Raspberry Pi

The Raspberry Pi 4 Model B is used as the main processing unit of the system. It performs image processing and runs the AI model using ONNX Runtime to detect plastic waste. It also communicates with the Arduino Uno for controlling hardware components and supports web-based monitoring.

Fig 3.2 Raspberry Pi

### 3.3 Usb camera

The USB camera is used to capture real-time images of the beach surface. These images are sent to the Raspberry Pi for processing and detection of plastic waste using AI techniques.

Fig 3.3 Usb camera

### 3.4 L298N Motor Driver

The L298N Motor Driver Module is used to control the DC motors. It allows the Arduino to control the speed and direction of motors used for robot movement and conveyor operation.

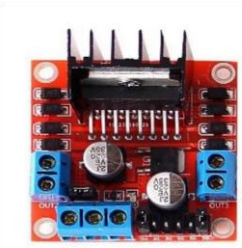

Fig 3.4 L298N Motor Driver

### 3.5 Servo motor

Servo motors are used for controlling the direction of waste flow. They help in diverting waste into different bins such as metal, recyclable, and non-recyclable categories.

### 3.8 Dc gear motors

The DC gear motors are used for the movement of the robot. They provide sufficient torque to move the robot on sandy beach surfaces.


*Fig 3.5 servo motor*

### 3.6 ESC (Electronic Speed Controller)

The Electronic Speed Controller (ESC) is used to control the speed of the BLDC motor. It ensures smooth operation of the shredding mechanism.

Fig 3.6 Electronic Speed Controller

### 3.7 Bldc motor

The BLDC motor is used in the shredding system to crush collected plastic waste into smaller pieces for easier recycling.


Fig 3.7 Bldc motor

Fig 3.8 Dc gear motors

### 3.9 Solar panel

A solar panel is used as a power source to supply energy to the system, which is stored in a battery and distributed.

Fig 3.9 Solar panel

## 4 CIRCUIT DIAGRA

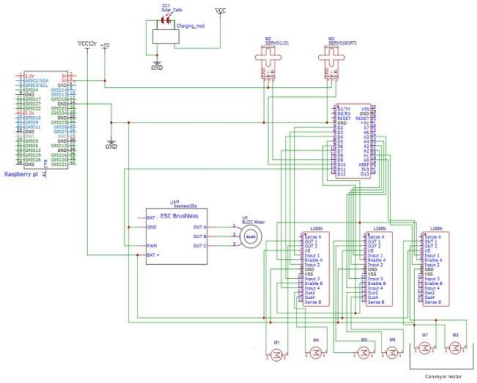

Fig 4.1 Circuit Diagram

## 5 RESULT AND DISCUSSIONS

The developed beach cleaning robot was successfully tested for its ability to detect and collect waste from the beach environment. The system was able to identify both plastic and metal waste using the USB camera and ONNX Runtime, providing satisfactory detection results under normal lighting conditions. The coordinated operation between the Raspberry Pi 4 Model B and Arduino Uno ensured smooth functioning of both processing and control tasks .The robot demonstrated efficient movement using DC gear motors and successful operation of the conveyor and shredding mechanisms. However, the system performance was affected by factors such as uneven sandy surfaces, varying lighting conditions, and limited processing speed during real-time image analysis. Despite these limitations, the overall performance of the system was effective, and it proved

to be a reliable solution for automated beach cleaning and waste management applications.

## 5. CONCLUSION

In conclusion, this project successfully demonstrated the potential of a beach cleaning robot incorporating AI-based waste detection and automated collection, highlighting the feasibility of integrating Raspberry Pi 4 Model B, Arduino Uno, camera-based sensing and ONNX Runtime, while also identifying areas for future improvement in detection accuracy, system efficiency, and real-time performance.

## 6. REFERENCES

[1] Sivasankar et al., "Autonomous Trash Collecting Robot," 2017.Wolpaw, J. R., Birbaumer, N., McFarland, D. J., Pfurtscheller, G., & Vaughan, T. M. (2002). Brain–computer interfaces for communication and control

[2] Thiagarajan and S. Satheesh Kumar, "Machine Learning Model for Beach Litter Detection," 2018.J. Arnil, Y. Punsawad and Y. Wongsawat 2011 Wireless Sensor Network based Smart System for Healthcare Monitoring international conference on robotics and biomimetics, pp. 2073- 2076.

[3] N. Bano and A. Amin, "Radio-Controlled Beach Cleaning Bot," 2019

[4] Narayanan et al., "Plastic Waste Profiling System Using Deep Learning," 2020.

[5] Kong et al., "IWSCR: Intelligent Water Surface Cleaner Robot for Floating Garbage Collection," 2021.