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A Surface Water Trash Collector Based On Object Detection

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Abstract: Water pollution caused by plastics has come into being as a prevalent and alarming environmental problem with detrimental consequences on aqua systems and human well-being. The presence of ubiquitous plastics such as bottles, bags, and other packaging materials in the environment has resulted in plastics pollution of rivers, lakes, and oceans, which is a critical issue that requires immediate action and comprehensive solutions. Discarded plastic bags, bottles, and packaging materials enter water bodies through various routes such as poor disposal, storm water, and poor waste management, among others. Once in water, plastics begin to physically degrade and breakdown into smaller pieces which are commonly known as microplastics. They are microscopic substances mostly not visible to the naked eye, yet they have affected water sources worldwide. Garbage classification has become an increasingly popular topic in recent years. The rivers are used for disposing untreated plastic wastes which are responsible for degrading the amount of dissolved oxygen in water.

The main aim of the project is to introduce a surface water trash collector based on object detection. This system will help in collecting plastic waste from waterbodies. This innovative system will employ cameras and sensors strategically positioned to monitor and detect plastic in real-time. The collected data will be processed and analysed using OpenCV image detection to identify and categorize the plastic accurately. The system also includes conveyor belt that picks up plastic and dumps it in the designated trash bin.

Considering the growing concern for environmental preservation, our project seeks to address this critical issue and provide a cost-effective, and efficient solution for the management of surface water pollution. Our project primarily aims at reducing the manual labour and time consumption involved in cleaning the water bodies. Automating the process of waste collection using deep learning techniques and segregating the wastes will make it easy for the industries to recycle plastic wastes.

Keywords: Raspberry Pi 3, H Bridge circuit, Opencv, Catamaran, COCO

I. INTRODUCTION

One of the primary contributors to water pollution is plastic waste. Single-use plastics, in the form of bottles, bags, and packaging materials, have inundated water sources, breaking down into smaller fragments known as microplastics. These microscopic particles not only pose a direct threat to aquatic life but also have the potential to infiltrate the human food chain, with unknown consequences for public health. The persistence of plastics in the environment exacerbates the problem, as they can take centuries to decompose fully.

According to ‘Water Aid’, 80 percent of India’s water sources are contaminated. The Central Pollution Control Board (CPCB) monitors water Quality of aquatic resources at 4484 locations in 28 States and 7 Union Territories.

Based on analysis of water quality data of 603 rivers on 1920 locations for the years 2019 and 2021, CPCB in year 2022, has identified 311 polluted rivers. An expedition to document underwater biodiversity led by the European Union-supported Project Ecomarine in the Department of Aquatic Biology and Fisheries, University of Kerala, found reefs beyond 40 metres depth dumped with plastics.

Underwater sites were littered with plastic bottles, bags, fishing nets, and fragments of single-use plastics. The importance of reducing water pollution due to garbage cannot be overstated. Addressing this multifaceted challenge demands a comprehensive and collaborative approach.

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To address the significant challenge of waste collection in water bodies, particularly the pervasive issue of plastic pollution, this project proposes the design of a surface water trash collector based on object detection. The objective is to provide a partially automated system capable of efficiently collecting plastic waste from aquatic environments. Central to the system's functionality is the utilization of Raspberry Pi and a Pi camera for waste detection, coupled with air propulsion for navigation. By employing advanced image processing techniques, the system enhances the accuracy and efficiency of waste detection and collection processes. The underlying motivation behind this project is to promote environmental sustainability by reducing reliance on conventional methodologies of waste collection, which are often highly inefficient. By integrating technology-driven solutions, this project aims to contribute towards more effective and environmentally friendly approaches to addressing plastic pollution in water bodies.

II. BLOCK DIAGRAM OF THE PROPOSED SYSTEM

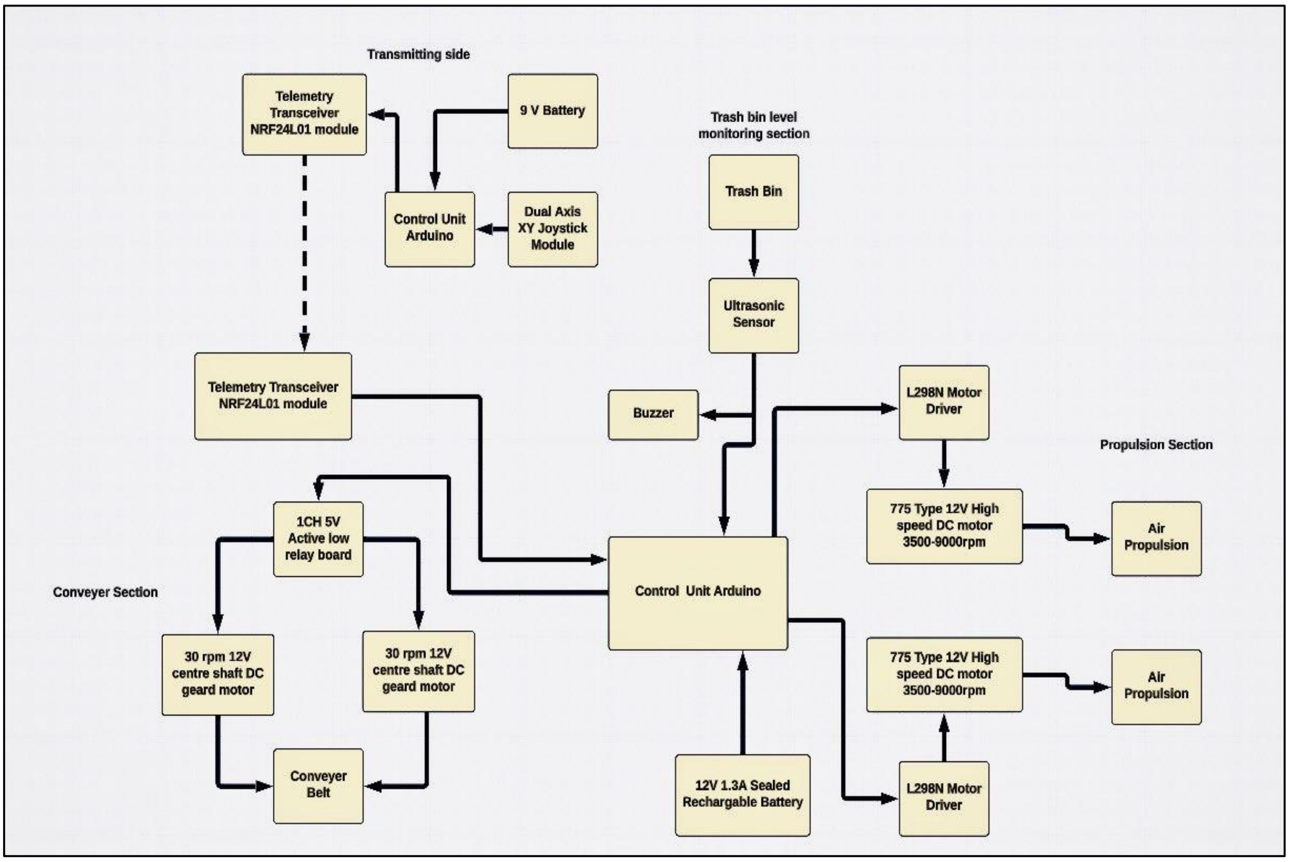

Fig.1 Proposed Block Diagram

The system is meticulously designed to facilitate remote control movement, collection and monitoring of trash collector which makes use of a conveyor belt system for collection which is enhanced with trash level monitoring capabilities. It is structured into two fundamental segments: the receiving end and the transmitting end. Fig.1 shows the Block diagram of the system which includes both receiver and transmitter side. The transmitter side is for controlling the movement of the boat and the conveyor belt manually.

Receiver side

At the receiving end, the central control unit is an Arduino microcontroller, orchestrating seamless integration and functionality across various subsystems.

The propulsion section governs the movement of the entire structure, utilizing two high-speed DC motors (775 type). These motors are controlled by motor drivers (L298N Motor Driver), ensuring precise regulation of speed and direction. Additionally, a relay operated switch interface allows users to toggle the conveyor belt on or off which is powered by two 12V 30rpm geared DC Motors, providing simple yet effective control over waste collection.

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Trash level monitoring is facilitated by an ultrasonic sensor seamlessly integrated into the system. This sensor continuously monitors the fill level of the trash bin, enabling proactive waste management.

Furthermore, a telemetry transceiver module is integrated on both sides, enabling wireless communication between both ends. This bidirectional exchange of control signals and data facilitates remote operation and monitoring.

Transmitter side

The transmitting end features a joystick interface for intuitive control over the propulsion system. Users can manipulate the joystick to precisely control the speed and direction of the DC Motors for air propulsion. A switch is also incorporated in the transmitter side to provide on/off functionality for the conveyor belt through the 1CH Active low relay board, offering convenient control options. A 9V battery serves as the primary power source, ensuring portability and autonomy in operation. The Arduino microcontroller acts as the control hub at the transmitting end, coordinating the transmission of control signals to the receiving end through the telemetry transceiver module.

III. OPERATING METHODOLOGY

The basic operation of the proposed model is outlined as follows. The boat's navigation is controlled by a joystick located on the transmitter side. Movement commands, such as forward, backward, left, and right, are transmitted to the boat via the joystick's manipulation. The boat's propulsion system consists of two 775 type DC Motors, which utilize air propulsion. These motors are controlled by two L298N motor drivers employing an H-bridge circuit.

The navigation of the boat is facilitated by the following motor movements:
When the left motor rotates while the right motor remains stationary, the boat moves towards the right.
Conversely, when the right motor rotates while the left motor remains stationary, the boat moves towards the left.
Both motors rotating clockwise from a rear-view result in the boat moving forward.
Conversely, both motors rotating counterclockwise from a rear view cause the boat to move backward.

In this manner, the boat adeptly maneuvers through the water body, directed towards the target trash for collection.
The Raspberry Pi, interfaced with the Pi camera, provides live streaming of objects in front of the boat. Utilizing OpenCV software, the system detects objects within the camera's field of view. Upon successful identification of plastic waste, indicated by the system's recognition, the LEDs blink to signify detection. After detection, the system operates the two 12V 30rpm geared DC motors through a switch-operated 1CH active low relay board.

This control mechanism allows for precise management of the conveyor belt's movement. In this manner, the system collects the trash onto the conveyor belt and subsequently transfers it into the trash bin. The process continues, with trash being picked up until the bin reaches its maximum capacity.

An ultrasonic sensor, mounted on top of the trash bin, performs real-time sensing of the collected trash level. Once the trash reaches a predetermined maximum level, the buzzer alarm activates, signalling that the limit has been reached. When the limit is reached, the boat navigates back to the dock and empties the contents of the trash bin. Upon successful emptying, the boat is once again prepared for collection.

IV. ELECTRICAL DESIGN

Designing the electrical system for a surface water trash collector involves integrating various components such as batteries, DC motors, sensors, and control systems to efficiently navigate water bodies and collect debris. The main factors to be considered for the electrical design are the battery and DC motor selection.

A. Load Calculations for the selection of propulsion motors

Amount of waste to be collected = 2 kg
Weight of the empty boat = 8 kg
Overall boat weight (in kilograms) = 8 kg + 2 kg = 10 kg
For weight less than 10 kg, 0.7 HP motor or lower HP rated motor can be chosen.
Total electric motor load = 0.3 HP
We choose 2 motors each of capacity 0.15 HP = 112 W
Motors chosen are 12V, 120 W DC Motors.
We are using 2 motors on the rear end of the boat, each of capacity 120W.

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B. Selection of Battery

Total electric load = 0.3 HP = 0.224 kW
Energy required to move the boat= 0.224 * 2 =0.448 kWh/day (works for 2 hours a day).
For marine applications, Lead-Acid battery is chosen.
Since weight is less than 25 kg, 12V battery is chosen.
Battery storage = Energy/Depth of discharge = 0.448/0.9 = 0.498 kWh
Ampere hour rating = 0.498 *1000/ (12*2) = 20.74 Ah
Therefore, we choose a 12 V, 20 Ah sealed rechargeable battery.

C. Selection of DC Motors for Conveyor Belt

Load force F = 100N
Drive pulley radius, r = 0.1m
Frictional torque = 5Nm
Motor efficiency, η=0.85
Voltage, V = 12V

Calculation of Torque:
$T = (100\ N \times 0.1m) + 5Nm = 10Nm + 5Nm = 15Nm$

Calculation of Power:
$P = (15\ N\ m\times(2\pi\times 30\ RPM/ 60))/0.85$
$= 15\ N\ m\times(2\pi\times30/60)/0.85 \approx 27.76\ W$

Calculation of Current:
$I = 27.76W/12V \approx 2.31\ A$

Based on these calculations, a 12 volt, 30 RPM DC geared motor with sufficient torque, power, and current rating should be selected for use in the conveyor belt of the surface water trash collector.

Ensuring the considerations of safety margins and real-world conditions in the selection process is also necessary.

V. MECHANICAL DESIGN

Mechanical calculations

Choice of material: PVC
Choice of hull: Catamaran
Size: 1.4 m x 0.42 m x 0.3 m (length x width x height)
Area of the hull = 1.4 m x 0.42 m = 0.6 sq.metre
Total weight of the boat = 10 kg
Amount of waste collected = 2 kg
Buoyant force = Wt = 10 kg
Weight of water = 1000 kg/$m^3
Water Displaced (m^3) = (Weight of boat + Load) kg / 1000 kg per m^3
Depth of boat that sinks in water = Water Displaced (m^3) / (Length*Width of Boat (m^2))
Depth of displacement = (Weight in kilograms)/Weight of water * (Area in m^2)
= 10 kg / (1000 kg per m^3 * 0.6 m^2) = 0.016 m

Therefore, we choose 0.3 metres as the height of the boat.

Design Considerations

The choice of using Catamaran Structure

1. It is a multi-hulled watercraft featuring two parallel hulls of equal size.
2. It is a geometry-stabilized craft.

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Some advantages of catamaran ship are as follows:
1. Its larger deck can easily carry passengers, vehicles, and large quantity goods.
2. With different hull from mono hull, this has important role to reduce the resistance on the vessel.

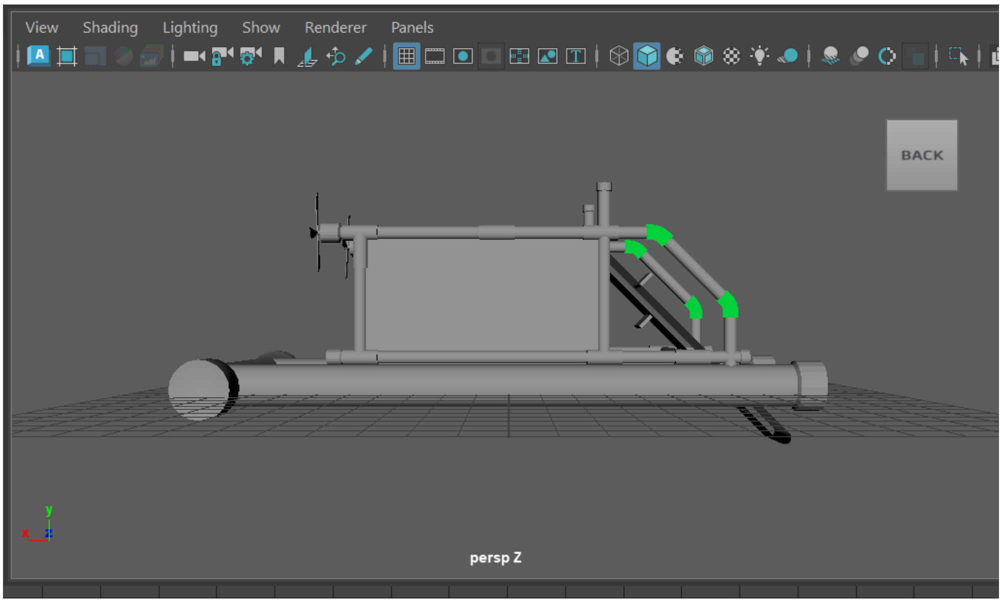

Fig.2 Model of the prototype

VI. IMPLEMENTATION

A. Hardware Body

The structural framework of the hardware body is composed of PVC pipes intricately interconnected through precision-engineered T and L joints. These joints are strategically positioned to ensure optimal structural integrity and stability while accommodating the desired configuration. Additionally, each pipe extremity is securely sealed with end caps, firmly affixed using specialized adhesive techniques, thereby enhancing the overall robustness of the assembly. Furthermore, the hardware framework serves as the foundational support for the integration of a conveyor system, meticulously aligned and seamlessly integrated into the structural design. Alongside the conveyor, an array of carefully selected and strategically positioned circuitry components is incorporated, ensuring precise functionality and smooth operation. This comprehensive integration of hardware components not only demonstrates meticulous engineering but also underscores the attention to detail essential for the seamless operation of the system. Overall, this carefully crafted hardware framework is designed and executed to meet the exacting standards of modern research and development endeavours. Its precise construction, coupled with its seamless integration of conveyor systems and circuitry components, establishes a solid foundation for the successful realization of research objectives and the advancement of scientific knowledge in the field.

Fig.3 Hardware Body

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B. Object Detection Software

Open-CV (Open-Source Computer Vision Library) is the software used here for plastic detection. It is a highly optimized library with a focus on real-time applications. Open-CV is designed to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in commercial products. Being a part of the Open-CV ecosystem, it extensively supports a wide range of programming languages such as Python, C++, Java, and others. The library offers over 2500 optimized algorithms, which include a comprehensive set of both classic and state-of-the-art computer vision and machine learning techniques. These algorithms can be used to detect and recognize faces, identify objects, classify human actions in videos, track camera movements, track moving objects, extract 3D models of objects, and much more.

C. Raspberry pi 3

The Raspberry Pi 3 stands out as a particularly effective platform for image processing tasks due to its enhanced processing capabilities, affordability, and compact size. Equipped with a 1.2 GHz quad-core ARM Cortex-A53 processor and 1 GB of RAM, it provides a substantial performance boost compared to its predecessors. This makes the Raspberry Pi 3 capable of handling more complex image processing algorithms efficiently. The integration of both Wi-Fi and Bluetooth connectivity directly onto the board further enhances its utility, allowing for easy networking and the ability to communicate with other devices wirelessly, which is particularly useful in remote image capturing and processing applications. Additionally, the Raspberry Pi 3 supports a range of peripherals and modules, including the Raspberry Pi camera module, which can be directly connected to the board through a dedicated CSI interface. This allows for high-quality image capture, which is crucial for subsequent processing tasks. The GPIO pins on the Raspberry Pi also support the integration of additional sensors and actuators, enabling the development of sophisticated image-based systems like security cameras, automated inspection systems, and interactive robotics. With its low cost and extensive support community, the Raspberry Pi 3 democratizes access to advanced computing, making it an ideal choice for educators, hobbyists, and professionals developing image processing projects on a budget.

D. COCO Library

COCO (Common Objects in Context) dataset is a large-scale object detection, segmentation, and captioning dataset. OpenCV itself does not have a specific "COCO library", but it can utilize models trained on the COCO dataset through its deep learning module. This allows users to load pre-trained models and use them for object detection, segmentation, and other tasks that COCO supports. This trained library is how the Raspberry Pi will know what certain objects and animals generally look like. pre-trained libraries for all manner of objects, creatures, sounds, and animals are found here. Once set up, the system will be able to use video data coming in from a Raspberry Pi Camera to identify all kinds of everyday objects.

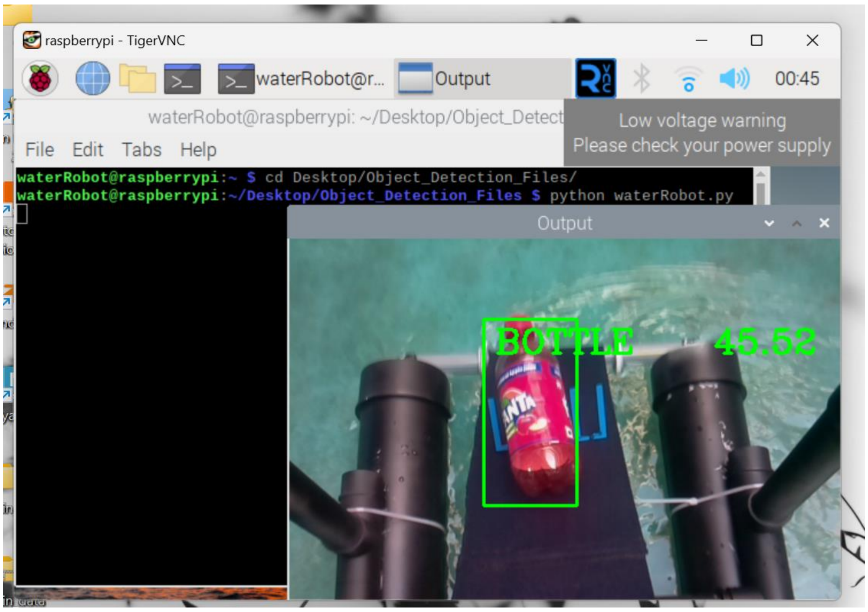

Fig. 4 Plastic Bottle Detection while testing

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VII. CONCLUSION

This Surface Water Trash Collector based on object detection is proposed to mitigate water pollution and the degradation of water caused by plastic. It also aims to bring a cost efficient, technologically advanced and environmentally viable solution to this problem. Our project primarily aims at reducing the manual labour and time consumption involved in cleaning the water bodies of harmful plastic. Collecting plastic waste based on object detection will make it easy for industries to recycle plastic waste. Our project is essentially a plastic waste collecting robot which detects plastic using a raspberry pi camera module and makes use of OpenCV algorithms and image processing techniques to identify whether the objects are plastic or not. The motors and other components are chosen based on the load calculations performed. The materials are chosen in such a way that the weight can balance the buoyant force of water. Object detection using OpenCV is done here which detects the plastic in captured images efficiently. The plastic waste collected can be processed and recycled to form different products.

The mechanical calculations are performed such that the system runs in lake water. By making a few modifications and expansions it can collect more quantities of waste as well as waste from oceans and other water bodies. On later years the system can be made fully autonomous with improving technology. The aim of proposing this idea is to ensure environmental sustainability and reduce reliance on conventional methodologies of waste collection which are highly inefficient.

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