
IoT-Based Underwater Robotic System for Object Detection and Navigation

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Abstract.

This paper presents the design and testing of a low-cost underwater robot used for monitoring applications. The system is built using an ESP32-CAM module, which allows real-time video streaming and wireless control through a mobile application. A camera captures underwater visuals, and the frames are implemented using basic techniques like grayscale, conversion, edge detection and contour detection to identify objects such as pipes and debris. Along with this, proximity and depth sensors are used to improve navigation and detect obstacles. The robot moves using thrusters controlled through a motor driver circuit. The setup was tested in a small water tank under different conditions. During testing, it showed stable movement and was able to detect objects with reasonable accuracy. From the testing, it can be seen that the system is suitable for small-scale underwater tasks. The underwater robot is designed with focus on simplicity, cost-effectiveness, and ease of operation, the designed robot can be extended for practical real-world applications.

Keywords. Underwater Robotics, IoT, Object Detection, Autonomous Navigation, Underwater Communication, Computer Vision, Robotic Systems

1. INTRODUCTION

The underwater environment faces many challenges like poor visibility and safety risks. Because of this robots are often used instead of humans for inspection tasks. These robots are commonly used in areas like pipelines, tanks, and underwater structures. Most low-cost systems available today depend on manual control, which makes them harder to operate continuously. Also many of these systems do not include real-time object detection features. This limits their usefulness in practical situations. To minimise these problems our work focuses on developing a simple underwater robotics system that can assist the user by providing basic object detection and easier control.

2. LITERATURE SURVEY

Recent studies have explored underwater robotic systems for inspection and monitoring tasks. Advanced systems provide high accuracy but require expensive hardware and complex algorithms[1],[3]. Low-cost systems focus on simplicity but often lack real-time detection capability[4]. Image-processing techniques such as edge detection and contour analysis have been used for object detection in underwater environments[2],[6]. Embedded systems like Raspberry Pi and microcontrollers have also been used for cost-effective solutions[4],[7]. This research indicates that most systems either focus on high-cost solutions or lack real-time detection capability in low-cost environments. Due to this, we need a simple and affordable robot that detects objects.

3. KEY CONTRIBUTION

The main contributions of this work are as follows:

- Development of a low-cost underwater robotic system using ESP32-CAM
- Integration of image processing and sensor-based navigation for object detection
- Design of a simple and efficient system suitable for small-scale underwater inspection tasks
- Implementation of a real-time monitoring system with mobile-based control

4. EXISTING SYSTEM LIMITATION

Existing underwater robotic systems are mostly dependent on manual operation. This increases operator workload and reduces efficiency. Many systems do not support real-time object detection, making it difficult to identify underwater objects automatically. Communication delay and signal loss are also common issues. Additionally, limited sensor integration reduces the system's ability to adapt to environmental changes.

5. METHODOLOGY



Fig 5.1. Methodology flowchart

The workflow of the system is shown in Fig. 1. The working of the robot is divided into simple steps. The architecture begins by capturing underwater video, which is converted to grayscale and processed using edge and contour detection. After that, edge detection is applied to highlight object boundaries. To identify objects, contour detection is used. At the same time, proximity sensors keep checking for nearby obstacles. If something is detected within a certain distance, the robot either stops or changes its direction. All these operations

are handled by the ESP32-CAM module, which also manages communication with the mobile application.

6. SYSTEM DESIGN

The design of the underwater robot integrates multiple components to improve performance

1. Camera for real-time monitoring
2. Thrusters for movement
3. Sensors for environmental data
4. Mobile interface for control. This combination improves usability and allows better control compared to traditional systems.

7. OBJECT DETECTION:

A lightweight image-processing approach is used to reduce computational requirements on embedded hardware. Captured video frames are converted into grayscale and processed using edge detection techniques. Contour detection is used to identify object boundaries. This method is suitable for embedded systems and provides faster execution with lower consumption [4], [6]. While less accurate than deep learning methods, it provides sufficient performance for basic detection tasks.

7.1. Navigation

The framework of our system includes semi-autonomous navigation using proximity sensors. When an obstacle is detected, the robot automatically changes direction or alerts the operator. This feature improves safety and reduces manual effort during operation.

8. System Architecture

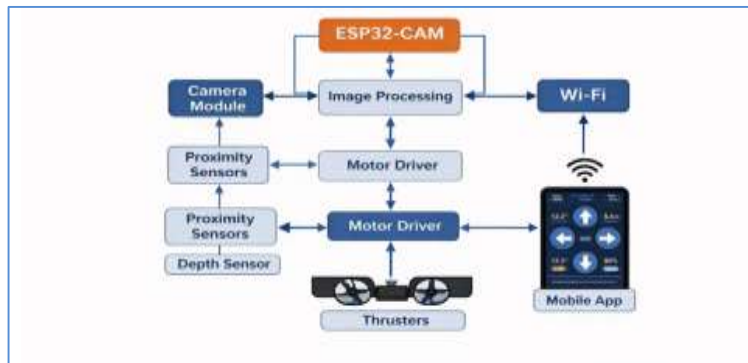


Fig 8.1. System architecture

The system architecture is shown in Fig. 2. The architecture of system of:

- ESP32-CAM microcontroller
- Camera module
- Motor drivers and thrusters
- Sensors

- Mobile control system

All these components help to detect underwater objects.

9. EXPERIMENTAL RESULTS

The experiment was conducted in a controlled water tank environment where different objects such as pipes and solid obstacles were placed to simulate real conditions. The system was tested multiple times under similar conditions to ensure consistency. Detection was considered successful when object boundaries were clearly identified in the processed output. The performance was evaluated based on detection success rate and response time.

Table 1. Experimental results

Parameter	Value
Test Environment	Water tank
Number of Trials	20
Successful Detection	16
Accuracy	80%
Response Time	1.5 sec

10. CONCLUSION

In this work, a low-cost underwater robotic system was developed and tested for basic inspection tasks. The system combines image processing and sensor-based navigation to reduce manual effort and improve usability. During testing in a controlled water tank, the robot showed stable movement and was able to detect objects in most cases. It was also observed that detection accuracy decreases when water clarity is low. The current design is simple and suitable for small-scale applications where cost and ease of use are important. Although the system is basic, it provides a strong foundation for further development. Future improvements can include better detection techniques, improved sensors, and more reliable communication systems.

11. REFERENCES

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