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IoT-based Water Surface Cleaning Robot with Live Streaming

***Abstract**. The disposal of trash into bodies of water such as rivers, lakes, and oceans, is a significant environmental concern with detrimental effects on ecosystems and human welfare. Single-use plastics, such as bottles, bags, and packaging materials, are among the most common types of trash found due to their durability and slow degradation. Therefore, the Water Surface Cleaning Robot with Trash Monitoring System is proposed. The robot is developed to collect trash on the water's surface and display the entire process by using live streaming. The purpose of the project is to develop the robot movement and trash collector mechanism and to collect data on trash collection using IoT. The proposed robot is controlled by RC controller and consists of several parts namely the ESP32-WiFi, camera, and Internet of Things (IoT) system.Live streaming will allow the robot's operations to be observed and evaluated. The result shows the robot is able to detect and collect trash and show live streaming during the process. The collected data on trash collection can be viewed a laptop and mobile phone.*

***Streszczenie.** Wyrzucanie śmieci do zbiorników wodnych, takich jak rzeki, jeziora i oceany, jest poważnym problemem środowiskowym, mającym szkodliwy wpływ na ekosystemy i dobrobyt ludzi. Jednorazowe tworzywa sztuczne, takie jak butelki, torby i materiały opakowaniowe, należą do najczęściej spotykanych rodzajów śmieci ze względu na ich trwałość i powolną degradację. Dlatego zaproponowano Robota Czyszczącego Powierzchnię Wody z Systemem Monitorowania Śmieci. Robot ma zbierać śmieci z powierzchni wody i wyświetlać cały proces za pomocą transmisji na żywo. Celem projektu jest opracowanie ruchu robota i mechanizmu zbierania śmieci oraz zbieranie danych o zbieraniu śmieci z wykorzystaniem IoT. Proponowany robot jest kontrolowany przez kontroler RC i składa się z kilku części, a mianowicie ESP32-WiFi, kamery i systemu Internetu rzeczy (IoT). Transmisja na żywo pozwoli na obserwację i ocenę działania robota. Wynik pokazuje, że robot jest w stanie wykrywać i zbierać śmieci oraz wyświetlać transmisję na żywo podczas procesu. Zgromadzone dane dotyczące odbioru śmieci można przeglądać na laptopie i telefonie komórkowym. (**Robot do czyszczenia powierzchni wody oparty na IoT z transmisją na żywo**)*

Keywords: Water Surface Cleaning Robot, IoT, Live Streaming; Monitoring System
Słowa kluczowe: Robot do czyszczenia powierzchni wody, IoT, transmisja na żywo; System monitorujący

Introduction

Water is essential in sustaining life, ecosystems, and human activities. It is important to manage and conserve water resources such as rivers, seas, and lakes effectively. Wise water usage, responsible waste disposal, and sustainable practices are necessary to ensure its availability for future generations. The disposal of trash such as single-use plastics, such as bottles, bags, and packaging materials into the water is one of the main problems that lead to water pollution. In particular, this kind of trash takes hundreds of years to decompose. Many studies have been done to clean the trash either in or on the water. However, some of the cleaning processes need human intervention to remove the trash manually, which is often proven to be inefficient. Especially when the trash is located in a hard to reach or dangerous spaces. Robots have been used in various fields such as manufacturing [1]–[3], healthcare [4]–[6] , agriculture [7]–[9], environmental [10], [11] and others. Therefore, the introduction of the robot in the water cleaning robot [12]–[16] is a good solution to overcome the trash problem in the water.

The water-cleaning robot combines a vision module, a motion control module, and a grip module. It performs the following three tasks in sequence: cruising and detection, tracking and steering, and grasping and collection [17]. Several previous related projects have recently been conducted on water-cleaning robots using different control methods, including the Internet of Things IoT [18]–[21], Bluetooth[12] , automation system [22], deep learning [23] and others. Additionally, the robot incorporates a monitoring camera [23] to provide real-time vision for the user to scan the surrounding area for waste and to gather trash remotely and more efficiently. This will contribute to the reduction of ecosystem imbalance, human health problems, and emissions.

Remotely operated robots use various equipment based on the robot's purpose and design [14], [15], [24]. The integrated system incorporates the usage of IoT technology [25], enabling the monitoring and c control the entire process [21]. The robot is equipped with a motor and floats on the water's surface. A camera is mounted on it to live stream videos, which are then transmitted to a web application [24]. With all these functions, the smart robot can be used for multiple applications. Furthermore, the system can include water quality checking as an additional feature to understand water pollution through data analysis [13], [26]. The goal of this project is to create an IoT-based microcontroller-based water surface cleaning robot and waste monitoring system.

Mechanism of the Water Surface Cleaning Robot with Live Streaming

The IoT, electronic, and mechanical components are the main parts of the water surface cleaning robot. The cleaning robot utilizes an ultrasonic sensor to detect, collect, and deposit trash in the trash can., A load sensor measures the weight of the waste to ensure maximum capacity of the trash can. The robot comprises the trash collector, trash basket, two propellers, and a circuit system as shown in Fig. 1. Blynk is an IoT open-source platform designed to streamline the connectivity between smartphones and microcontrollers. The connectivity features enable device management, storage, monitoring, and data analysis from numerous IoT sources. The design of the water surface cleaning robot must enable it to float and remain stable while moving on the water surface. Therefore, a twin-hull boat with a round bottom was chosen as the foundation to ensure buoyancy.The water surface cleaning robot is illustrated in a 3-D representation in Fig. 2, and its primary structure is constructed using PVC pipes with diameters of 42mm and 47mm.

The PVC material is cost-effective and highly durable. The front of the robot is equipped with a net to gather debris, while the waste collection container is positioned at the center of the robot. The robot moves by the two propellers located at the back. An electrical box at the rear houses the electrical components such as batteries, motor drivers, and a microcontroller.

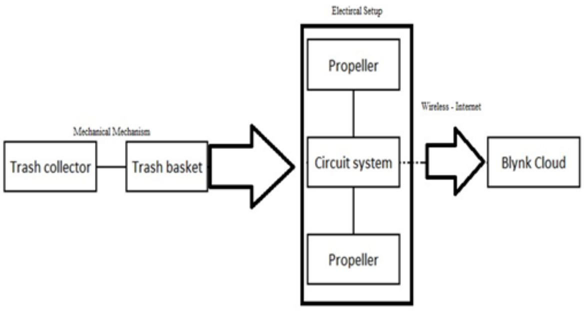

Fig.1. Water Surface Cleaning Robot Block Diagram

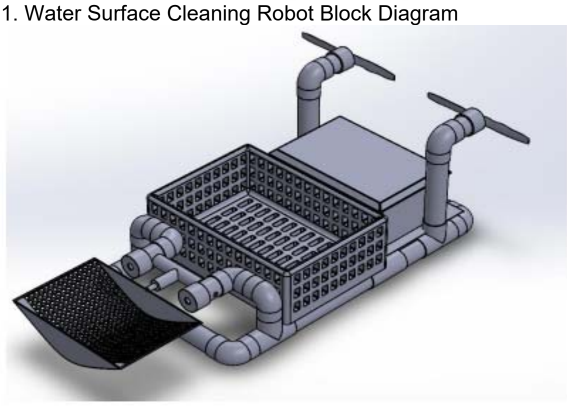

Fig.2. 3-D Model of the water surface cleaning robot

System Implementation

The main system in the water surface cleaning robot is a microcontroller, ESP32 and connected to sensors, motor as in Fig.3.

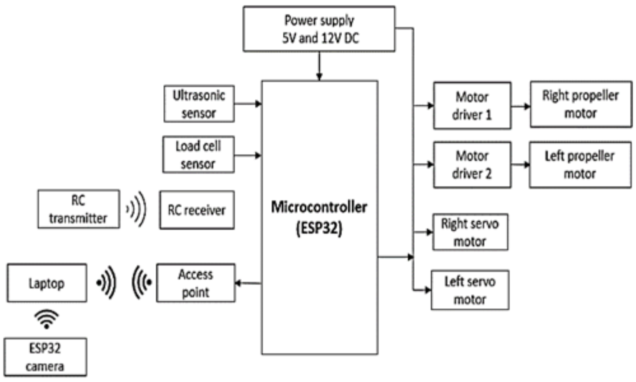

Fig.3 The water surface cleaning robot system.

The ESP32 microcontroller is responsible for connecting the sensors and the servo motor, shown in Fig. 3. The ultrasonic sensor is utilized to determine the height of the trash in the trash can, while the load sensor is used to measure its weight. The motor propellers control the direction of the propellers; forward, backward, right, and left. The Arduino IDE software was used to write code for IoT and to control servo motors and sensors and connect the microcontroller to the Blynk Cloud, allowing for data monitoring from the ultrasonic and load sensors, as depicted in Fig. 4(a). The Blynk cloud server presents a graphical representation of the sensor data in real time. Additionally, the water surface cleaning robot incorporates an ESP32 camera for live streaming, as shown in Fig. 4(b).

The camera streaming server can be accessed on the same local network by entering the IP address in a browser. The live streaming output from the camera is accessible on a laptop. This feature is to facilitate the navigation and waste collection for the operator. The mechanism for the water surface robot was tested in a real-world setting.

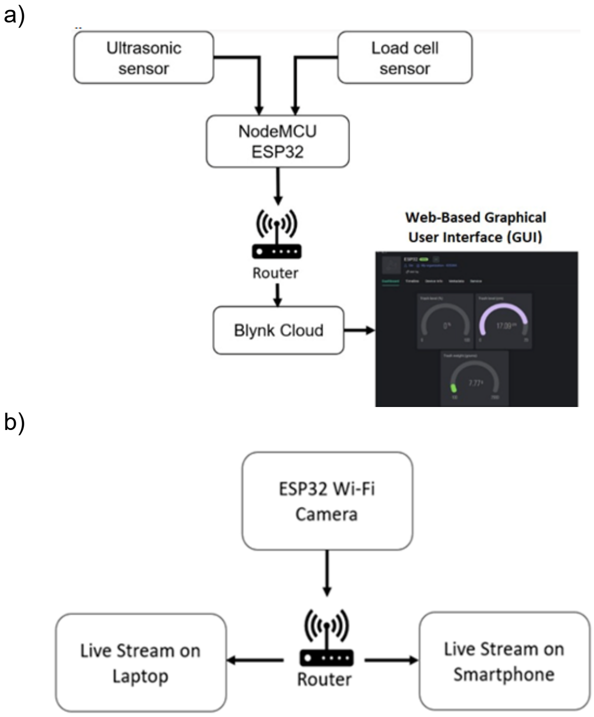

Fig.4: Diagram for the sensing and live streaming

The experiment involved various tests, including evaluating the performance of the robot's operation, live streaming, and trash pickup. These tests were conducted to assess the robot's movement mechanism and sensing system.

Result

In the performance evaluation of the robot's operation, a functionality test was conducted by floating the robot on a lake to observe its floating and movement capabilities. The test environment is depicted in Fig. 5.

The robot was able to float properly on the lake during the testing, demonstrating successful buoyancy. The robot's ability to move and collect trash while on the water's surface was tested by controlling the RC transmitter which sends the control signals to the movement mechanism and collecting mechanism. The robot's movement direction test was

Fig.5. The water surface cleaning robot on the lake

performed ten times, while the collecting mechanism test was carried out five times. The purpose of these tests was to identify any issues in the interface between the RC transmitter, RC receiver, and ESP32 microcontroller. The data pertaining to the movement and collecting mechanism, obtained from the conducted tests, is presented in Table 1.

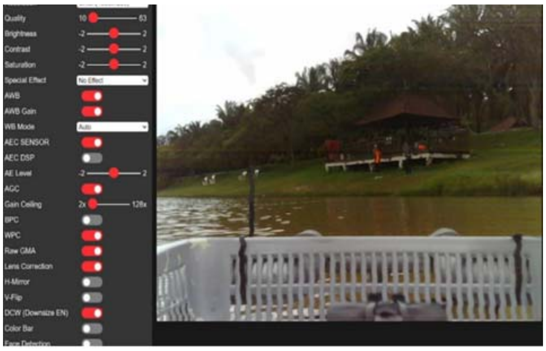

Fig.6. Visual from the robot

Table 1. The robot movement and collecting mechanism functionality test

Functionality Test	Parameters	Observation
Movement direction	Forward	Success
	Reverse	Success
	Left	Success
	Right	Success
Collecting Mechanism	0° to 180°	Success
	180° to 0°	Success

The results of the tests, shown in Table 1, reflect the success of the project's objective, which is to develop the robot's movement and trash collector mechanism using an RC transmitter. The robot's movement direction was tested using an RC transmitter to verify its ability to move forward, reverse, left, and right on the water's surface.

Following the successful performance evaluation of the robot's operation, the functionality test for live streaming was conducted. This feature aims to facilitate navigation and waste collection for the operator. Based on the testing, the robot was able to successfully function on the live streaming feature with clear vision, as shown in Fig. 6. The live visual allows for navigation and waste collection remotely by the operator, while also allowing users to monitor the surroundings and the entire cleaning procedure.

In the sensing system test, the efficiency of the sensors was evaluated by measuring the distance between the sensor (Point A) and the trash (Point B) at nine different distances, as depicted in Figure 7.

The value obtained from the sensor was compared with a manually measured value using a ruler. The sensor efficiency was tested at these nine different distances, and the values obtained from the sensor were compared with the manually measured values. Data from the sensor was successfully uploaded to the Blynk cloud and displayed in the Blynk app, as shown in Fig. 8. The display shows the trash distance value and level. The weight of the rubbish is also shown.

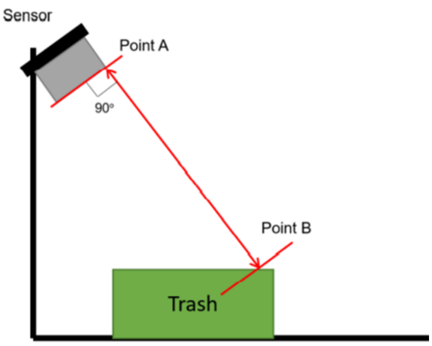

Fig.7 Measuring trash distance

A comparison between the manually measured value and the sensor reading was conducted to analyze the accuracy of the robot's sensor and the functionality of the Blynk app. The measured data is presented in Fig. 9. Both the sensor values and the manually measured graph patterns show a high degree of comparability. Despite some variances in the measurements at a distance value of 14 cm, the results are acceptable and nearly accurate. The load cell sensor was tested with nine different items or trash weights, and the values were compared with the measurements from an electronic scale. The effectiveness of collecting various waste weights was studied during testing for trash collection using a water surface cleaning robot. Three bottles, three carton boxes, and three tin cans were used, totalling nine different items. Each trash item had a different weight and shape. The weight of the trashes is compared with the measurements from the manual weighing scale to confirm the effectiveness of the load cell sensor. The obtained data is presented in Fig. 10. Both sets of data exhibit similar graph patterns, the measurements can be deemed successful. The straight red line on the graph represents the threshold weight of 141g for trash pickup. Hence, these results align with the project's objective of utilizing IoT to track the weight of waste. However, there are slight variations in measurements due to the load cell sensor not resetting to zero accurately when multiple measurements are taken.

Fig.8 Display on Blynk cloud

For example, for bottle 1, the electronic scale indicates a weight of 21g, while the sensor shows a weight of 18.25g. This discrepancy highlights a difference in measurement between the electronic scale and the load sensor. Nevertheless, the comparable graph pattern and the small difference render the obtained results acceptable. The variation in measurement may be attributed to the initial setup of the load sensor and the Blynk Cloud display.

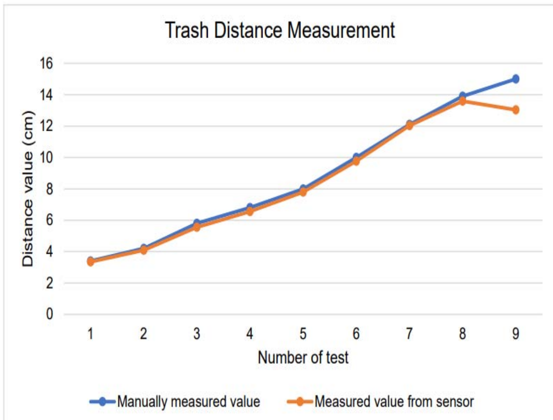

Fig.9 Manual and sensor value for distance measurement.

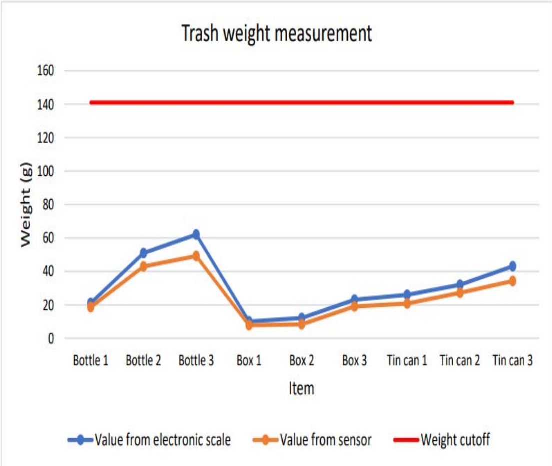

Fig.10. Manual and sensor value for weight measurement.

Conclusion

In conclusion, this project development has successfully achieved all the project objectives. The design of the water surface cleaning robot allows it to float properly on the water surface and move by utilizing a controller based on an RC transmitter. The inclusion of an ESP32 WiFi camera enables video streaming to support the robot's movement. Additionally, the trash collecting mechanism functions effectively with the RC transmitter, allowing for the collection of trash on the water surface, up to a maximum weight of 141g. Furthermore, the robot has been enhanced with a trash monitoring system using IoT. The efficiency of the ultrasonic and load cell sensors in obtaining data from the trash was analyzed through testing. Although there is a slight measurement error, the average results still align with the pattern of manually measured values. Overall, this project has been successfully developed, with room for future improvements.

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