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CSE - 405

Project Proposal Report

Design and Implementation of IoT-Enabled Boat for Water Pollution Monitoring and Floating Waste Collection in Small Water Bodies

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Design and Implementation of IoT-Enabled Boat for Water Pollution Monitoring and Floating Waste Collection in Small Water Bodies

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***Abstract*—Water pollution poses a significant threat to ecosystems and human health, especially in countries like Bangladesh where water bodies are heavily contaminated with plastic and industrial waste. This paper presents the design and implementation of a semi-autonomous floating waste collection boat with water quality monitoring system. The system integrates temperature, turbidity, and Total Dissolved Solids (TDS) sensors to provide real-time water quality data, transmitted to a IoT analytics platform named Blynk for analysis and visualization. The boat utilizes a catamaran hull and is controlled via Radio Frequency (RF) through a mobile phone, with an efficient conveyor belt for waste collection. While its low-cost design is effective, limitations include weather dependency and potential sensor fouling. Nonetheless, this feasible solution enhances the efficiency of waterway cleaning and pollution management, addressing the escalating water pollution challenges in small water bodies.**

***Index Terms*—Water quality monitoring, water surface cleaning, catamaran hull, boat**

I. Introduction

Water pollution in Bangladesh has reached critical levels, with immense volume of waste such as plastics and industrial pollutants being dumped indiscriminately into the water bodies. As highlighted in the 8th episode of the *SDG Café* monthly round table discussion series by UNOPS Bangladesh, South Asia ranks as the second-largest contributor to global plastic waste, with Bangladesh standing sixth in the world for plastic and polythene pollution in its water bodies [1]. The contamination poses severe risks to aquatic ecosystems, human health and the environment. Despite efforts, manual cleaning of these water bodies are labor-intensive, time-consuming and often insufficient to handle extensive wastes. This persistent challenge of maintaining waterways necessitates an automated solution that can operate independently, reduce human labour, and provide consistent results, all while maintaining a low manufacturing cost.

The motivation behind our project arises from this critical need. Current conventional practices in water quality monitoring and waste management face significant challenges, including the inability to provide continuous, real-time data and the high labor costs associated with manual processes. Additionally, the existing automated waste collection method methods often fail to provide real-time water pollution monitoring system, leading to gaps in data collection and ineffective pollution control.

Recognizing these limitations, we aim to advance the water pollution management through the integration of autonomous systems and Internet of Things (IoT) technologies. Our proposed system is a water pollution monitoring and floating waste collection boat equipped with a conveyor belt mechanism designed to collect floating waste and debris from water bodies, and monitor the water pollution level through sensors mounted on the chassis. Controlled remotely via a mobile application, this boat navigates the water surface, ensuring thorough cleaning while minimizing the need for human intervention.

Despite being initially planned on a smaller scale, automated garbage cleaning offers a viable and impactful solution to the escalating water pollution challenges of Bangladesh. Our proposed system can significantly enhance the management of water pollution, contributing to healthier aquatic ecosystems and improved public health. By providing real-time data and efficient waste collection, our project supports the sustainable management of water resources, aligning with global environmental goals and policies. Additionally, the reduction in manual labor associated with traditional methods can lead to cost savings and increased efficiency for environmental agencies.

Our system aims to achieve the following objectives:

- To develop a semi-autonomous boat for efficient collection of floating garbage using a conveyor belt
- To implement a system for monitoring water quality by measuring turbidity, total dissolved solids, and temperature
- To develop real-time water pollution indicator using IoT analysis for timely data and insights

Possible outcomes of our system include:

- Effective removal of small floating garbage, resulting in cleaner water bodies
- Continuous monitoring of turbidity, TDS, and temperature, providing crucial environmental data

- Easy control and navigation of the boat via a smartphone app, enhancing user accessibility
- Real-time surveillance of water condition, supporting environmental assessments and proactive planning

II. Background Study

Annually, 360 million tons of plastic are produced globally, with only 7% being recycled. The majority of plastic waste accumulates in the environment, particularly in freshwater ecosystems, contributing to microplastic pollution [2]. The resulting microplastic pollution poses a significant threat to aquatic life and human health. In response to this pressing issue, innovative projects and conceptual designs have emerged, focusing on integrating advanced sensors and monitoring devices to address the challenges of water pollution. We have divided our literature review into two sections, one exploring floating waste collection systems and the other exploring the existing water quality monitoring systems.

A. Floating Waste Collection System

In 2020, a system was designed on a water floating garbage cleaning machine capable of efficiently removing waste debris from water bodies [3]. The base frame was fabricated using L-section and T-section joints, with compressed air-filled PVC pipes for buoyancy. A conveyor belt mounted on inclined shafts collected the garbage, which was then deposited in a rear collection tank. However, the project identified a gap in automation techniques, particularly the integration of Internet of Things (IoT).

For vehicle control, various methods exist, including remote control via Radio Frequency (RF) modules, and autonomous navigation. A study [4] highlighted efficient wireless data transfer between a controller panel and a robotic wheelchair using RF module based on wireless mobility, ease of installation, minimal wiring, cost-effectiveness, and flexibility in control. Similarly, another study [5] demonstrated the effective performance of RF-controlled remotes in managing DC motor operations, including direction and speed adjustments.

Building on these foundations, a low-cost water surface cleaning robot was introduced [6] using RF module. The robot used three DC motors: one for the conveyor belt and two for boat movement. Despite being cost-effective and reducing manual labor, the robot faced limitations due to the motors' low power rating (0.1 HP) and the restricted transmission capability and range of the RF module.

A comparative analysis between catamaran and monohull was done in 2021 [7] using Reynolds Average Navier Stokes (RANS) based numerical simulations to evaluate flow patterns, velocity contours, wave patterns, pressure distribution, and ship resistance. The catamaran resulted in superior flow characteristics and lower resistance compared to the monohull. Particularly, the front-side hull flow was notably less effective in the monohull design. In case of ocean waste collection, catamaran remains preferable over monohull model according to the study.

A more robust waste collection system was developed in 2024 using the catamaran hull model [8]. For light debris (<0.5 kg), a collection basket directs the waste through the gap into a rear basket. For heavier objects (˜10 kg), the collection basket is lowered below the water by electric push rods to facilitate collection. Despite lacking an integrated smart system for real-time data analysis, the boat was stable and provided better results for small water areas.

B. Water Quality Monitoring System

In 2020, an unmanned boat system for floating garbage salvage and water quality monitoring based on OneNET was developed, integrating system hardware, software, and a cloud platform [9]. The water quality monitoring module included temperature, humidity, pH value sensor and turbidity sensors. The software manages sensor data, boat movement, and communication with the cloud, while a mobile app allows remote control and video streaming. The challenges with this system includes the lack of an overall pollution assessment method and cost-effectiveness.

In 2021, an autonomous water quality monitoring and surface cleaning unmanned surface vehicle (MF-USV) was developed [10]. It utilizes ultrasonic sensors and a threshold-based algorithm for obstacle avoidance while navigating water. Equipped with a pH sensor and sample collection system, it detects and records real-time pH levels, collecting water samples when anomalies are detected.

In 2024, a cost-effective IoT system using Arduino and sensors was developed to monitor water quality in rural areas [11]. This initiative focuses on detecting pollutants such as temperature, pH, TDS, and turbidity, crucial for ensuring water safety. Real-time data accessible via a mobile app enables proactive responses to fluctuations in water quality. The most notable limitation in this system is the lack of smart predictive models regarding the water pollution level. In this sector, AI-based analytics have shown significant improvement. Monitoring precision has been improved using AI and IoT based smart system for real-time *E.Coli* concentration [12].

The water surface waste collection systems commonly utilize a conveyor belt system with a mounted garbage bin due to being low-cost and affordable solution. In terms of boat structure, the catamaran hull design is favored for its reliability and stability. However, a notable limitation across these systems is the absence of proper water monitoring tools. Water monitoring boats typically use turbidity sensors, pH sensors, temperature and humidity sensors, along with water sampling tools. While these robots provide real-time analytics of water conditions, they often lack comprehensive pollution assessment methods.

Table - I provides a concise summary of the literature review's structure and findings.

III. Methodology

In our project, we have proposed a boat with two integrated systems - one collecting floating wastes and debris via conveyor belt, and the other module containing water quality monitoring system.

TABLE I
COMPARISON OF WATER MONITORING AND WASTE COLLECTION SYSTEMS

Article	Floating Waste Collection Mechanism	Propulsion	Boat Structure	Control Mode	Pollution Monitoring Mechanism
Vaidya *et.al* (2020) [3]	Conveyor belt	Propeller mechanism	L-section/T-section joints, compressed air-filled PVC pipes	Manual control via RF module	Not present
Satheesh *et.al* (2020) [6]	Conveyor belt	Two DC motors	Basic frame made of foam sheets	Manual control via RF module	Not present
Wang *et.al* (2024) [8]	Collection basket (light debris), electric push rods (heavy debris)	Frostless shaftless underwater propulsor	Catamaran hull	Not specified	Not present
Xing *et.al* (2020)[9]	Mechanical arm controlled by mobile app	Motor driver module	Not specified	Remote control via mobile app	Temperature, humidity, pH value, turbidity sensors
Chang *et.al* (2021) [10]	Mechanical system with salvage net	Electric propeller	Basic frame	Autonomous navigation (Ultrasonic sensors with threshold-based algorithm)	pH sensor, sample collection system
Dsouza *et.al* (2021) [13]	Not specified	DC geared motors	Sqaure frames with PVC pipes	Remote control via mobile app	Electrical conductivity, pH, TDS, and temperature

A. Hardware Implementation

The main control system serves as the central hub of the boat, managing power, steering mechanisms, and overall functionality. It is controlled via a mobile app terminal using Wi-Fi through the Blynk app joystick. The boat's movement is driven by two 180 short shaft DC motors, which are powered by an L298N motor driver connected to an 11.1V DC battery. This setup allows the user to remotely control the boat's movement, speed, and steering.

The ESP32-CAM module is responsible for capturing real-time video footage and transmitting it through Wi-Fi. The video data is displayed on a PC terminal and processed using an OpenCV object detection algorithm to identify floating waste, enabling remote monitoring of the boat's surroundings in real-time.

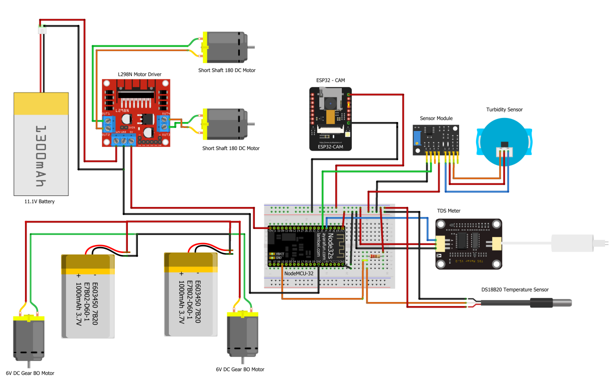

Fig. 1. Circuit Diagram

For waste collection, the boat is equipped with a custom-built conveyor belt system powered by two 6V 100 RPM BO DC motors. These motors are powered by two 3.7V batteries connected in series, providing a 7.4V output. The conveyor belt system collects floating garbage from the water's surface at the front of the boat and transfers it to the rear, ensuring efficient waste collection.

The water quality monitoring system includes sensors for TDS, temperature, and turbidity. These sensors are connected to the main control unit, where the data is processed. The processed information is transmitted to the PC terminal via the Wi-Fi module, providing real-time insights into the water's overall quality and the environmental conditions.

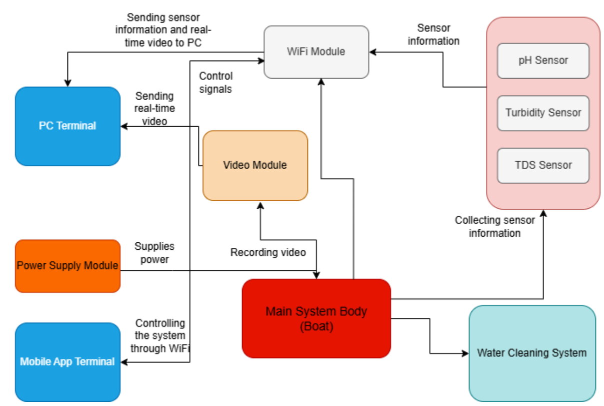

Fig. 2. System Architecture

B. Sensors and IoT Implementation

1) Turbidity: Turbidity is a measure of the cloudiness or haziness of water, which is caused by the presence of suspended particles such as silt, algae, and other microorganisms. In this project, a turbidity sensor is utilized to monitor water clarity. The sensor works by passing a light beam through the water and measuring the amount of light scattered by suspended particles. Higher turbidity levels indicate a larger presence of such particles, which is often a sign of pollution.

The turbidity sensor used in the boat is interfaced with the ESP32 microcontroller. The sensor outputs an analog voltage corresponding to the turbidity level, which the microcontroller converts into digital data. This data is then transmitted to the Blynk IoT platform, where it is displayed in real-time on the user's dashboard with the corresponding results of NTU, such as "Clear", "Cloudy" or "Dirty".

2) DS18B20 Temperature Sensor: The DS18B20 is a digital temperature sensor used in this project to monitor the water temperature. Temperature is a critical parameter for assessing water quality, as it affects the biological and chemical processes in the water. The DS18B20 sensor is highly accurate and capable of measuring temperatures in the range of -55°C to +125°C with an accuracy of ±0.5°C over a wide range.

The DS18B20 sensor utilizes a one-wire communication protocol to transmit temperature data directly in digital form to the ESP32 microcontroller. After collecting the temperature readings, the data is sent to the Blynk IoT platform, where it is displayed on the dashboard in real time, along with a live graph to track temperature variations.

3) TDS Sensor: The Total Dissolved Solids (TDS) sensor is used in this project to measure the concentration of dissolved particles in the water, including minerals, salts, and organic matter. TDS is an important indicator of water quality, as higher TDS levels can signal pollution or contamination. The TDS sensor provides an output in parts per million (ppm), indicating the concentration of dissolved solids in the water.

The TDS sensor operates by detecting the electrical conductivity of the water, which correlates with the concentration of dissolved solids. The sensor generates an analog signal that is fed into the ESP32 microcontroller, where it is digitized for processing. The microcontroller then sends the TDS readings to the Blynk IoT platform, allowing real-time data visualization.

4) Water Index Quality (WQI): The Water Quality Index (WQI) is a numerical expression used to assess the ecological state of a water body. The NSF-WQI (National Sanitation Foundation-Water Quality Index) incorporates nine water quality parameters: TDS (total dissolved solids), pH, turbidity, phosphates, nitrates, biochemical oxygen demand (BOD), coliforms, dissolved oxygen (OD), and temperature. Each parameter contributes differently to the NFS-WQI index, which is calculated using the formula:

$$\text{NSF-WQI} = \sum_{i=1}^{n} W_i Q_i \tag{1}$$

Here, WQI-NFS ranges from 0-100; W_i is the weighting factor for each parameter, and Q_i is the corresponding sub-index, derived from a conversion curve [14]. Our system uses temperature parameter with weight 0.1 and turbidity parameter with weight 0.08 according to the weight scores of NSF-WQI parameters. The calculated NFS-WQI index classifies water quality into one of five categories - "Very Good", "Good", "Moderate", "Poor" and "Very Poor", as shown in II.

TABLE II
WATER QUALITY VALUE (NFS–WQI)

NFS - WQI	Water Quality
90-100	Very good
70-90	Good
50-70	Moderate
25-50	Poor
0-25	Very poor

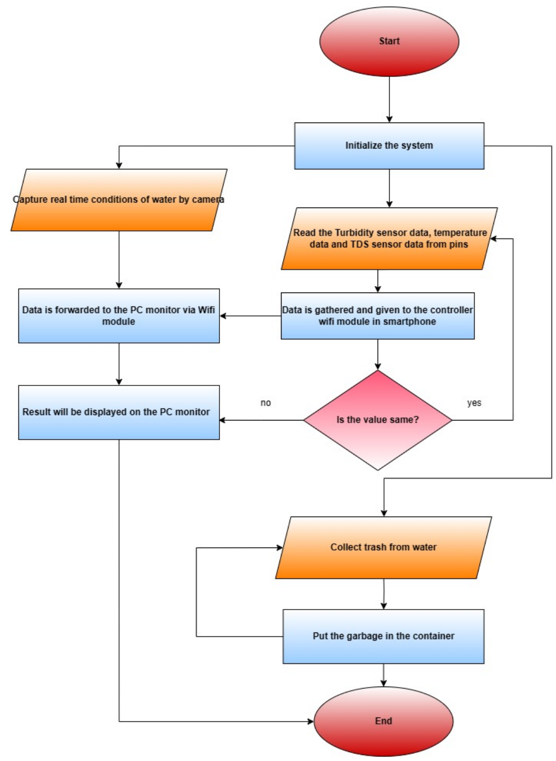

Fig. 3. Flowchart

C. Software Implementation

The ESP32 microcontroller was programmed using Arduino IDE version 2.3.3, with ESP32 board support added via the Board Manager URL. The Blynk library was installed from the Library Manager to connect the ESP32 to the Blynk cloud. The Blynk app was used to generate an authentication token, which, along with Wi-Fi credentials, was added to the ESP microcontroller code.

In the Blynk web console, each sensor was assigned to specific virtual pins, as shown in Table III. This allowed for the visualization of sensor data through widgets, such as charts for temperature data, labels for TDS, turbidity and WQI.

TABLE III
THE SENSORS ASSIGNED TO VIRTUAL PINS.

Sensors	Virtual Pins
DS18B20 Temperature Sensor	V0
Turbidity Sensor	V7
TDS Meter V1.0	V2
Joystick	V9, V10

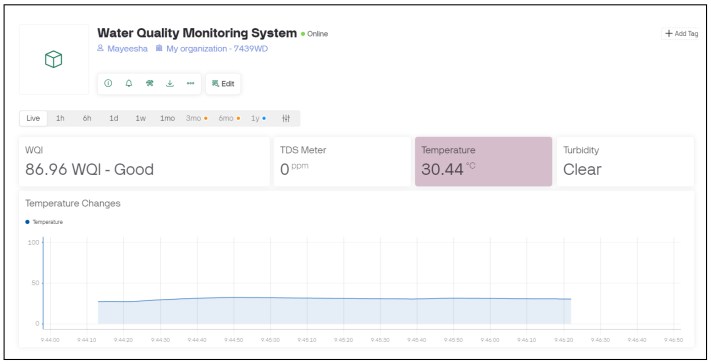

Fig. 4. Blynk Console on Web

The Blynk mobile app was set up to control the boat's movement in real-time. Joystick inputs adjust the propeller's rotation, enabling forward, backward, and sideways navigation.

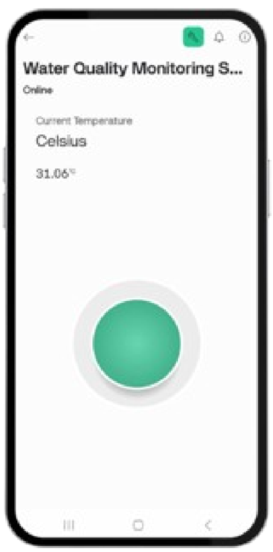

Fig. 5. Controlling Boat via Joystick in Blynk Mobile App

D. Real-Time Object Detection System Implementation

This project uses the ESP32 CAM for object detection and identification with OpenCV and the cvlib library, leveraging the YOLOv3 model trained on the coco-names dataset [15]. This object detection algorithm can effectively detect plastic items such as bottle, cup, fork, knife, spoon, bowl and toothbrush and electronic wastes such as cell phone, remote, keyboard, mouse and laptop parts. Figure 6 shows real-time demonstration of object detection system.

IV. Environment Setup

A. Equipment

1) The Main Body: The main body consists of two hulls connected together. The hulls are each 24×4 inches. A

Fig. 6. Real-time Object Detection using OpenCV

propeller and radar are attached to each hull, which are operated by DC motors. These motors are controlled remotely by a WiFi module through a mobile app.

2) Waste Collection Module: This part consists of a conveyor belt and a waste storage box. It is placed between the two hulls and connected to the main body. The belt is rotated by a DC motor to collect floating waste from the water surface.

3) Circuit House: This part is placed at the back of the main body. It contains the entire controller unit and equipment, which includes the Arduino Mega, batteries, motor driver, sensors (Temperature, Turbidity, and TDS), and the camera-WiFi-Bluetooth module. The probes of the sensors are submerged in the water to monitor the water quality.

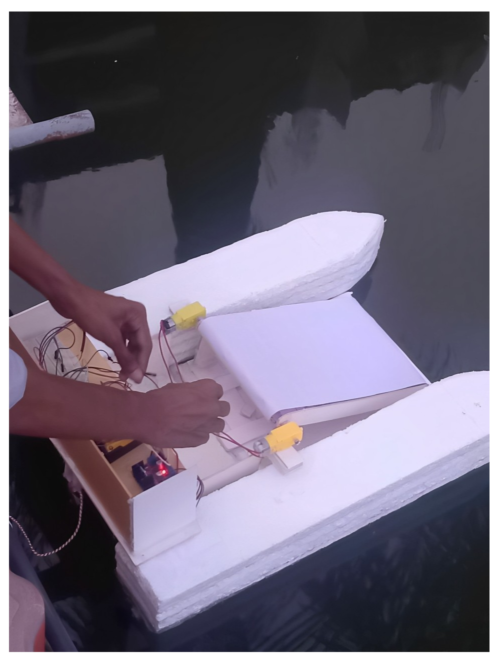

Fig. 7. Experimental Setup of Our System

B. Software

- **Arduino IDE v2.3.3**: Serves as the primary development environment to upload firmware to the ESP32 microcontroller. We utilized essential libraries such as *WiFi.h* for network setup, *BlynkSimpleEsp32.h* for IoT functionality, *OneWire.h* for sensor communication, and *DallasTemperature.h* for reading temperature data. The software was run on a Windows 11 Pro system with a 64-bit operating system and an x64-based processor.
- **Blynk IoT v1.21.1**: Blynk is used for IoT prototyping and deployment, offering real-time data visualization from connected sensors through virtual pins. It is compatible with Android 6.0 and up, and for our experiment we used it on Android 14.
- **Fritzing v0.9.10**: Fritzing is used in our experiment for creating circuit diagrams, visually representing connections between the ESP32, sensors, and other components.

C. Conditions and Controls

For experimentation, we operated our boat on a small water body of less than 10 km² with minimal wave flow and optimal weather. Small lightweight floating debris was collected through the conveyor belt.

D. Assumptions

The water body where the boat will function is assumed to be a small water body such as a pond or lake. The floating debris and waste in the water body will be small to medium-sized items such as small plastic bottles, juice boxes, leaves, paper wastes, or any debris not exceeding 100 grams. The water body will be of moderate flow with negligible wind resistance to maintain the boat's position.

V. Result and Discussion

This project demonstrated effective small debris removal from water surfaces, continuously monitoring turbidity, TDS, and temperature. The remote smartphone control added convenience, while live water quality data supported real-time environmental assessments. These insights help in proactive planning and decision-making for more sustainable water management.

VI. Limitations and Future Scope

The boat currently faces several limitations, including a low weight tolerance, a limited number of water quality sensors, and the lack of a sustainable power source. To improve waste detection and collection, future enhancements could focus on scaling the design to accommodate larger volumes of waste. Implementing solar-powered systems would not only extend operational time but also minimize environmental impact. Additionally, integrating advanced sensors and artificial intelligence will facilitate more precise water quality monitoring and informed decision-making through a fuzzy logic system, further optimizing the project's effectiveness.

VII. Conclusion

In conclusion, the Water Pollution Monitoring and Floating Waste Collection Boat offers an efficient, autonomous solution to water pollution. This scalable system has the potential to improve water quality and support sustainability efforts in Bangladesh and beyond.

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