IOT Water Pollution Monitoring RC Boat

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Abstract - Water pollution has emerged as a critical environmental issue, posing serious threats to aquatic ecosystems, human health, and economic stability. The presence of pollutants in water sources affects biodiversity, contributes to the spread of waterborne diseases, and disrupts industrial and agricultural operations. Traditional water quality monitoring methods rely on manual sampling and laboratory analysis, which are time-consuming, labor-intensive, and often ineffective in providing real-time insights. This paper presents a cutting-edge Internet of Things (IoT)-enabled remote-controlled (RC) boat system, specifically designed to facilitate real-time water pollution monitoring. The proposed system integrates an ESP32 microcontroller with a suite of water quality sensors, including pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), and temperature sensors. A GPS module is incorporated to provide precise location tracking, allowing for efficient mapping of pollution hotspots. Additionally, an ESP32 CAM module is used to offer live visual monitoring of water conditions. Data collected by the boat is transmitted wirelessly to a cloud-based platform, ensuring remote access and continuous monitoring. The system aims to provide a cost-effective, scalable, and autonomous solution for large-scale environmental monitoring, improving the efficiency of pollution detection and mitigation strategies. This paper elaborates on the complete design, implementation, performance analysis, and potential applications of this innovative water monitoring system.

Key Words: IoT, Water Pollution , Remote - Controlled Boat, Real-Time Monitoring , Sensor- Based Analysis, Environmental Sustainability,

1. INTRODUCTION

Water pollution is a significant issue worldwide, affecting the health of ecosystems, human populations, and economies. Sources of pollution include industrial discharge, agricultural runoff, and urban waste, leading to the contamination of water bodies with harmful chemicals and microorganisms. Addressing this challenge requires effective water quality monitoring to detect pollutants early and take corrective actions. Traditional water quality monitoring methods involve collecting samples manually and analyzing them in a laboratory, which can be slow, expensive, and limited to specific locations and times. Recent advancements in technology, particularly the Internet of Things (IoT), have enabled the development of automated monitoring systems that provide real-time data, allowing for quicker responses to pollution events. The "IoT Water Pollution Monitoring RC Boat" project aims to leverage IoT technology by deploying an autonomous remote-controlled (RC) boat equipped with sensors to measure critical water quality parameters continuously. Real-time monitoring allows for continuous data collection and instant alerts if pollution levels exceed safe thresholds, enabling quick interventions to protect ecosystems and public health. The project integrates water quality sensors, a GPS for location tracking, and a camera for live visual monitoring, making it a comprehensive solution for assessing water conditions. By automating the data collection process, this system reduces the need for manual sampling, minimizes human error, and provides more extensive spatial and temporal coverage.

The primary objective is to develop a portable and efficient system for real-time water quality monitoring using an IoT-enabled RC boat. The system should be capable of accurately collecting data from various sensors and transmitting the information wirelessly for remote access.

Specific objectives include:

- **Cost-effectiveness:** Design an affordable solution that can be easily replicated and deployed across different water bodies.

- **Multi-parameter monitoring:** Incorporate sensors to measure pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), and temperature, providing a comprehensive picture of water quality.

• **Data transmission:** Use the ESP32 microcontroller to collect data from the sensors and transmit it via Wi-Fi to a cloud server.

• **Real-time surveillance and mapping:** Include a camera for live video feed and a GPS module for location tracking, enabling spatial analysis and visual inspection.

• **User interface development:** Create a web-based dashboard or mobile app for real-time data visualization and analysis.

3. LITERATURE REVIEW

Several studies have explored IoT-based water quality monitoring systems that utilize sensor based methodologies to detect pollution levels. These systems have successfully measured essential water parameters such as pH, turbidity, TDS, DO, and temperature. However, most of these monitoring systems are either stationary or require manual deployment, limiting their applicability in large water bodies.

Other research has investigated the use of autonomous surface vehicles (ASVs) and underwater drones for pollution detection. While these solutions offer improved mobility and automation, they are often expensive and complex to implement. Furthermore, some existing models lack real-time cloud integration and remote accessibility, restricting their efficiency in large-scale monitoring.

The proposed IoT-enabled RC boat aims to bridge these gaps by offering a mobile, cost-effective, and real-time solution for large water bodies. Unlike stationary sensors, this RC boat can navigate across different locations autonomously or via remote control, transmitting real-time data to a cloud server. With GPS tracking, visual monitoring, and an easy-to-use mobile application, the system ensures comprehensive environmental monitoring and efficient pollution management.

4. METHODOLOGY

This project, "IoT Water Pollution Monitoring RC Boat," employs a systematic methodology to develop an Internet of Things (IoT)-enabled remote-controlled (RC) boat equipped with various sensors to monitor water quality. The process begins with the system design phase, where the layout of the boat is structured to securely accommodate sensors, an ESP32 microcontroller, a camera, a power supply, and communication modules. This stage focuses on creating a compact and efficient design that balances functionality and portability. In the hardware integration stage, essential water quality sensors—such as pH, turbidity, total dissolved solids (TDS), dissolved oxygen (DO), and temperature sensors—are mounted on the boat. Each sensor interfaces with the ESP32 microcontroller, ensuring that signal conditioning provides precise and reliable readings. A camera is also installed for real-time video monitoring, while a rechargeable battery supplies power to all components, enabling seamless operation. Following integration, data acquisition occurs, with the ESP32 collecting sensor data at regular intervals. This allows for a continuous flow of real-time data representing current water quality conditions, which is vital for analyzing environmental parameters accurately. Next, data transmission is enabled by configuring the ESP32 to wirelessly send data through Wi-Fi to a cloud server and a mobile application. This setup ensures that data on water parameters can be monitored in real-time remotely, supporting timely assessments of environmental conditions across multiple water bodies. The real-time camera surveillance capability enhances this system by streaming live video to a remote interface, allowing users to observe water conditions directly and offering visual insights that aid in immediate responses to anomalies. Once data is collected and transmitted, the data analysis and visualization phase begins. Sensor readings and video feeds are displayed on a web-based dashboard or mobile application, with graphs illustrating trends such as pH levels or fluctuations in dissolved oxygen. This visual representation of data allows users to interpret water quality parameters effectively, fostering informed decisions on environmental interventions. Testing and calibration of the system follow, where field tests are conducted in different water bodies to validate the system's performance. Calibration of sensors further enhances accuracy, optimizing the device to yield reliable readings under varying environmental conditions. Finally, deployment and monitoring take place, with the RC boat deployed in specific water bodies for continuous, real-time monitoring. The boat collects, analyzes, and transmits data, offering a sustainable approach to tracking water quality over time. By providing remote operation, real-time data collection, and wireless communication, this methodology establishes a robust and portable water monitoring solution. This IoT-enabled RC boat supports environmental conservation efforts by facilitating efficient, continuous water quality assessments across various ecological settings.

5. SYSTEM ARCHITECTURE

1) BLOCK DIAGRAM

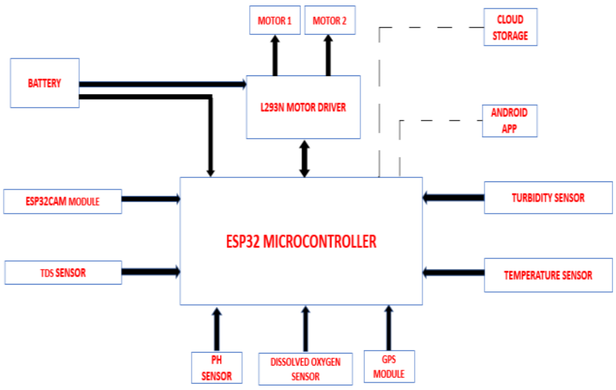

Fig 1. Block Diagram of proposed system

The block diagram of the IoT-based water pollution monitoring RC boat showcases the integration of various sensors and modules, all interfaced with the ESP32 microcontroller, which serves as the central processing unit. The system includes sensors for monitoring pH, turbidity, total dissolved solids (TDS), dissolved oxygen, and temperature to measure different water quality parameters. Each sensor provides real-time data to the ESP32, allowing for continuous monitoring. The GPS module tracks the boat's location, enabling geo-referenced water quality readings. An ESP32CAM module is incorporated for real-time visual surveillance, providing live video footage. The motor driver controls the movement of the boat using a DC motor setup, powered by a rechargeable battery. The ESP32 also communicates with an Android device, facilitating data transmission and remote control. This design ensures comprehensive monitoring of water conditions while providing GPS coordinates and real-time visual feedback.

2) SOFTWARE REQUIREMENTS

In IoT-based water pollution monitoring project, the integration of Arduino IDE, Arduino Cloud, and Blynk IoT plays a pivotal role in achieving seamless operation and monitoring.

1. Arduino IDE: Firmware Development

The Arduino Integrated Development Environment (IDE) serves as the primary tool for developing and uploading firmware to the ESP32 microcontroller.

- ESP32 Board Configuration:

  - Install the ESP32 board package in the Arduino IDE to enable code compilation and uploading.

  - Configure the IDE with the appropriate board settings to match the ESP32 hardware specifications.

- Sensor and Module Integration:

  - Incorporate libraries and write code to interface with various sensors, including dissolved oxygen, TDS, turbidity, pH, and temperature sensors.

  - Develop routines to handle data acquisition from the GPS module and manage live video streaming from the camera module.

- Communication Protocols:

  - Implement Wi-Fi connectivity to facilitate data transmission to cloud platforms.

  - Utilize HTTP protocols for efficient communication between the ESP32 and cloud services.

2. Arduino Cloud: Real-Time Data Monitoring

Arduino Cloud provides a platform for real-time visualization and monitoring of sensor data and GPS location.

- Thing and Device Setup:

  - Create a new Thing in Arduino Cloud, defining variables corresponding to each sensor's data and GPS coordinates.

  - Link the ESP32 device to the Thing, enabling it to publish data to the cloud.

  - Design a custom dashboard to display live data, utilizing widgets such as gauges, charts, and maps.

  - Set up real-time updates to monitor water quality parameters and the boat's GPS location effectively.

- Data Logging and Alerts:

- Enable data logging features to record historical sensor data for analysis.

- Configure alerts to notify users when specific thresholds are exceeded, ensuring timely responses to potential issues.

3. Blynk IoT: Remote Control and Live Video Streaming

Blynk IoT offers a versatile platform for remote control of the RC boat and live video streaming capabilities.

- Mobile Application Development:

- Utilize the Blynk app to create a user-friendly interface for controlling the boat's movements, including navigation controls and speed adjustments.

- Integrate widgets that allow users to start and stop the boat remotely, enhancing operational flexibility.

- Live Video Integration:

- Set up the ESP32-CAM module to capture live video feeds.

- Incorporate a Video Stream widget within the Blynk app, enabling real-time visual monitoring of the boat's surroundings.

- Two-Way Communication:

- Implement functionalities that allow the ESP32 to send sensor data to the Blynk app, providing users with immediate feedback on water quality parameters.

- Enable control commands from the app to the ESP32, facilitating responsive and interactive operation of the RC boat.

3) ALGORITHM

Real-Time Water Quality Monitoring Using Arduino Cloud

Step 1: Initialize System

1. Power on the ESP32 and establish a WiFi connection.

2. Initialize all connected sensors (TDS, Turbidity, pH, DO, Temperature, GPS).

Step 2: Configure Arduino Cloud

3. Define cloud variables for each parameter: - TDS_Value, Turbidity_Value, pH_Value, DO_Value, Temperature_Value, Latitude, Longitude.

4. Connect ESP32 to Arduino Cloud using Device ID and Secret Key.

Step 3: Read Sensor Data

5. Read TDS sensor data from the analog pin and convert it to ppm.

6. Read Turbidity sensor data and convert it to NTU.

7. Read pH sensor data and convert it to pH scale.

8. Read Dissolved Oxygen (DO) sensor data and convert it to mg/L.

9. Read Temperature sensor (DS18B20) and convert to Celsius.

10. Read GPS module (Neo-6M) for latitude and longitude.

Step 4: Process and Send Data

11. Apply necessary calibrations for sensor accuracy.

12. Transmit all sensor values to Arduino IoT Cloud.

Step 5: Display Data on Dashboard

13. Update real-time sensor values on the Arduino Cloud Dashboard.

14. Plot graphs for historical trends and monitor GPS location on a map.

Step 6: Repeat the Process

15. Wait for 5 seconds and repeat steps 3-5 continuously.

Blynk IoT for Control and Live Video Streaming

Step 1: Create a Blynk IoT Account

1. Go to [Blynk Cloud](https://blynk.cloud/) and sign up.

2. Create a new project and select ESP32 as the hardware.

3. Note down the Blynk Authentication Token from the email.

Step 2: Install Required Libraries

4. Open Arduino IDE and install the following libraries:

- BlynkSimpleEsp32.h
- WiFi.h

Step 3: Hardware Setup

5. Connect the ESP32-CAM module and sensors:

- Camera connected to ESP32-CAM.
- Motor control (Relays/PWM pins) for movement.
- WiFi module initialized for connectivity.

Step 4: Configure Blynk App

6. Open the Blynk App on a smartphone.

7. Add the following widgets:

- Video Streaming Widget → Enter ESP32-CAM's streaming URL.
- Buttons → Assign them to GPIO pins for motor control.
- Virtual Pins → For additional functionalities.

Step 5: Program the ESP32 for Blynk

8. Define WiFi credentials and Blynk Authentication Token in the Arduino sketch.

9. Initialize Blynk, Camera, and Motor Control Pins.

10. Start the ESP32-CAM video stream using the MJPEG stream server.

11. Continuously send sensor and camera data to

Step 6: Upload Code and Monitor

12. Upload the program to ESP32-CAM via Arduino IDE.

13. Open Serial Monitor to check connectivity status.

14. Open the Blynk App and control motors while watching the live video stream.

Step 7: Repeat the Process

15. Continuously update Blynk with sensor readings and stream video.

16. Ensure stable WiFi connectivity

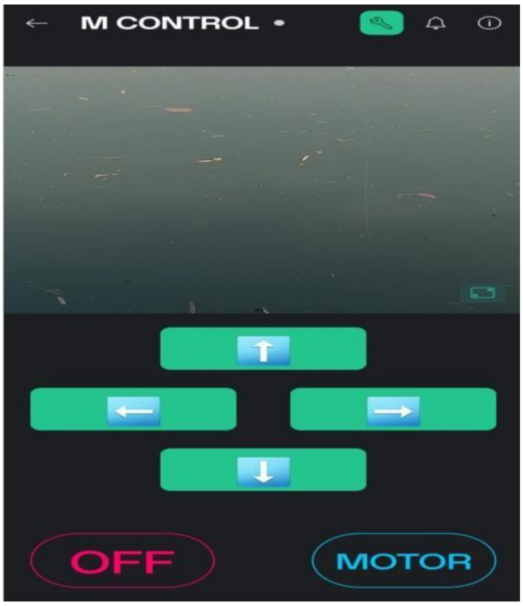

Figure 2. Front page of Blynk App

4) CIRCUIT DESIGN

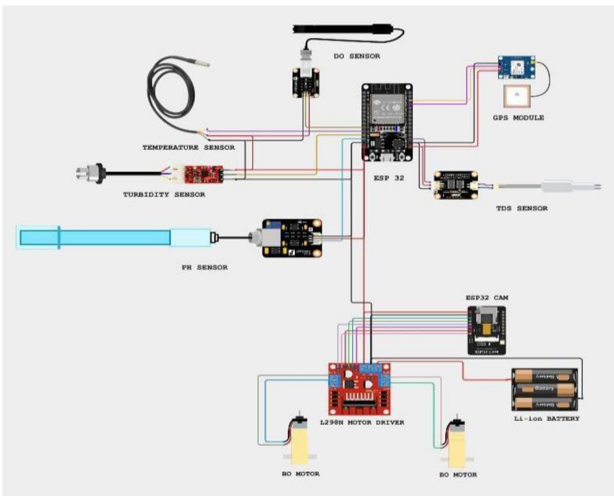

Figure 3.Circuit Diagram of proposed system

The IoT Water Pollution Monitoring RC Boat is designed to autonomously navigate water bodies while analyzing water quality in real time. At the core of the system is an ESP32 microcontroller, which gathers data from multiple sensors, including a dissolved oxygen (DO) sensor for oxygen concentration, a temperature sensor for thermal monitoring, a turbidity sensor to measure water clarity, a pH sensor for acidity levels, and a total dissolved solids (TDS) sensor to assess dissolved impurities. These sensors provide comprehensive insights into water pollution levels. Additionally, a GPS module enables real-time location tracking, ensuring the boat can be monitored remotely. An ESP32 CAM is integrated to capture live images or video footage of the water environment for visual assessment. The movement of the boat is controlled via an L298N motor driver, which operates two BO motors for propulsion and steering. Power is supplied through a rechargeable Li-ion battery pack, ensuring prolonged autonomous operation. The ESP32 processes all collected data and transmits it via IoT to a cloud platform or a mobile application, allowing users to monitor water quality remotely. This smart system enables efficient, real-time pollution tracking and can be deployed in lakes, rivers, or reservoirs for environmental monitoring and research.

5) 3D PRINTED MODEL

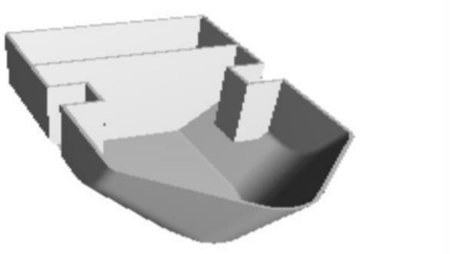

Figure 4. 3D model of Boat

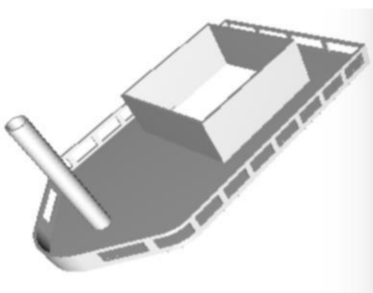

Figure 5. 3D model of Boat Deck

6. WORKING & IMPLEMENTATION

The RC boat autonomously navigates water bodies, continuously collecting pollution data. Sensor readings are processed in real-time and uploaded to the cloud.

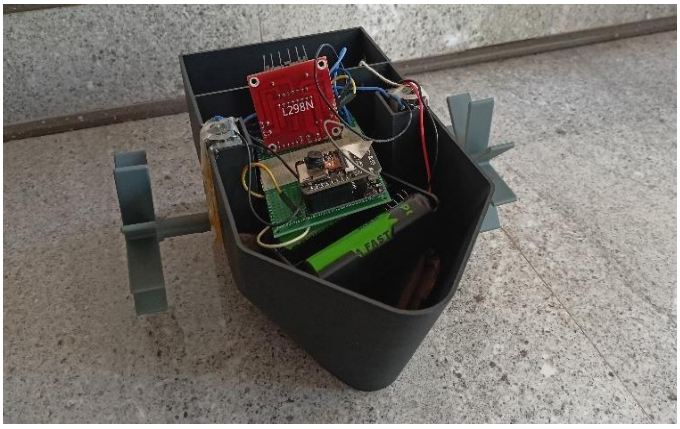

Figure 6. Boat Model

The GPS module tracks the boat's movements, ensuring precise mapping of contamination levels. The ESP32 CAM module provides a visual assessment of pollution sources. Users can control the boat remotely using a mobile app, allowing them to adjust the boat's position and capture specific areas of interest. This fully automated system minimizes human intervention while maximizing efficiency.

Figure 7. Boat Model

The real-time monitoring capability ensures that environmental authorities and researchers can take timely action to mitigate pollution risks.

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Figure 8.Page for water quality Analysis

6. RESULT AND DISCUSSION

Testing of the prototype in various water bodies demonstrated high accuracy in detecting pollution levels. The system effectively mapped pollution hotspots, providing actionable insights for environmental authorities. Compared to traditional monitoring methods, the IoT-based RC boat significantly improved data collection speed, geographic coverage, and cost-effectiveness. Sensor calibration and Wi-Fi stability were optimized through iterative refinements to ensure consistent data transmission and accurate readings. Future enhancements could include refining data accuracy through AI-driven analytics and increasing operational efficiency through enhanced battery life.

7. FUTURE SCOPE

Future improvements include AI-powered analytics for predictive pollution monitoring, solar-powered charging for extended operational capabilities, and 5G connectivity for enhanced real-time data transmission. Additional sensor integration for heavy metal detection and microbial contamination analysis can expand the system's applications. Deploying multiple interconnected RC boats can further enhance scalability, enabling synchronized monitoring across large water bodies. The integration of blockchain technology for secure and transparent data logging can improve reliability and authenticity in environmental reporting. Autonomous decision-making capabilities through AI-driven insights can enhance proactive responses to pollution events, further strengthening the efficiency of the monitoring system.

8. CONCLUSION

The IoT-based water pollution monitoring RC boat provides an innovative approach to assessing water quality in real-time. By integrating multiple sensors for measuring pH, turbidity, dissolved oxygen, TDS, and temperature, the system offers a comprehensive solution for monitoring various water quality parameters. The use of an ESP32 microcontroller allows for efficient data processing, while the GPS module and ESP32CAM enable location tracking and real-time visual surveillance. The integration of a motor control system enables automated or remote navigation, making the boat suitable for use in different aquatic environments. The design leverages IoT technology to transmit data wirelessly, allowing for continuous monitoring and reporting. This system can be used for applications such as detecting pollution sources, monitoring the health of aquatic ecosystems, and providing data for environmental protection efforts. The project demonstrates how combining sensor technology, wireless communication, and automated navigation can significantly improve water quality monitoring and management.

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