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Development of IoT-based Water Surface Waste Collecting Robot

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ABSTRACT – The rapid urbanization and population growth have resulted in a surge in solid waste production, presenting a critical threat to both the environment and public health. The haphazard disposal of solid waste into rivers has led to increased pollution, disrupted ecosystems, and posed health hazards for communities residing near these water bodies. Traditional river cleanup methods are often intricate, time-consuming, and expensive, struggling to keep pace with the scale of pollution. In response to these challenges, an Internet of Things (IoT) - based Water Surface Waste Collecting Robot was proposed and developed in this research. The primary aim of this project is to design and develop an efficient water surface cleaning robot that can navigate water bodies autonomously. The robot is designed with a robust chassis and motorized wheels for mobility, and trash collection mechanisms with two motors. An IoT platform is integrated for remote monitoring and control of the robot. The developed Water Surface Waste Collecting Robot successfully navigates rivers and collects solid waste, offering real-time monitoring and control through the IoT platform, enhancing efficiency and reducing the need for human intervention. The project's implementation demonstrated the feasibility of utilizing IoT technology and robotics to address river pollution. The results showed that an IoT-based Water Surface Waste Collecting Robot could turn left, turn right, move backward, and move forward when controlled using the Blynk Application. At the same time, this robot also can use the forward and backward conveyors to collect the waste on the water surface. Therefore, the innovative proposed robot can reduce human exposure to hazardous cleaning environments.The IoT-based river cleaning robot presents a promising solution to the persistent problem of water pollution caused by improper waste disposal. Its efficient operation and remote monitoring capabilities make it a viable tool for environmental conservation and public health. To further improve the system, future work should focus on enhancing the robot's waste collection efficiency, optimizing power consumption, and implementing machine learning algorithms for advanced obstacle avoidance.

KEYWORDS: Urbanization, ESP32, Solid waste production, Robot, Internet of Things.

1.0 INTRODUCTION

The Malaysian government has launched several programs to enhance solid waste management and lessen trash pollution because it recognizes the significance of solving this issue [1]. These programs encourage trash separation and recycling, promote the use of biodegradable products, and encourage the spending of money on waste management facilities [2]. Notwithstanding these initiatives, trash contamination is still a serious problem in Malaysia, emphasizing the demand for ongoing action and innovation in waste management techniques. The health of rivers and the ecosystems nearby can both be improved by river clean-up. The removal of pollutants, a decrease in the quantity of waste and pollution entering the river, and the restoration of habitats that have been harmed by pollution can all be part of this. River clean-up can offer economic advantages in addition to environmental benefits. Healthy rivers can facilitate leisure activities like boating and fishing while also serving as vital resources for sectors like agriculture and tourism [3].

The problem of garbage in river pollution refers to the contamination of rivers and other bodies of water with various types of waste, including plastics, chemicals, sewage, and other pollutants [4]. This type of pollution is a significant environmental issue that can harm wildlife, damage ecosystems, and even threaten human health [5]. Garbage in the river pollution is caused by various factors, including inadequate waste management, industrial activities, and agricultural practices. Improper disposal of waste, such as littering, dumping, and inadequate waste treatment, can all contribute to the problem [6]. The consequences of garbage in the river pollution are far-reaching and can have severe impacts on both the environment and human health. It can lead to the destruction of aquatic habitats, the death of marine animals, and the contamination of drinking water sources. Additionally, it can contribute to the spread of water-borne diseases, posing a significant risk to public health.

Therefore, an Internet of Things (IoT)-based Water Surface Waste Collecting Robot was proposed and developed in this research. This proposed robot able to clean rivers efficiently while minimizing environmental impact. The IoT-based river cleaning robot presents a promising solution to the persistent problem of water pollution caused by improper waste disposal. Its efficient operation and remote monitoring capabilities make it a viable tool for environmental conservation and public health. The implementation of such a system requires collaboration among various stakeholders to ensure its sustainability and scalability. Addressing these challenges can help reduce water pollution and preserve the integrity of our natural ecosystems, promoting sustainable development.

2.0 LITERATURE REVIEW

River cleaning robots are innovative devices designed to tackle the issue of water pollution, specifically in rivers and other freshwater bodies. These robots aim to remove floating waste, plastics, and other debris, helping to maintain water quality and protect ecosystems. Various types of river-cleaning robots have been developed, each with different approaches to the task. Table 1 shows a review of the river-cleaning robot from existing studies.

Table 1. Review of the river-cleaning robot

Authors & Year	Title
R. Raghavi, K. Varshini, and L. Kemba Devi, 2019 [7]	Water Surface Cleaning Robot
S. Phirke, A. Patel and J. Jani, 2021 [8]	Design of an autonomous water-cleaning bot
B. N. Rumahorbo, A. Josef, M. H.Ramadhansyah, H. Pratama and W. Budiharto, 2021 [9]	Development of robot to clean garbage in river streams with deep learning
M.Y. Takawy, A.G. Ezz-Eldin and A. Bayoumy, 2023 [10]	Design and Implementation of an Autonomous Water Surface Cleaning Robot

Raghavi et al. described “Water Surface Cleaning Robot” [7]. The main aim of the work proposed was to develop a surface vehicle. The robot was employed with water quality monitoring sensors. The major limitation observed with this method is not cost-efficient and the process of manufacturing is complex. “Design of an autonomous water-cleaning bot” was described by Phirke et al. [8]. Autonomous water cleaning bots, designed to operate independently and remove waste from rivers, lakes, and oceans, have numerous advantages, such as continuous operation and reduced human intervention. However, despite their innovative potential, several limitations impact their effectiveness and deployment such as Navigation and Mobility Challenges, waste collection efficiency, maintenance and durability.

In year 2021, the development of a robot designed to clean garbage from river streams using deep learning techniques was proposed by Rumahorbo et al. [9]. The focus could be on enhancing the robot's ability to identify and remove waste autonomously, utilizing deep learning models to detect and classify objects in the water. The design and implementation of a robot aimed at cleaning water surfaces was described by Takawy at al. [10]. It may describe the hardware and software architecture, including sensors, navigation systems, and waste collection mechanisms, used to achieve autonomous functionality in removing floating debris from water bodies. Both robots have innovative approaches to environmental cleanup, but face challenges related to operational efficiency, environmental adaptability, and technical limitations that might hinder their widespread adoption or large-scale deployment.

Therefore, an IoT-based river-cleaning robot was proposed and developed in this research. This robot is an innovative device designed to tackle the issue of water pollution, specifically in rivers and other freshwater bodies. These robots aim to remove floating waste, plastics, and other debris, helping to maintain water quality and protect ecosystems.

3.0 METHODOLOGY

3.1 Block Diagram

Figure 1 shows a block diagram and a series of tools consisting of several components contained in an IoT-based Water Surface Waste Collecting Robot.

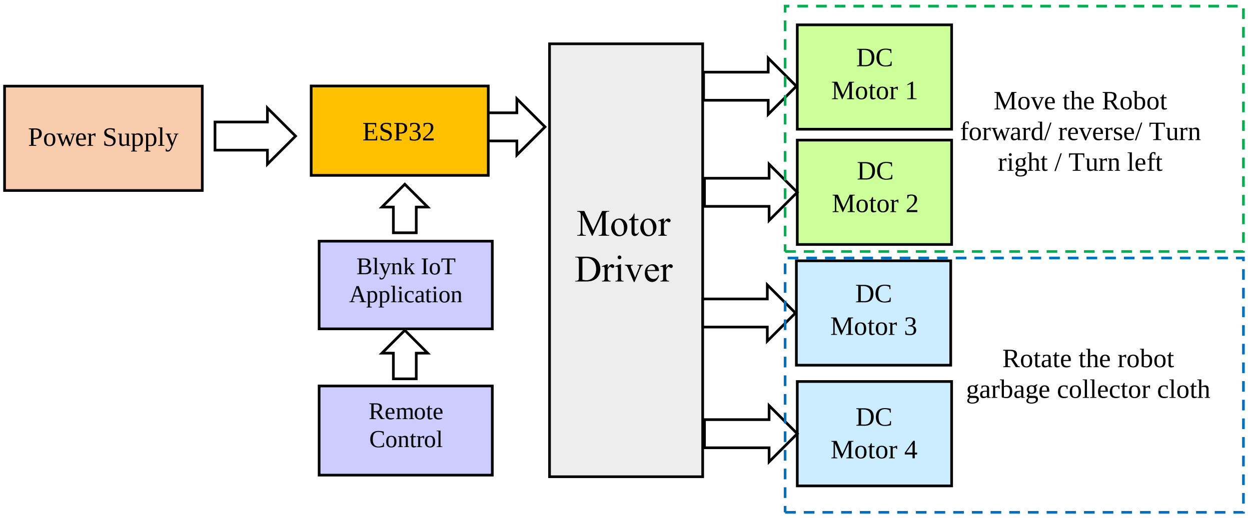

Figure 1. Block Diagram for an IoT-based Water Surface Waste Collecting Robot

A power Supply is a series of components that function to supply electricity to the circuits contained in the system. ESP32 is an embedded chip designed for Wi-Fi-based communication [11]. An ESP board's primary purpose is to operate as a platform for firmware or software applications that communicate with the physical environment using sensors, actuators, and other hardware [12]. These programs can be created in a variety of programming languages, including C++, Python, or MicroPython, and uploaded to the board over Wi-Fi or a USB cord. The ESP32S includes integrated Wi-Fi and Bluetooth connection and is based on a dual-core, 32-bit Xtensa LX6 CPU with a clock speed of up to 240 MHz The ESP32S's ability to offers a versatile and potent platform for creating Internet of Things (IoT) applications is one of its primary purposes. It is perfect for a variety of IoT applications because it has built-in Wi-Fi and Bluetooth capabilities that allow it to connect to the internet and communicate with other devices wirelessly [13].

An electric motor that transforms electrical energy into mechanical energy is known as a DC motor. The Lorentz force, which asserts that a current-carrying conductor experiences a force perpendicular to both the magnetic field and the direction of the current flow, underlies its operation [14]. A stator and a rotor are the two major parts of a DC motor. The motor's stator, which is a stationary component, houses the magnets and generates the magnetic field. The motor's spinning component, the rotor, which is joined to the output shaft and houses the wire coils, rotates. The rotor rotates when a current is given to its wire coils through an interaction between its magnetic field and the magnetic field of the stator. The direction of the rotor's spinning is determined by the passage of current through the coils. In this research, two DC motors are used to drive the movement of the robot, while another two DC motor are used to rotate the robot garbage collector cloth.

3.2 Programming Flow Chart

Figure 2 shows the flow chart for an IoT-based Water Surface Waste Collecting Robot. The user can control this robot's movement through the Blynk Application. When the ESP32 microcontroller receives a command from the Blynk application to move forward, ESP32 will control the DC Motor 1 and DC Motor 2 to rotate forward to move the robot in front. If the command received by the ESP32 microcontroller is to move reverse, then the ESP32 will control DC Motor 1 and DC Motor 2 to rotate reverse to move the robot backward. If the ESP32 microcontroller receives the command to move left, then the ESP32 will control DC Motor 1 and DC Motor 2 to turn left to move the robot to the left-hand side. If the ESP32 microcontroller receives the command to move right, then the ESP32 will control DC Motor 1 and DC Motor 2 to turn right to move the robot to the right-hand side. If waste is on the river, the robot will control DC motor 3 and motor 4 to rotate forward to control the belt conveyor, which will collect the waste.

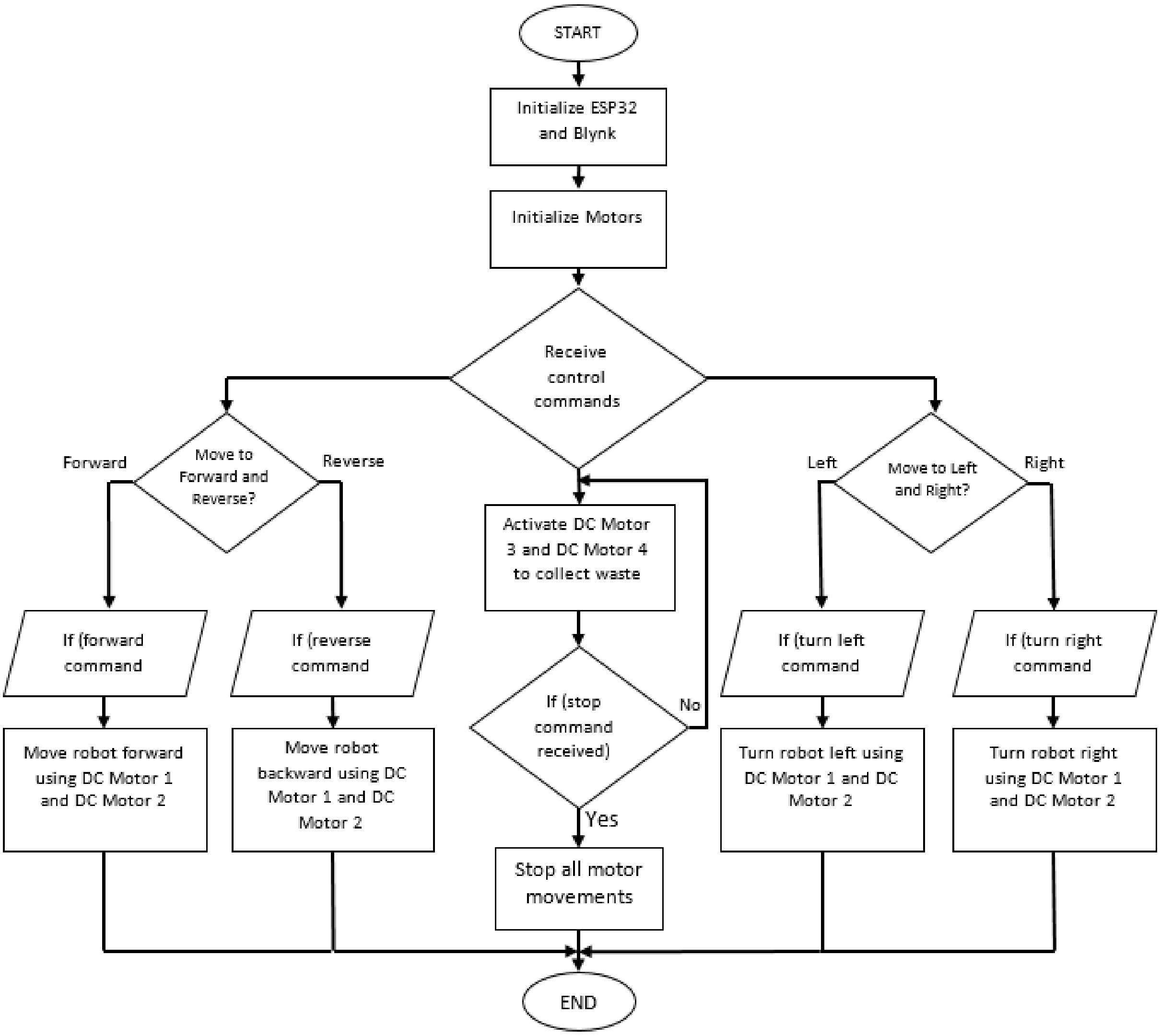

Figure 2. Flow Chart of Proposed System

3.3 Hardware Development

Figure 3 shows the materials such as grip liner, wireman enclosure box, mega net PVC, cable tie, polyform sheets, DC motor, and PVC are used to develop an IoT-based Water Surface Waste Collecting Robot. The two DC motors at the bottom of the robot are used to move the robot forward, backward, turn left, and turn right. Then, two more DC motors at the top are used to drive the conveyor belt to collect garbage on the river. A polyform sheet is used so that this robot can float on water. Mega net PVC is used to build the trash can and is located on the top of this robot. A PVP pipe is used to make the skeleton for this robot. The grip liner is used as a conveyor belt for this robot.

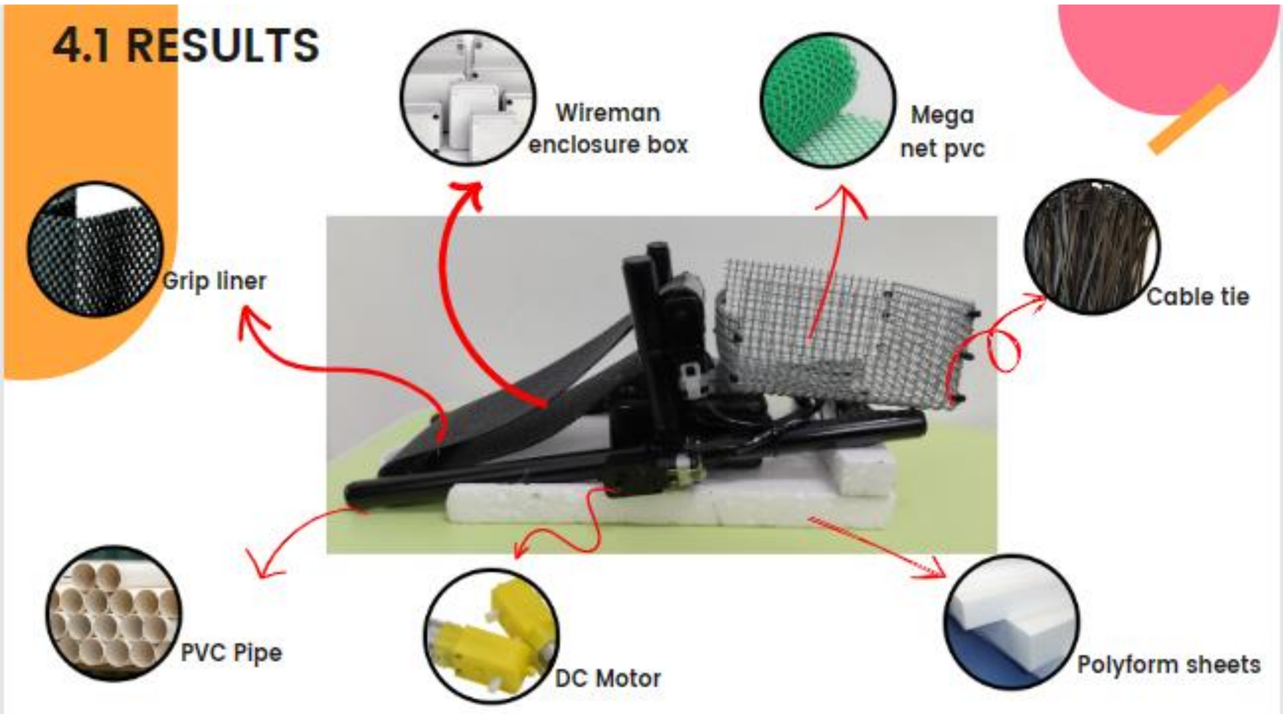

Figure 3. Materials used to develop this project.

3.0 RESULT AND DISCUSSION

Figure 4 shows the river cleaning robot project employs four DC motors, each managed by two motor drivers for precise control. Motors 1 and 2 play a pivotal role in the trash transportation system, facilitating the movement of waste via a conveyor mechanism. The trash conveyed by these motors is efficiently deposited into a designated storage bin. Meanwhile, Motors 3 and 4 are responsible for propelling the robot, ensuring its mobility and navigation. The entire system operates under the command of an ESP32 microcontroller, meticulously programmed with code designed to orchestrate the functionality of all these motors. This code grants seamless control over both the robot's movement and the trash transportation process.

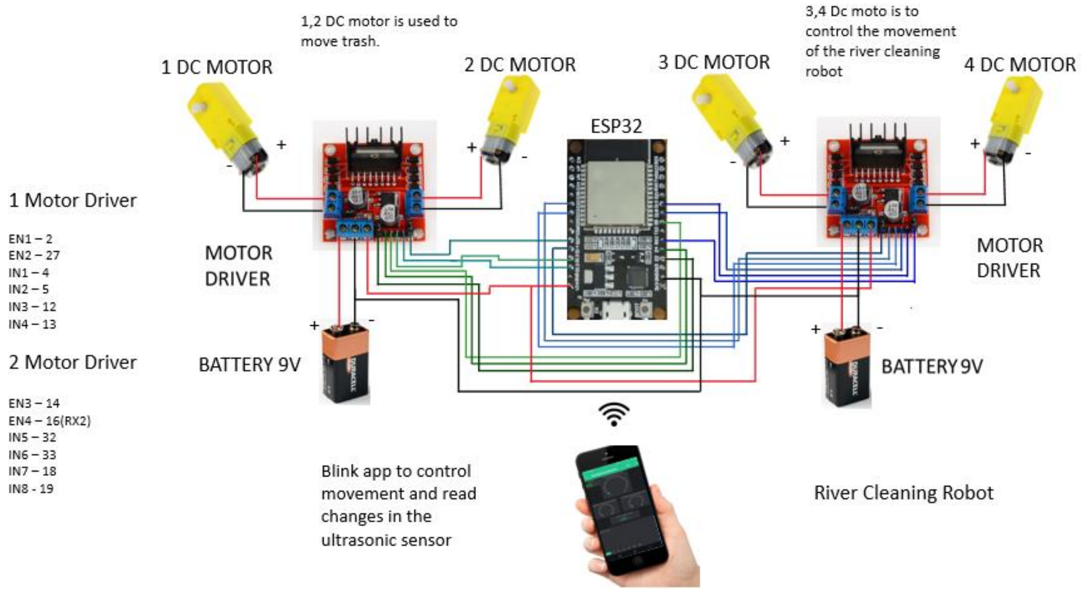

Figure 4. Schematic for an IoT-based Water Surface Waste Collecting Robot.

Figure 5 to Figure 7 shows the finished project from the left-right view and top view. The remote control from the Blynk application is shown in Figure 8. The purpose of using the Blynk application to control a river-cleaning robot is to provide an intuitive, real-time, and remote control interface that allows users to monitor and manage the robot's operations efficiently. Blynk is a versatile IoT platform that simplifies the integration of hardware, sensors, and mobile applications, making it ideal for controlling autonomous systems like river-cleaning robots. The Blynk application enhances the functionality, efficiency, and ease of use of river-cleaning robots by offering real-time control, monitoring, and automation features. Its integration enables users to manage operations remotely, optimize resource usage, and ensure consistent waste collection, making it an essential tool for effective environmental management.

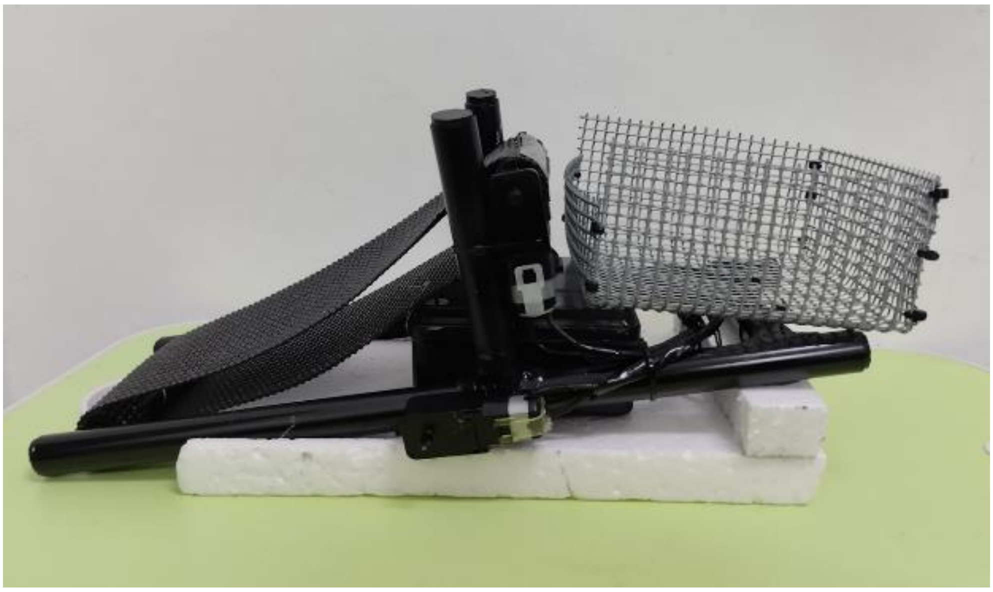

Figure 5. Left view

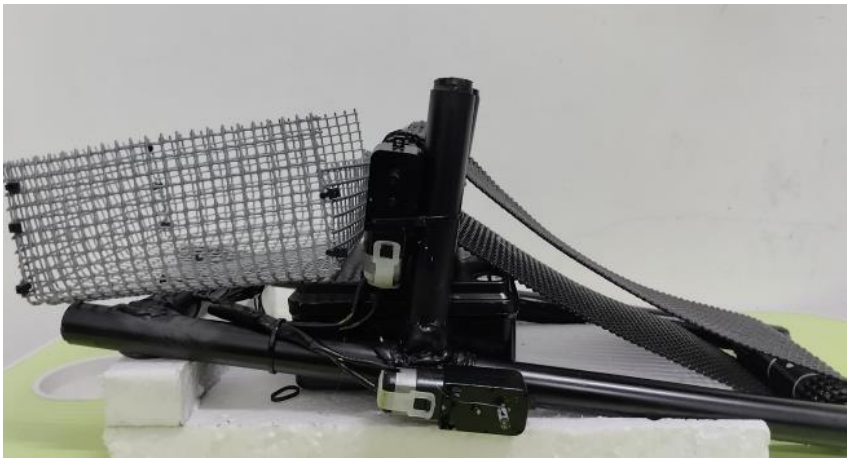

Figure 6. Right view

Figure 7. Top view

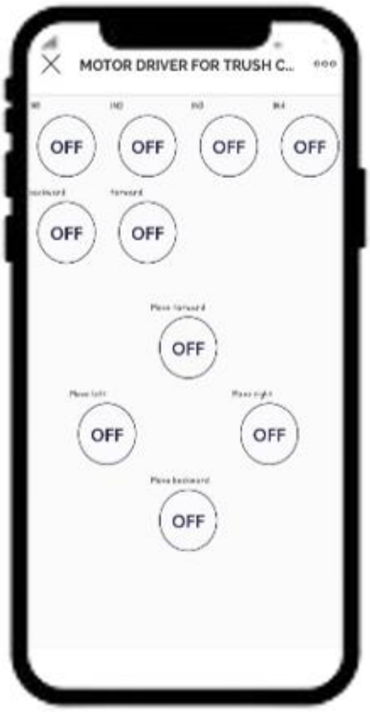

Figure 8. Remote control from Blynk application

Figure 9: Testing project on the water

Figure 9 shows the demonstration of an IoT-based Water Surface Waste Collecting Robot on water. This robot was able to turn left, turn right, move backward, and move forward. In addition, this robot can use the forward and backward conveyors to collect the waste on the water surface. All movements are controlled by the Blynk application. Figure 10 shows a real test of my project river cleaning robot using a remote control from the Blynk app.

Figure 10. Cleaning the waste on the water surface

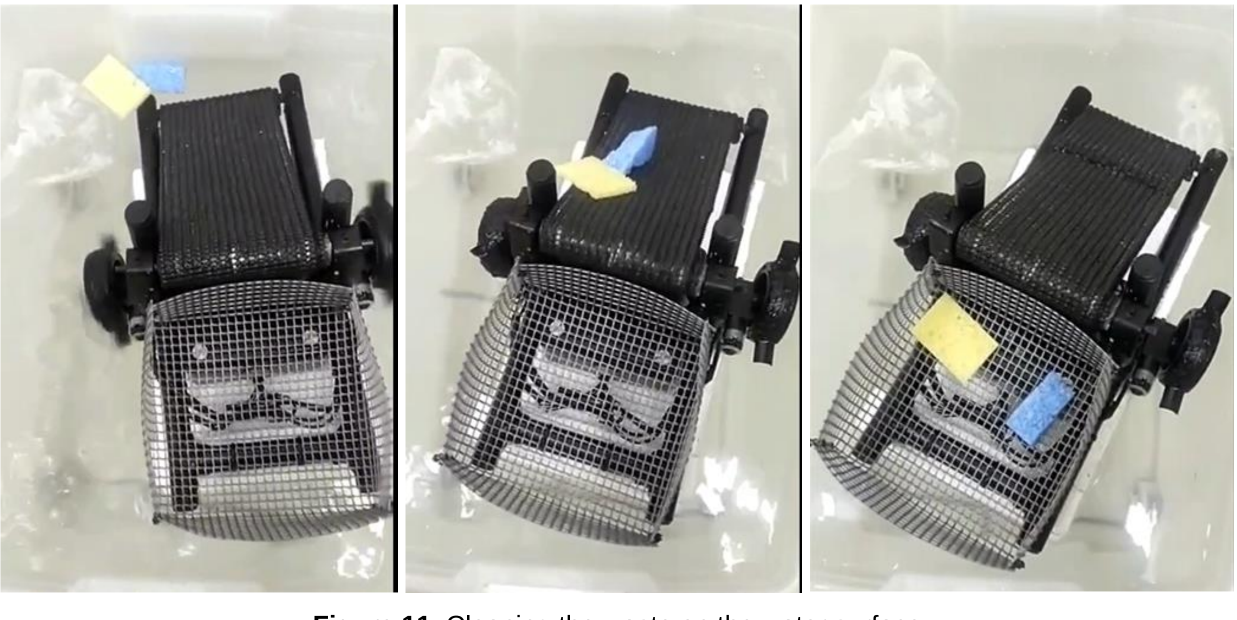

Figure 11. Cleaning the waste on the water surface

Figure 11 shows a Water Surface Waste Collecting Robot, leveraging IoT technology with components including the ESP32, 2 motor drivers, and 4 DC motors, effectively addresses water pollution by enhancing debris collection, navigating diverse river terrains, and enabling remote monitoring. This integrated solution offers a comprehensive approach to mitigating pollution, ensuring efficient and adaptable cleaning operations in aquatic environments.

4.0 CONCLUSION

In conclusion, an IoT-based Water Surface Waste Collecting Robot equipped with advanced sensing and cleaning capabilities is a promising solution for improving the health of our rivers and waterways. This robot can collect and remove debris, monitor water quality, and navigate challenging terrain. Therefore, this innovative robot has the potential to significantly reduce pollution and protect aquatic ecosystems. As we continue to face environmental challenges, investing in innovative technologies like river-cleaning robots will be crucial for preserving our natural resources and ensuring a sustainable future.

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