Aquarover: An IoT Based Water Surface Cleaner Robot

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Abstract - *The dumping of waste into water bodies has increased in recent times. The maintenance of water bodies must be done regularly. This paper presents an unmanned surface vehicle (USV) to collect garbage like plastic bottles and algae from the water surface. The system consists of conveyor belt and waste storage tank for waste collection. The system incorporates obstacle avoidance, live-streaming video and movement control. The USV uses camera and YOLOv8 algorithm to detect waste. An Android application is created using MIT App Inventor to operate the robot remotely. The app provides a simple interface for directional control (forward, left, right). A level detection system is also integrated to monitor the fill level of the waste storage tank and gave notification when it reaches its limit.*

***Key Words*: Unmanned Surface Vehicle, Obstacle Avoidance, YOLOv8 algorithm, MIT App Inventor, Waste Storage Tank, Level Detection System.**

1.INTRODUCTION

The amount of waste that is dumped into water bodies has on rise. Currently, the availability of clean water is limited due to the increase in dumping of waste in water bodies. The regular maintenance of water bodies is crucial. Current methods of cleaning water surfaces are mainly based on manual labor or traditional boats, which are often inefficient, expensive, and time-consuming. These methods require substantial human resources and cannot keep up with the continuous flow of waste, especially in large or remote water bodies. Furthermore, manual cleaning processes expose workers to potentially hazardous materials and polluted environments. Traditional waste collection methods, such as manual cleanup, are labor intensive, time consuming and inefficient for large areas. As a result, there is a pressing need for an automated and scalable solution that can address these challenges efficiently and sustainably. To address these challenges, an innovative and automated solution is needed that can efficiently collect and remove floating debris. "Aquarover" aims to overcome this situation by developing an unmanned surface vehicle for collecting floating plastic bottles and algae from the water. The water surface cleaner robot is designed with chain conveyor system to collect the solid wastes from the surface of water and a waste storage tank for waste collection. The unmanned surface vehicle uses camera and machine learning algorithms to detect waste. Aquarover employs a level detection system to monitor the fill level of the waste storage tank and give alert when the bin reaches its limit to unload the bin. A user interface is also used for controlling and monitoring the movement of the robot remotely.

2. LITERATURE SURVEY

In 2022, "Azman Ismail" , et.al developed an Unmanned Surface Vehicle for water wastes collection, to clean Malaysian rivers and reduce flood risks caused by waste ac cumulation. The USV is designed to operate in both remote-controlled and autonomous modes, ensuring efficient and flexible cleaning operations. The system consists of four key subsystems: Obstacle Avoidance (SS1): Uses sensors to detect and avoid obstacles, ensuring smooth navigation. Coordinate Detection (SS2): Determines the USV's location for precise movement and guided navigation. Live-Streaming Video (SS3): Provides real time visuals to monitor operations and assist in manual control. Movement Control (SS4): Manages propulsion and steering to collect waste effectively. The USV is integrated with Internet of Things (IoT) technology, allowing users to monitor and control it remotely via the Blynk app. The system is powered by a Raspberry Pi and programmed using Python to enable automation. By efficiently removing waste from rivers, this project helps to prevent blockages, reduce flood risks, and improve water quality, contributing to a cleaner and more sustainable environment in Malaysia [1].

In 2022, "Joy Jacqueline Pereira", et.al. This study assesses the economic impact of small-scale flash floods in Kuala Lumpur, Malaysia, from 2010 to 2016. Unlike large-scale disasters, the cumulative effects of frequent small floods are often overlooked. The study estimates the direct and indirect damage costs of 204 flash flood events, using a heuristic approach due to limited data. The findings reveal that total damages reached RM48.7 million, representing 0.04% of Kuala Lumpur's GDP in 2016. Indirect costs, mainly from disrupted road networks and lost productivity, were up to four times higher than direct damages, which included damage to roads, commercial, and residential areas. The paper highlights that flash flood damages are expected to rise due to rapid urbanization and climate change, emphasizing the need for risk reduction strategies, particularly in the transportation sector. The study serves as baseline information for future research and policymaking to mitigate flood-related economic losses in Kuala Lumpur[2].

In 2022, "Shahaziya Parvez M", et.al developed a Surface Water Garbage Collector and Quality Monitoring System designed to clean floating garbage from water bodies while also monitoring the water quality in real-time. The authors propose an intelligent robotic solution that autonomously locates and collects floating waste using a robotic arm and stores it in a dedicated compartment. The system utilizes a Raspberry Pi microprocessor to control operations, including the garbage collection process and the monitoring of water quality parameters such as turbidity, conductivity, and temperature. These parameters are measured using various sensors and can be accessed through a web server, allowing for real-time monitoring. The movement of the robot is powered by a motor-driven propeller system, and an ultrasonic sensor is used to avoid obstacles. The proposed system is an improvement over earlier garbage collection methods, which either relied on manual labor or simple mechanical systems like pedal-operated machines. This system, however, minimizes manual intervention and can autonomously cover a large area for waste collection. It also addresses environmental concerns by preventing further pollution in water bodies that have been cleaned. One of the key advantages of this design is its ability to continuously monitor water quality while collecting garbage, thus serving as both a cleaning and monitoring tool. However, a notable limitation is that the system requires periodic recharging to maintain its operation [3].

In 2022, "Jiannan Zhu", et.al developed a SMRUF; A Fully Autonomous Water Surface Cleaner Robot, this paper focuses on the design and implementation of SMURF, a fully autonomous water surface cleaning robot. The aim is to address the inefficiencies and dangers of traditional, manual waste-cleaning methods on water bodies. SMURF incorpo rates a novel coverage path planning (CPP) technique that adapts to irregular boundaries and obstacles, and an improved nonlinear model predictive controller (NMPC) for better tracking of the planned path. The robot's hull is designed for stability and resistance to corrosion, and its trash collection system includes an efficient gathering and trapping mechanism. The hardware features advanced sensors and processors for precise navigation and environmental perception. SMURF operates autonomously, requiring only an initial boundary setup, and it effectively detects and collects waste in various water bodies. Real-world tests demonstrate its significantly higher efficiency compared to traditional cleaning methods [4].

In 2021, "P. N. F. M. Shamsuddina", et.al. developed a Water Trash Collector (WTC), an Unmanned Surface Vehicle (USV) aimed at cleaning floating waste from water bodies like lakes and rivers. The catamaran hull design is chosen for its stability and capacity to hold a trash collection system. The WTC is constructed using high-quality stainless steel for durability and corrosion resistance. The system is remotely controlled using a FlySky controller and powered by SmartDrive Duo-30 and Duo-10 motor drivers, along with high-torque electric scooter motors and DC gear worm motors. The WTC successfully operates on water without leakage, efficiently collecting floating waste. For future improvements, the paper suggests making the WTC autonomous by integrating navigation, control, and guidance (NGC) systems using neural networks. Additional sensors such as GPS, accelerometer, gyroscope, and distance sensors could enable the vehicle to detect and navigate towards waste autonomously, reducing human intervention. The project aims to minimize water pollution and prevent drain clogging, promoting an environmentally friendly waste management solution[5].

3. PROPOSED SYSTEM

AquaRover: An IoT-Based Water Surface Cleaner Robot, is designed as an autonomous and remotely controlled solution for efficient waste collection from water surfaces. The system consists of an unmanned surface vehicle (USV) equipped with a chain conveyor and a waste bin to collect floating debris such as plastic bottles and algae. A camera module integrated with the YOLOv8 object detection algorithm enables real-time waste identification, ensuring targeted and efficient waste collection. The robot is controlled via a Wi-Fi-enabled Android application called WAT_BOT, developed using MIT App Inventor, which allows users to navigate Aquarover in multiple directions (forward, left, and right). Additionally, a fill-level detection system is implemented to monitor the waste storage tank and alert the user when it reaches its capacity, ensuring timely waste disposal.

3.1 WAT_BOT Development

The Android App is built using MIT app inventor with the help of block codes. The Android app sends movement commands (left, right and forward) via Wi-Fi to the NodeMCU. NodeMCU decodes the received command and signals the ESC to adjust the BLDC motor's speed and direction. The ultrasonic sensor continuously monitors the surroundings for obstacles. If an obstacle is detected, the NodeMCU redirects its movement.

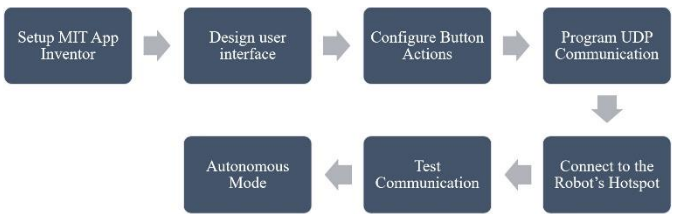

Fig -1: Stages of WAT_BOT Development

Identify the functions the app needs to perform, such as controlling the robot's movement (forward, left, right). Sketch the user interface (UI) layout, including buttons for navigation and speed control.

- Control Logic: Define the behavior for each button. For example, when the "Forward" button is clicked, send a signal to the NodeMCU to move the robot forward.
- Communication: Set up Bluetooth or Wi-Fi modules to send and receive commands between the app and NodeMCU.
- Testing and Debugging: Connect the Android app to the NodeMCU. Test each button to ensure the robot moves correctly.
- For autonomous operation, raspberry Pi camera captures real time video for waste detection. A pre-trained deep learning model YOLO is used for detecting waste in the water. By analyzing the position of detected waste, if the waste is detected on the right the left propeller rotates to move the robot towards the waste and vice-versa. If the waste is at the center, both propellers guide the robot forward.

4. METHODOLOGY

4.1 Project flow

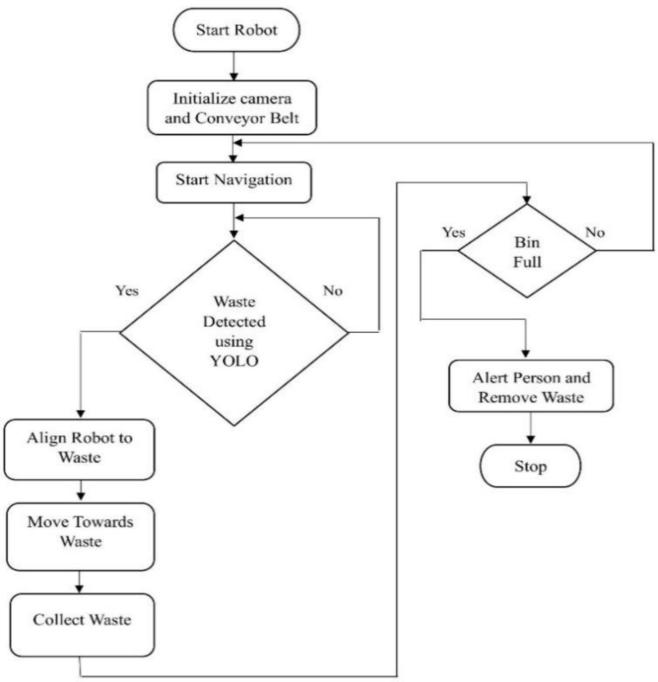

Fig -2: Flowchart

The operation starts with initializing Aquarover, activating the camera module for waste detection and the chain conveyor for waste collection. Aquarover starts navigating while continuously scanning the water surface for waste. If no waste is detected, it continues navigation. When waste is detected, Aquarover identifies its type using YOLO algorithm, aligns the robot towards the waste and moves in its direction for collection. The chain conveyor picks up the waste and stores it in a waste collection bin. An ultrasonic sensor is used to monitor the bin's capacity, and if it becomes full, a notification is sent to the operator to remove the collected waste. After waste disposal, the operator decides whether to continue navigation or stop. By leveraging IoT and automation, Aquarover offers an efficient and scalable alternative to conventional water cleaning methods, reducing manual effort and enhancing waste collection in water bodies.

4.2 Block Diagram

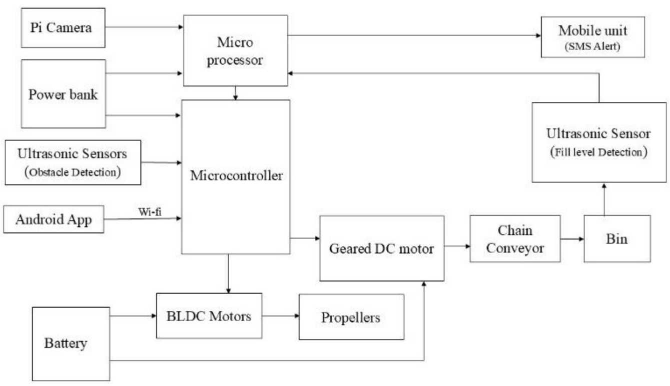

Fig -3: Block Diagram

- The camera captures real-time images of the water surface and sends the data to the microprocessor, which processes the image for waste detection using YOLO, an object detection algorithm. The processed information is then communicated to the microcontroller, which acts as the central control unit.
- The battery provides power to all the electronic components, including the microcontroller, motors, and ultrasonic sensors. The ultrasonic sensors detect obstacles in the path and assist in navigation, sending data to the microcontroller for decision-making.
- For movement, the motors receive signals from the microcontroller to control the cleaning robot navigation. The geared DC motor drives the chain conveyor, which helps to collect waste from the water surface and transfer it to the waste collection bin.
- An Android app is integrated for remote monitoring and control of the robot. The app receives data from the microcontroller via a wireless communication

module, allowing users to track the operation of the cleaner. Additionally, a notification system informs the user about the bin capacity.

4.3 Hardware Implementation

- **NodeMCU(ESP32):** Acts as the central controller. It receives commands from the Android app and processes signals from sensors.
- **Ultrasonic Sensors:** These sensors detect obstacles in the water and measure distances. An ultra sonic sensor is placed in waste storage bin for fill detection.
- **BLDC Motors and ESC (Electronic Speed Controllers):** Two BLDC motors are used for propulsion. ESCs control the motors' speed and direction based on PWM signals from the NodeMCU.
- **Raspberry Pi:** Connected to the NodeMCU, it handles the YOLO-based waste detection algorithm using a camera feed.

4.3 YOLO Algorithm

YOLO algorithm identifies and classifies waste like plastic bottles and algae in real time. The Raspberry Pi camera captures images of the water surface, and YOLO processes them to detect waste. If YOLO detects waste on the right side, it sends signals to activate the propeller on the left side. And if the waste is detected on the left side, the propeller on the right side turns and Aquarover moves toward the waste.

5. RESULTS AND DISCUSSIONS

5.1 Confusion Matrix

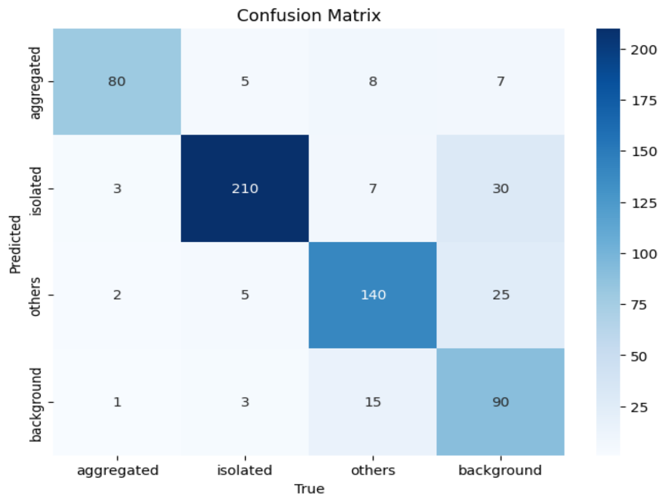

Fig -4: Confusion matrix

- **True Positive (TP):** 80 times the model correctly predicted Class 0.
- **False Positive (FP):** 5 samples were actually Class 0, but the model predicted them as Class 1.
- **True Negative (TN):** For Class 0, TN includes all samples correctly predicted as Classes 1, 2, and 3 when the actual class was not 0.
- **False Negative (FN):** 30 samples of Class 1 were wrongly predicted as Class 3.

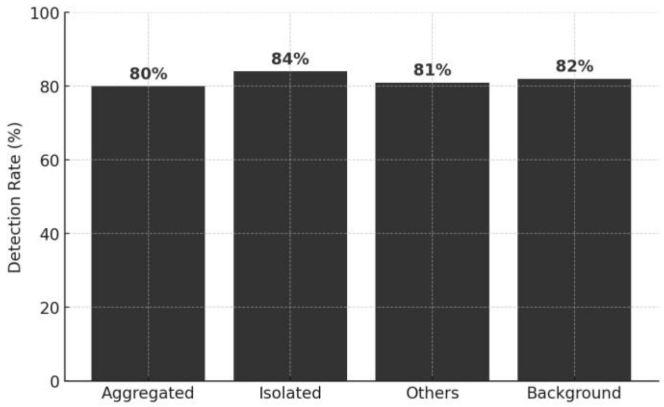

Chart-1: Classification performance

5.2 Evaluation matrices

- **Accuracy:**

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

- **Precision:**

$$Precision = \frac{TP}{TP + FP}$$

- **Recall:**

$$Recall = \frac{TP}{TP + FN}$$

Where:

- True Positives (TP) = The model accurately predicts a positive case.
- True Negatives(TN) =The model accurately predicts a negative case.
- False Positives (FP) = The model predicts a positive case when it is not (also referred to as a Type 1 error).

- False Negatives (FN) = The model falsely predicts a negative instance when it is indeed positive (also referred to as a Type 2 error).

5.3 Precision curve

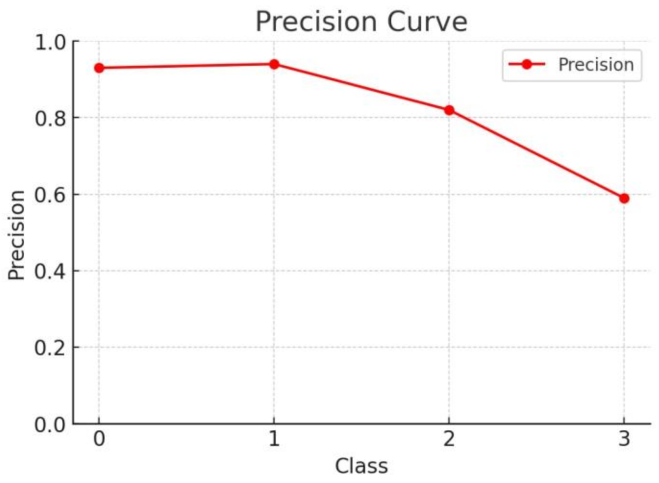

Chart-2: Precision curve

5.4 Recall curve

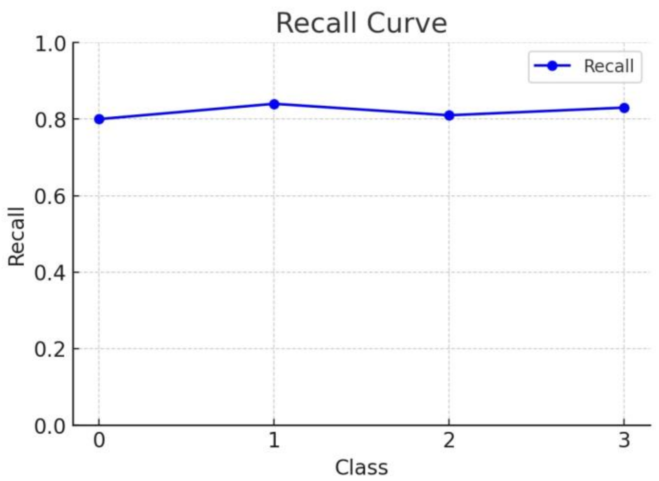

Chart-3: Recall curve

6. CONCLUSION

In today's world, where environmental pollution has become a serious global issue, particularly in water bodies, it is crucial to develop advanced technological solutions that can address these challenges effectively and sustainably. The AQUAROVER represents a forward-thinking approach to tackling water pollution by providing an automated, IoT-based robotic system that can clean water surfaces without the help of human beings. By designing and developing an unmanned surface vehicle (USV), we have taken significant steps towards creating a hands-off, efficient, and scalable solution to the persistent problem of floating waste in water bodies. The AQUAROVER, through its combination of modern sensors, IoT technology, and energy-efficient motors, presents an innovative solution to one of the most serious environmental challenges. By integrating key components such as ultrasonic sensors for obstacle detection, the Node MCU ESP8266 for wireless control, and a BLDC motor for propulsion, an autonomously navigate, avoiding obstacles while collecting floating debris robot have developed. The use of the Android application WAT BOT further enhances the user's ability to monitor and control the robot remotely, providing a seamless and user-friendly interface to operate the system.

7. FUTURE SCOPE

For future phases of AQUAROVER, we can integrate water quality sensors (such as pH, turbidity, and temperature sensors) to collect data about the water's health while cleaning. This information could be sent to the cloud in real-time for monitoring and analysis, allowing users to track water quality over time and additional features, like scheduling, real-time status updates, and failure alerts. Using cloud platforms, you could enable remote monitoring and control of the robot from anywhere. One of the key contributions of the AQUAROVER project is the reduction of human labor and manual intervention in cleaning water bodies.

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