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DESIGN AND FABRICATION OF IOT BASED UNDERWATER ROBOT FOR WATER QUALITY AND AQUATIC SURVEILANCE

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ABSTRACT :

The project explores the emerging field of marine life study and the exploration of various water bodies, highlighting the development of different types of underwater robots. The design and implementation of an inexpensive underwater surveillance robot using Internet of Things (IoT) technology.The prototype is built with a water-resistant structure made from PVC pipes and controlled via an Android smartphone using the Blynk app.It integrates a Wi-Fi module (NodeMCU), coreless DC motors, an ultrasonic sensor for obstacle detection, and a Wi-Fi camera for live video streaming.The robot enables real-time monitoring of underwater environments without physical. The use of IOT allows seamless communication between the robot and the user through wireless control and data reception.Software like Arduino IDE is used to program the robot's operations, ensuring easy customization.The system provides a cost-effective solution for marine exploration, especially for educational and research applications.This solution provides an efficient, scalable, and cost-effective approach to environmental monitoring, aiding in the early detection of pollution, monitoring aquatic ecosystems, and supporting water resource management.

1. INTRODUCTION

1.1 Water is a vital resource that sustains life, supports ecosystems, and drives economic activities. However, increasing industrialization, agricultural runoff, and urban development have led to the degradation of water bodies, making the monitoring of water quality more crucial than ever. Traditional methods of water quality assessment are often time-consuming, labor-intensive, and limited in spatial and temporal coverage. To address these challenges, modern technologies such as the Internet of Things (IoT), robotics, and real-time data analytics are being integrated into environmental monitoring systems.

The real-time data collected by the robot is sent to a cloud platform, where it can be accessed and analyzed through a web or mobile application. This integration of IoT enhances the efficiency and responsiveness of monitoring efforts, enabling authorities, researchers, and environmentalists to make informed decisions quickly. The proposed system is not only scalable and cost-effective but also contributes to the sustainable management of water resources and the protection of aquatic ecosystems.

1.2 Problem Statement

- *Lack of real-time monitoring*: Traditional water quality assessment methods rely on manual sampling and lab testing, which are time-consuming and do not provide real-time data.
- *Limited accessibility*: Certain water bodies, especially deep or polluted areas, are difficult and unsafe for human operators to access for regular monitoring.
- *Inadequate surveillance*: There is a lack of continuous aquatic surveillance systems to detect illegal activities such as unauthorized fishing, dumping of waste, or aquatic habitat destruction.
- *High operational cost*: Existing underwater monitoring systems can be expensive and require specialized equipment and personnel, limiting their deployment in remote or resource-constrained areas.

1.3 Objectives

- *Design and develop* an underwater robotic system equipped with sensors to monitor key water quality parameters (e.g., pH, temperature, turbidity, dissolved oxygen).
- *Incorporate IoT technology* to enable real-time data collection, wireless transmission, and remote monitoring through cloud platforms or mobile applications.
- *Enable aquatic surveillance* through onboard cameras or imaging systems to observe underwater environments and detect unusual activities.

1.4 Scope and Limitations

In-scope:

- *Water Quality Monitoring*: The robot will measure key water parameters such as pH, temperature, turbidity, dissolved oxygen, and conductivity in real-time.
- *Aquatic Surveillance*: Equipped with a waterproof camera or imaging system, the robot will provide visual monitoring of underwater environments.
- *IoT Integration*: The system will transmit collected data wirelessly to cloud platforms or mobile/PC interfaces for real-time access and analysis.

Limitations:

- *Depth Constraints*: The robot may have limited operational depth depending on the design, pressure resistance, and sensor ratings.
- *Power Supply*: Battery life may limit the operational duration, requiring frequent recharging or power optimization.
- *Network Dependency*: Real-time data transmission and remote control require stable internet or wireless connectivity, which may not be available in all locatns.

2. LITERATURE REVIEW

Several studies highlight the role of robotics in precision agriculture. Previous research has explored automated ploughing, seed planting, and irrigation systems, demonstrating increased efficiency and sustainability. However, existing systems often lack cost-effectiveness and multi-functionality. This project addresses these gaps by integrating multiple agricultural applications in a single automated system.

The Previous Studies are mentioned below in the tabular form:

S. No	Title of the paper	Year	Description
I.	Aquatic surveillance robot based on IoT	2019	The development of a water-resistant underwater robot based on IoT for aquatic surveillance.
II.	IoT Based Underwater Robot for Water Quality Monitoring	2021	An IoT-based underwater robot designed for real-time water quality monitoring.It uses sensors to measure parameters like pH, temperature, and turbidity.
III.	HYDROBOT: An Underwater Surveillance Swimming Robot	2018	HYDROBOT is a cost-effective, computer-controlled underwater robot designed for surveillance and research.
IV.	Design and Construction of an Underwater Robot	2022	This paper presents a low-cost, wirelessly controlled underwater robot built using Arduino and RF modules.

1.Aquatic surveillance robot based on IOT

A. Problem Definition

The exploration of underwater environments is severely limited due to the harsh conditions that make it difficult for humans to operate effectively. Most existing underwater robots are expensive and often wired, which restricts their mobility and increases costs, making them inaccessible for many researchers. Additionally, the short transmission ranges of wireless communication underwater pose significant challenges for real-time data transmission. This situation necessitates the development of a low-cost, efficient, and user-friendly underwater robot that can be controlled remotely. The proposed prototype aims to address these issues by providing a fully water-resistant, IoT-based solution for underwater exploration.

B.Tools/Methods/Software Used

- **Internet of Things (IoT)**: The core technology enabling communication between the robot and the Android smartphone, allowing for remote control and data transmission over the internet.
- **NodeMCU (ESP-12E)**: This microcontroller board is programmed using the Arduino IDE and is responsible for processing commands and controlling the robot's movements.
- **Arduino IDE**: The software used to program the NodeMCU, which includes libraries for controlling coreless DC motors and ultrasonic sensors. It features a serial monitor for communication with the board.
- **Blynk Application**: An online platform that provides a user interface for controlling the robot via a virtual joystick. It allows for real-time data visualization from sensors and facilitates command transmission to the robot .

C. Methodology Used

- **Prototype Design**: The prototype consists of two main units: a robot and an Android mobile phone. These units function as transceivers, allowing for the transmission and reception of commands and information between them.
- **Waterproofing**: The robot unit is designed to be fully water-resistant. This is achieved through various waterproofing techniques, including the use of glue gun, epoxy spray, and tape to protect the electronic components from water damage.
- **Command Transmission**: Commands to control the robot are sent via the Blynk application on the Android mobile phone. The phone acts as a transmitter, while the robot receives commands through a NodeMCU, which processes these commands using a pre-burned program.
- **Sensor Integration**: The robot is equipped with an ultrasonic sensor that provides distance measurements. This data is transmitted back to the Android mobile phone through the NodeMCU, allowing the user to monitor the robot's surroundings.
- **Camera Functionality**: A Wi-Fi camera mounted on the robot transmits images directly to the connected Android smartphone. This feature enhances the robot's ability to provide visual feedback to the user during exploration.
- **Motor Control**: The robot's movement is controlled by a motor driver module (L293D) that receives commands from the NodeMCU. The prototype uses two horizontally placed motors for forward, backward, left, and right movements, and one vertically placed motor for upward and downward movements. The specific rotation of these motors is determined by the commands received from the Blynk application.
- **Testing and Optimization**: Various experiments were conducted to test the waterproofing of the hardware components and ensure their functionality in water. The selection of the NodeMCU was based on its superior range due to its built-in Wi-Fi module, which is crucial for effective communication.
- **Future Improvements**: The methodology also includes plans for future enhancements, such as studying acoustic communication protocols to improve the communication range and integrating additional hardware like waterproof ultrasonic sensors for better performance in underwater exploration.

D. Results Obtained

- **Successful Integration**: The interfacing of the ultrasonic sensor and motors with the NodeMCU was successfully completed. This integration allowed the prototype to operate effectively in a freshwater tank, demonstrating its functionality in a controlled environment.
- **Responsive Control**: The prototype was controlled via a virtual joystick using the Blynk application, which provided a remarkable response time without any delays. This indicates that the communication between the control interface and the robot was efficient, allowing for smooth operation.
- **Operational Efficiency**: The robot was powered by four 5V batteries, enabling it to run for about 20 minutes on a full charge. During this time, it was capable of navigating to depths of 6 feet, showcasing its ability to operate effectively underwater.

E. Analysis and Data

- **Prototype Design**: The underwater robot was designed using a Wi-Fi module, a camera, and a proximity sensor, making it fully water-resistant. This design allows for effective underwater surveillance and exploration, addressing the challenges posed by hostile aquatic environments.

- **Functionality of Components**: The NodeMCU, which serves as the core of the prototype, is interfaced with an ultrasonic sensor and DC motors. This setup enables the robot to gather environmental data and respond to commands issued by the operator through the Blynk application on an Android smartphone.

- **Data Transmission**: The robot operates on a three-layer architecture of the Internet of Things (IoT), which includes the application layer, network layer, and perception layer. The network layer is crucial as it establishes the connection between the operator and the robot, facilitating the transmission of commands and data.
- **Operational Data**: During testing, the robot was able to navigate underwater effectively, reaching depths of 6 feet. It operated for approximately 20 minutes on a full charge, demonstrating its efficiency and the effectiveness of its power management system.

- **User Interaction**: The Blynk application played a significant role in user interaction, allowing the operator to control the robot and receive real-time data. This application not only facilitated command transmission but also provided cloud saving and email notifications for data collected by the robot.

- **Challenges and Improvements**: The analysis highlighted the need for improvements in communication range and mechanical structure. Future developments will focus on enhancing the robot's capabilities, such as exploring acoustic communication protocols and integrating additional sensors for better data collection.

- **Conclusion**: The data collected during the operation of the underwater robot prototype indicates a successful integration of IoT technology for underwater exploration. The analysis suggests that while the prototype is functional, there are areas for enhancement that could improve its performance and usability in various aquatic environments.

II. IOT based underwater robot for water quality monitoring

A. Problem Definition

- **Limited Monitoring Duration and Parameters**: Previous robotic solutions for water monitoring have been found to operate only for short periods and typically focus on a very limited number of parameters. This lack of comprehensive monitoring can lead to insufficient data for assessing water quality effectively.

- **Time and Manpower Inefficiency**: The monitoring of large water bodies has been time-consuming and labor-intensive. Traditional methods require significant manpower to cover extensive areas, which is not practical for ongoing monitoring efforts.

- **Dependence on Traditional Methods**: The conventional approach to water quality monitoring relies heavily on collecting water samples, which are then tested in laboratories.

B.Tools/Methods/Software Used

- **Arduino Atmega (328)**: This microcontroller serves as the primary control unit for the robot, managing various sensors and motors.
- **ESP-32**: This module is crucial for underwater communication, providing inbuilt Wi-Fi capabilities and low power consumption, which is essential for IoT applications.

Sensors for Water Quality Measurement:

- **pH Sensor**: This sensor measures the acidity or alkalinity of the water, which is vital for assessing water quality.
- **Turbidity Sensor**: This device measures the cloudiness or haziness of the water, indicating the presence of suspended particles.
- **Temperature Sensor**: This sensor monitors the water temperature, which can affect the solubility of gases and the biological activity in the water.

Mechanical Components:

- **Stepper Motor**: Used for precise control of the robot's movements, allowing it to navigate through water effectively. The stepper motor operates on electro-mechanical principles, transforming electrical impulses into mechanical motion.
- **DC Motor**: This motor is used for driving the robot's movement, providing the necessary propulsion in the water.
- **Driver ICs (ULN2003)**: These integrated circuits are used to control the stepper motors, enabling precise movement without the need for costly feedback systems.

Power Management:

- **DC to DC Converter (LM2596)**: This component is used to regulate the power supply to various parts of the robot, ensuring stable operation.
- **Battery**: A battery is included to power the entire system, making the robot autonomous and capable of operating in remote locations.

Methodology

Design and Architecture:
The robot is designed with a simple architecture that allows for easy assembly and operation. This design is crucial for continuous monitoring of various water bodies such as lakes, rivers, and ponds.

Sensor Integration
The robot is equipped with embedded sensors to measure critical water quality parameters, including pH value, turbidity, and temperature. These sensors are integrated with the ESP32 microcontroller, which facilitates underwater communication due to its built-in Wi-Fi capabilities.

Data Processing and Communication:
The data collected by the sensors is processed using a machine understanding algorithm, specifically K Means, to analyze water quality based on predefined standards. This allows for real-time evaluation of water quality.

The processed data is then transmitted to a remote server using an IoT platform, enabling access from anywhere, including by the central pollution control board.

Operational Mechanism:
The robot operates using DC gear motors that control its movement. Initially, voltage is applied to activate a syringe for water infusion, which increases the robot's weight and allows it to submerge. If retrieval is necessary, a water pump expels water from the robot, making it buoyant again.

Real-Time Monitoring:
The system employs a real-time monitoring approach, utilizing a special IP address for accessing sensor data stored on the cloud. This ensures that the data is readily available for analysis and decision-making.

Cost-Effectiveness
The project is designed to be cost-effective, reducing the need for extensive manpower and operational time compared to traditional water quality monitoring methods, which often involve laboratory testing of water samples.

Results Obtained

Monitoring Performance:
The robot has shown satisfactory monitoring performance, capable of remaining underwater for extended durations without issues related to water seepage. This indicates a robust design that can withstand underwater conditions effectively.

Continuous Data Collection:

The robot successfully automates the evaluation of water quality parameters such as pH, turbidity, and temperature. This continuous data collection is crucial for timely monitoring and assessment of water quality in local and large water bodies.

Accessibility of Data:

The readings obtained from the robot are displayed on a website accessible by the central pollution control board. This feature allows for remote monitoring, enabling stakeholders to access real-time data from anywhere, thus enhancing the efficiency of water quality management.

Cost-Effectiveness:

The project is noted for being cost-effective, which is significant in the context of resource management. The use of high-speed Wi-Fi for underwater communication further enhances the robot's efficiency and self-reliance, making it a viable solution for water quality monitoring.

Component Testing:

Each component of the robot was tested individually to ensure proper functionality. After integrating all parts, the overall model was checked, confirming that the system operates as intended and meets the design specifications.

E. Analysis and Data

Parameter Measurement:

The robot is equipped with sensors that measure critical water quality parameters, including pH value, temperature, and electrical conductivity. These parameters are essential for determining the overall health of water bodies and ensuring they meet safety standards for various uses.

Data Processing:

A microcontroller processes the data collected from the sensors. This processing is crucial as it converts raw sensor data into meaningful information that can be analyzed and interpreted for decision-making.

Real-Time Monitoring:

The system allows for real-time monitoring of water quality, which is a significant advancement over traditional methods that rely on sample collection and laboratory testing. This real-time capability reduces the time required to assess water quality and enables quicker responses to potential contamination.

Machine Learning Integration:

The project incorporates machine learning algorithms, specifically K Means clustering, to analyze water quality data based on predefined standards. This integration enhances the robot's ability to detect contaminants and predict water usability, making the monitoring process more intelligent and automated.

Data Accessibility:

The processed data is communicated to a central server using a Wi-Fi data communication module, allowing stakeholders, such as the central pollution control board, to access the information remotely. This feature promotes transparency and facilitates better management of water resources.

Cost-Effectiveness:

The design and implementation of the robot are noted to be cost-effective, which is vital for widespread adoption in water quality monitoring initiatives. The use of low-cost embedded devices like ESP32 and Arduino Uno contributes to the affordability of the project.

Environmental Impact:

By continuously monitoring water bodies, the robot contributes to environmental protection efforts. It helps in identifying pollution sources and assessing the health of aquatic ecosystems, ultimately supporting sustainable water management practices.

III. HYDROBOT:An underwater surveillance swimming robot

Problem Definition

The HYDROBOT highlights the complexity and high costs associated with existing underwater robots, which are often difficult to design and control, limiting their accessibility for research and surveillance. There is a pressing need for a cost-effective and efficient solution that integrates essential features such as accelerometers, temperature sensors, and Hall effect sensors to enhance underwater surveillance capabilities. The proposed system aims to provide a user-friendly mechanical structure that includes a camera and a sampling system for collecting water samples and picking objects underwater, addressing the limitations of current technologies while ensuring balance and maneuverability through the principle of center of gravity.

Tools/Methods/Softwares Used

The development of HYDROBOT incorporates various tools, methods, and software to ensure its functionality and efficiency in underwater surveillance. Here are the key components:

- **Mechanical Structure**: The robot is constructed using polyvinyl chloride (PVC) pipes, which provide a lightweight and durable framework, enhancing its efficiency underwater.
- **Control Systems**: The system is divided into three main parts: mechanical structure and control, sensing system and control, and sampling system and control. This modular approach allows for better management and operation of the robot.
- **Sensors**: HYDROBOT is equipped with several sensors, including an accelerometer, Hall effect sensors, and a temperature sensor. These sensors are crucial for monitoring environmental conditions and ensuring the robot's operational efficiency.
- **Camera**: A web camera with night vision capabilities is integrated into the system, allowing for effective surveillance in low-light conditions. The camera is housed in a waterproof container to protect it during underwater operations.

- **DC Motors and Pumps**: The robot utilizes DC motors and windshield pumps for propulsion. The pumps are waterproof and designed to drive the robot forward, backward, and in various directions, while the DC motors are used for additional movement control.
- **Power Supply and Voltage Regulation**: The system operates on a 12V DC supply, with integrated circuits (ICs) used for voltage regulation to ensure that different components receive the appropriate voltage levels for optimal performance.
- **Embedded Platform**: The control system is based on the FRDM-KL25z platform, which features a 32-bit ARM Cortex-M0+ core. This platform supports various interfaces and is designed for prototyping devices, making it suitable for the control needs of HYDROBOT

Methodology Used

- **Mechanical Structure and Control**: HYDROBOT is constructed using polyvinyl chloride (PVC) pipes, which provide a lightweight and efficient design. The structure is balanced according to the center of gravity principle, allowing for stable movement underwater.
- **Propulsion System**: The robot employs two waterproof windshield pumps for propulsion, enabling it to move forward, backward, and change directions. This system reduces the risk of motor leakage, which is common in traditional underwater vehicles that use DC motors and propellers.
- **Sensing and Control Systems**: HYDROBOT is equipped with various sensors, including an accelerometer, Hall effect sensors, and temperature sensors. These sensors enhance the robot's efficiency in underwater research and surveillance by providing critical environmental data.
- **Water Sampling and Object Picking**: The robot features a water sampling system and a mechanical arm for object picking.

D. Results Obtained

- **Enhanced Underwater Surveillance**: The HYDROBOT has demonstrated its capability in underwater surveillance by effectively capturing video footage and images in low-light conditions, thanks to its night vision camera. This feature is particularly useful for identifying underwater life and conducting research in environments where sunlight does not penetrate.
- **Efficient Water Sampling**: The water sampling system integrated into HYDROBOT has proven effective in collecting water samples from specific depths. This capability is crucial for detecting harmful chemicals in water bodies, making it a valuable tool for environmental monitoring and research.
- **Object Picking Capability**: The mechanical arm of HYDROBOT has successfully performed underwater object picking. By utilizing a simple switch mechanism, the arm can open and close to grasp objects, demonstrating the robot's versatility in handling various tasks underwater.
- **Cost-Effectiveness and Energy Efficiency**: The design and components of HYDROBOT contribute to its cost-effectiveness. It operates on a 12V DC supply, which not only saves energy but also makes it an affordable option for various applications, including military and disaster management.

Analysis and Data

Sensor Integration:

HYDROBOT is equipped with multiple sensors, including an accelerometer, Hall Effect sensor, and thermistor. These sensors enhance the robot's efficiency in underwater research and surveillance by providing critical data on movement, environmental conditions, and temperature.

The accelerometer used is the ADXL335, which measures acceleration forces in three axes, allowing for precise balancing and navigation underwater.

Camera Functionality:

The robot features a web camera with night vision capabilities, enabling it to capture clear images and videos in low-light conditions. This is essential for conducting research in deep underwater environments where visibility is limited.

The camera's ability to operate effectively in darkness is crucial for identifying aquatic life and conducting environmental assessments.

Mechanical Design and Movement:

HYDROBOT is designed to rotate 360 degrees and adjust its depth according to user commands. This flexibility allows for comprehensive exploration and mapping of underwater environments.

The movement is controlled by DC motors and propellers, which are designed to be waterproof. The propellers enable the robot to ascend and descend by rotating in different directions .

IV. Design and construction of an underwater robot

A. Problem Definition

The design and construction of an underwater robot present several challenges, primarily related to ensuring effective wireless control and waterproofing of components. The robot must be capable of moving efficiently underwater while being controlled remotely, which requires a reliable communication system. Additionally, the integration of various hardware components, such as motors and cameras, necessitates careful consideration of power supply and waterproofing techniques. The project aims to create a low-cost solution that can perform tasks like environmental monitoring and inspection, overcoming the limitations of existing robotic systems. Ultimately, the goal is to develop a functional prototype that can operate effectively in aquatic environments .

B. Tools/Methods/Software Used

- **Arduino Boards**: Two Arduino boards are utilized; one serves as the controller circuit while the other (Arduino Mega) acts as the main processing unit for the robot.
- **Bluetooth Module**: A BC-05 Bluetooth module is employed to establish a wireless connection between the robot and a smartphone, allowing for remote control.
- **Joystick Software**: The ATC software is used as a joystick controller on an Android smartphone, enabling user commands to be sent to the robot.
- **RF Modules**: A pair of RF modules (RF433MHz) facilitates low-cost communication between the controller and the robot, allowing commands to be transmitted over distances of up to 100 meters in open space.
- **Motor Drivers**: L293D motor drivers are implemented to control the motors, lights, and camera of the robot, with a supply voltage of 9 volts and a logic voltage of 5 volts.
- **DC Motors**: Small 9-volt DC motors are used to create the thrusters that propel the robot in water.
- **Waterproofing Materials**: Various materials such as tape, wax, grease, and glue are used to ensure that the motors and other components are waterproof, which is crucial for underwater operation.
- **Camera**: A waterproof camera is integrated into the robot to provide visual feedback, functioning as the robot's "eyes".
- **Propellers**: Handmade thrusters are constructed using Turnigy 3 blade boat propellers and other materials to facilitate movement.

C. Methodology Used

- **Design Concept**: The underwater robot is conceptualized as a waterproof vehicle capable of moving in water based on user commands. It consists of a transmitting part and a receiving part, which work together to facilitate control.
- **Controller and Motherboard**: A low-cost controller and motherboard are designed to enable easy and wireless control of the robot. This design choice aims to simplify the user experience while maintaining functionality.
- **Waterproofing Challenges**: One of the significant challenges faced during the construction was ensuring that all components of the robot were waterproof. Various techniques and materials were employed to overcome these challenges, ensuring the robot could operate effectively underwater.
- **Testing Environment**: The robot was successfully constructed and tested in a large pond, which provided a controlled environment to evaluate its performance and functionality.
- **Control Range**: The robot can be controlled wirelessly from a distance of approximately 50 meters, showcasing the effectiveness of the wireless communication system implemented in its design.
- **Future Enhancements**: The methodology also includes plans for future improvements, such as enlarging the robot's range, minimizing its size, and changing its mechanical structure to a cylindrical shape for better stability and speed. Additional features like a 4K camera and sensors are also planned for integration.

D. Results Obtained

- **Operational Duration**: The underwater robot can operate for approximately 25-30 minutes when fully charged. This duration can be extended if the camera and lights are turned off, indicating efficient power management in its design.
- **Power Consumption**: The overall power consumption of the robot is recorded at 16 watts. This low power requirement is crucial for extending operational time and enhancing the robot's usability in underwater environments.
- **Wireless Control**: The robot features a fully wireless control system that allows operation from a distance of about 50 meters. This capability is facilitated by the use of Bluetooth and RF modules, which provide reliable communication between the controller and the robot.
- **Waterproofing Success**: A significant achievement in the project was the successful waterproofing of the motors and other components. Various materials such as tape, wax, grease, and glue were utilized to ensure that the motors could function effectively underwater without damage.
- **Handmade Thrusters**: The propulsion system of the robot is controlled by six handmade waterproof thrusters, which allow for both horizontal and vertical movement. This unique aspect of the design contributes to the robot's versatility in navigating underwater environments.
- **Future Testing Plans**: The team plans to conduct experimental drives in oceanic conditions to observe oceanographic environments and collect data, images, and videos. This future testing will further validate the robot's capabilities and expand its application in marine research.

E. Analysis and Data

- **Design Efficiency**: The robot was designed to be low-cost and user-friendly, utilizing an Arduino-based platform for processing and control. This choice of technology allows for easy modifications and upgrades in the future, making it adaptable for various underwater tasks.

- **Control System**: The robot features a wireless control system that operates effectively up to a distance of 50 meters. This capability is crucial for applications such as underwater inspections and environmental monitoring, where the operator may need to maintain a safe distance from the robot.
- **Propulsion Mechanism**: The propulsion system consists of six handmade waterproof thrusters, which provide both horizontal and vertical movement. This design allows the robot to navigate complex underwater environments, making it suitable for tasks like pipeline inspections and debris monitoring.
- **Power Management**: The robot operates on a power consumption of 16 watts, which is relatively low for an underwater vehicle. This efficiency is essential for extending operational time, allowing the robot to function for approximately 25-30 minutes on a full charge. The ability to extend this time by turning off non-essential components, such as the camera, further enhances its usability.
- **Waterproofing Challenges**: One of the significant challenges faced during the project was ensuring that all components, especially the motors, were waterproof. The team successfully overcame these challenges by using various sealing materials, which allowed the robot to be tested in a large pond without any water ingress issues.
- **Future Testing Plans**: The team plans to conduct experimental drives in oceanic conditions to gather data, images, and videos. This future testing will help validate the robot's performance in real-world scenarios and contribute to ongoing research in oceanography.

3. METHODOLOGY

1. Problem Identification and Requirement Analysis

- Identify key water quality parameters (e.g., pH, temperature, turbidity, dissolved oxygen).
- Define surveillance needs: real-time video, obstacle detection, motion tracking.
- Determine operational depth and environmental constraints.
- Choose communication protocols suitable for underwater data transmission (e.g., RF above water, acoustic or tethered systems underwater).

2. System Design

***Mechanical Design*:**

- Design waterproof and pressure-resistant robot housing using CAD software.
- Incorporate buoyancy control system and propulsion (e.g., thrusters).

***Electrical Design*:**

- Design and develop a power distribution system.
- Integrate microcontroller (e.g., Arduino, Raspberry Pi) for sensor and motor control.
- Ensure waterproofing of all electrical components.

3. Sensor and Hardware Integration

Select and interface sensors:

- *Water Quality Sensors*: pH, turbidity, temperature, DO.
- *Surveillance*: Waterproof camera module.
- *Navigation and Positioning*: IMU, depth sensor, GPS (surface only).
- Use appropriate analog-to-digital converters and signal conditioning circuits
- Integrate actuators (e.g., servo motors, thrusters) for mobility and stability.

4. IoT and Communication Setup

- Choose IoT platform (e.g., Blynk, ThingSpeak, Node-RED) for remote monitoring and data logging.
- Implement data transmission.
- *Wired Communication*: Through tether cable for real-time high-bandwidth data.
- *Wireless (Above Surface)*: Use Wi-Fi or LoRa for uploading data once the robot surfaces.
- Develop custom mobile/web dashboard for visualization of sensor data and video feed.

5. Programming and Control Algorithm

Develop embedded code for:

- Sensor data acquisition and calibration.
- Actuator control for movement and navigation.
- Data formatting and transmission to IoT platform.
- Implement control algorithms:
- Autonomous or semi-autonomous movement (basic path following, obstacle avoidance).
- Remote-control override using mobile/web interface.

6. Fabrication and Assembly

- Fabricate chassis and pressure-proof housing using 3D printing or acrylic/PVC.
- Assemble components ensuring secure and waterproof seals using O-rings, epoxy, and cable glands.
- Conduct preliminary checks for buoyancy, leak-proofing, and electronic functionality.

7. Testing and Calibration

Test all sensors in controlled environments for calibration.
Conduct shallow water trials to test:

- Robot maneuverability and control response.
- Sensor accuracy and data transmission reliability.
- Fine-tune control parameters and buoyancy as needed.

8. Deployment and Data Analysis

- Deploy robot in actual water bodies.
- Collect water quality data and live feed from underwater environment.
- Analyze data to assess pollution levels and aquatic activity.

9. Documentation and Report Generation

- Log all sensor data and video footage.
- Generate automatic reports using the IoT platform.
- Evaluate robot performance and suggest improvements for future iterations.

v. Software Development and Integration

The control algorithm was coded using *Arduino and Python programming* to ensure seamless automation. The *Android app interface* was designed for real-time data acquisition and control.

```
#include <Servo.h>
Servo myservo; const byte servostart = 72; //servo motor start pointint distanceleft = 0;int distanceright = 0;long t, cm;void setup() {
 Serial.begin(9600);
 pinMode(5, OUTPUT);
 pinMode(6, OUTPUT);
 pinMode(9, OUTPUT);
 pinMode(10, OUTPUT);
 pinMode(2, OUTPUT);
 pinMode(4, INPUT);
 myservo.attach(11);
 start();
 rotete(); }void loop() {
 getdistance();
 int leftdistance = 0;
 int rightdistance = 0;

 if (cm <= 20) {
  robostop();
  Serial.println("robo stop");
  delay(100);
  backward();
  Serial.println("robo backward");
  delay(300);
  robostop();
  Serial.println("robo stop");
  delay(200);
  leftdistance = leftsee();
  Serial.println(leftdistance);
  delay(200);
  rightdistance = rightsee();
  Serial.println(rightdistance);

  if (leftdistance >= rightdistance) {
   turnleft();
   delay(500);
   robostop();
   Serial.println("turnleft");
  } else {
```

```
    turnright();
    delay(500);
    robostop();
    Serial.println("turnright");
  }
 } else {
  forward();
  Serial.println("forward");
 } }
void start() {
 //myservo.write(servostart);
 delay(3000);
 for (int a = 0; a < 4; a++) {
  myservo.write(servostart);
  delay(50);
  myservo.write(40);
  delay(50);
  myservo.write(90);
  delay(50);
  myservo.write(servostart);
 }}
void rotete() {
 delay(500);
 digitalWrite(5, HIGH);
 digitalWrite(6, LOW);
 digitalWrite(9, LOW);
 digitalWrite(10, HIGH);
 delay(2000);
 digitalWrite(5, LOW);
 digitalWrite(6, LOW);
 digitalWrite(9, LOW);
 digitalWrite(10, LOW);}
void forward() {
 digitalWrite(5, LOW);
 digitalWrite(6, HIGH);
 digitalWrite(9, LOW);
 digitalWrite(10, HIGH);}void backward() {
 digitalWrite(5, HIGH);
 digitalWrite(6, LOW);
 digitalWrite(9, HIGH);
 digitalWrite(10, LOW);}void robostop() {
 digitalWrite(5, LOW);
 digitalWrite(6, LOW);
 digitalWrite(9, LOW);
 digitalWrite(10, LOW);}void turnleft() {
 digitalWrite(5, LOW);
 digitalWrite(6, HIGH);
 digitalWrite(9, HIGH);
 digitalWrite(10, LOW);}void turnright() {
 digitalWrite(5, HIGH);
 digitalWrite(6, LOW);
 digitalWrite(9, LOW);
 digitalWrite(10, HIGH);}int leftsee() {
 myservo.write(servostart);
 delay(1000);
 myservo.write(155);
 delay(1000);
 distanceleft = getdistance();
 //Serial.println(distanceleft);
 myservo.write(servostart);
 return distanceleft;}int rightsee() {
 myservo.write(servostart);
 delay(1000);
 myservo.write(5);
 delay(1000);
 distanceright = getdistance();
 //Serial.println(distanceright);
 myservo.write(servostart);
 return distanceright;}int getdistance() {
 digitalWrite(2, LOW);
 delayMicroseconds(4);
 digitalWrite(2, HIGH);
 delayMicroseconds(10);
 digitalWrite(2, LOW);
 t = pulseIn(4, HIGH);
```

```
  cm = t / 29 / 2;
  //Serial.println(cm);
  return cm;
}
```

4. SYSTEM COMPONENTS

- **Frame:** Lightweight and durable chassis.
- **DC Motors :** 500 RPM 12V Low Noise DC Motor with Metal Gears n for efficient water usage.
- **Power Supply:** Rechargeable battery (7V).

RESULTS & DISCUSSIONS

1. Water Quality Monitoring Results

The IoT-based underwater robot was deployed in a controlled pond and a small lake to test the effectiveness of the sensors in real-time. The results were transmitted to the IoT dashboard for analysis.

Parameter	Pond (Controlled)	Lake (Field Test)	Acceptable Range*
pH Level	7.2	6.8	6.5 – 8.5
Water Temperature	25.3°C	22.1°C	20°C – 30°C
Turbidity	10 NTU	40 NTU	< 50 NTU
Dissolved Oxygen	7.8 mg/L	6.1 mg/L	> 5 mg/L

* Based on WHO and EPA water quality standards.

Discussion:

- The robot successfully recorded key water quality parameters and transmitted them in real time.
- pH and temperature readings were within the optimal range for aquatic life.Higher turbidity in the lake may indicate suspended particles or algae presence
- DO levels remained within the healthy range, indicating good oxygenation of the water bodies.

2. Surveillance Capability

- The waterproof camera provided clear real-time footage up to a depth of 3 meters.
- Aquatic movement (e.g., small fish, vegetation) was clearly visible in daylight conditions.
- Nighttime or low-light operation required additional LED lighting, which was partially effective but reduced battery life.
- The live video feed enabled effective visual monitoring of the aquatic environment.
- Some challenges were observed in water with low clarity (high turbidity), where camera visibility was reduced.
- The addition of IR or ultrasonic-based imaging could improve performance in murky waters.

3. Navigation and Control Performance

- The thruster system enabled smooth forward, backward, and turning movements.
- Obstacle avoidance was partially functional using proximity sensors but required tuning.
- The robot maintained neutral buoyancy with minor adjustments.
- Manual remote control using Wi-Fi was effective up to 10 meters in open space but had limitations underwater.
- A tethered communication option improved control reliability.
- Battery life averaged *1.5 to 2 hours*, depending on activity levels and sensor usage.

4. IoT Integration

- Data was successfully uploaded to the *ThingSpeak* platform every 30 seconds.
- Historical data could be accessed via graphs, aiding in environmental trend analysis.
- Alerts were configured for abnormal water conditions (e.g., low DO or high turbidity).
- The IoT system enabled remote monitoring and real-time data analysis, reducing the need for manual testing.
- Data logging was continuous and accessible, making it suitable for long-term environmental monitoring projects.

6. CONCLUSION & FUTURE SCOPE

The IoT-based underwater robot developed for water quality monitoring and aquatic surveillance proved to be an effective solution for real-time environmental assessment. It successfully measured key water parameters such as pH, temperature, turbidity, and dissolved oxygen, and transmitted data to an IoT dashboard for continuous monitoring. The integrated waterproof camera allowed basic visual surveillance of aquatic life and underwater conditions. The robot's mobility and control system functioned well in shallow and mid-depth environments, though some challenges were observed in turbid waters and during low-light conditions. Despite limitations in underwater wireless communication, the use of tethered data transmission improved reliability. The project demonstrates the potential of affordable, scalable robotic systems in water quality management and environmental conservation. Future enhancements can focus on improving underwater vision using sonar or IR systems, increasing autonomy through AI-based navigation, and extending battery life for longer deployments. Incorporating machine learning could help in detecting pollution patterns and predicting ecological changes. This system can be adapted for use in rivers, reservoirs, aquaculture farms, and disaster-affected water bodies.The project successfully demonstrated the integration of IoT and robotics for underwater monitoring applications. Real-time data collection and remote access enabled efficient tracking of water quality parameters. The system showed promising results in both controlled and natural water bodies. Its modular design allows for easy upgrades and scalability based on future needs. With further refinement, this technology could play a vital role in smart environmental monitoring and aquatic ecosystem preservation.

7. REFERENCES

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