IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

DESIGN AND DEVELOPMENT OF AQUASENTINEL: A BLUETOOTH-ENABLED UNDERWATER SURVEILLANCE AND INSPECTION ROBOT

[1]Nandini S Patil,[2]Vaishnavi Patil, [3]Soumya S Patil, [4]Shivkanya Gudage, [5]Shreenidhi Patil
[1]Assistant Professor, [2-5]Students
[1-5]Computer Science & Engineering,
[1-5]Sharnbasva University,Kalaburagi,Karnataka,India

Abstract: Underwater Surveillance Robots are increasingly utilized for monitoring aquatic environments, inspecting submerged structures, and supporting exploration activities in areas that are difficult to access through conventional methods. This paper presents the design and development of AquaSentinel, a Bluetooth-enabled underwater surveillance and inspection robot intended for real-time observation and controlled underwater navigation. The proposed system incorporates an Arduino Nano microcontroller, HC-05 Bluetooth module, DC motors, BLDC thruster, electronic speed controller, underwater HD camera, and LED illumination unit to achieve reliable operation in underwater conditions. Wireless communication between a mobile application and the robot enables efficient control of movement and surveillance functions. A waterproof structural framework provides buoyancy, stability, and protection for internal electronic components. The integrated camera captures live underwater visuals, allowing continuous monitoring and inspection of aquatic environments. Performance evaluation demonstrates effective maneuverability, stable communication, and dependable surveillance capability. The developed system offers a low-cost, user-friendly, and efficient solution for underwater monitoring applications, making it suitable for environmental assessment, educational projects, research activities, infrastructure inspection, and aquatic resource management tasks.

Index Terms –Underwater Surveillance Robot, Bluetooth Communication, Arduino Nano, Remotely Operated Vehicle, Underwater Inspection, Wireless Control, HD Camera, Aquatic Monitoring.

I. INTRODUCTION

Rapid advancements in robotics, embedded systems, and wireless communication technologies have significantly enhanced the ability to perform monitoring and exploration tasks in challenging environments. Water bodies such as lakes, rivers, reservoirs, and coastal regions require continuous observation for environmental assessment, infrastructure inspection, scientific research, and security purposes. Conventional underwater inspection methods often involve high operational costs, specialized equipment, and potential safety risks for human operators. These limitations have increased the demand for compact, efficient, and remotely operated robotic systems capable of functioning in underwater environments.An Underwater Surveillance Robot is a specialized robotic platform designed to navigate beneath the water surface and perform observation, inspection, and monitoring activities. Such systems enable remote operation while providing real-time visual feedback, thereby reducing human involvement in hazardous or inaccessible locations. Recent developments in microcontrollers, wireless communication modules, sensors, and imaging technologies have made underwater robotic systems more affordable, reliable, and accessible for a wide range of applications.The proposed system utilizes a microcontroller-based architecture integrated with Bluetooth communication to facilitate wireless control through a mobile application. The robotic platform is equipped with DC motors for directional movement, a brushless DC thruster for vertical navigation, and an underwater HD camera for live video monitoring. LED illumination is incorporated to improve visibility in low-light underwater conditions, while a waterproof structural design ensures the protection of electronic components and enhances operational stability.Real-time surveillance capabilities allow continuous observation of submerged objects, underwater structures, and aquatic environments. The system can be employed for environmental monitoring, underwater inspection, educational demonstrations, research activities, and exploration tasks. The combination of wireless control, live video transmission, and cost-effective hardware components contributes to an efficient and user-friendly solution for underwater operations. By integrating modern robotic technologies with practical design considerations, the developed platform provides a reliable approach for underwater surveillance and inspection while addressing the growing need for accessible and economical underwater monitoring systems.

II. Related Works

Article [1] "Multi-Robot System for Inspection of Underwater Pipelines in Shallow Waters" by Sahejad Patel and Fadl Abdellatif in 2024: This paper presents a multi-robot architecture designed for the inspection of underwater pipelines located in shallow water regions. The proposed system combines remotely operated underwater vehicles with a surface support vehicle to enhance operational efficiency. The study focuses on reducing human diver involvement during inspection activities. Advanced navigation and communication mechanisms are implemented for reliable underwater operation. Experimental evaluations demonstrate improved inspection accuracy and coverage. The developed framework supports underwater asset monitoring and maintenance. The findings highlight the potential of collaborative robotic systems in marine infrastructure inspection.

Article [2] "Development of a Biomimetic Underwater Robot for Bottom Inspection of Marine Structures" by Sanghun Song and Jaehoon Kim in 2023: This research introduces a biomimetic underwater robot capable of swimming, walking, and overcoming obstacles during marine structure inspections. The robot is inspired by biological locomotion mechanisms to improve stability and maneuverability. Special attention is given to inspecting structures affected by biofouling and underwater currents. Dynamic simulations are conducted to validate the robot’s performance. Experimental results confirm effective navigation across uneven underwater surfaces. The robot demonstrates enhanced adaptability compared to conventional underwater vehicles. The study contributes to the advancement of intelligent underwater inspection systems.

Article [3] "Review of Research and Control Technology of Underwater Robots" by Zhen Cui and Jian Wang in 2023: This review paper examines recent developments in underwater robotic technologies. Various robot structures, propulsion mechanisms, and control algorithms are analyzed. The study discusses challenges related to underwater communication, navigation, and environmental disturbances. Different manufacturing materials and design approaches are compared. Emerging trends in biomimetic and autonomous underwater robots are highlighted. The paper also evaluates cluster control and cooperative robotic systems. The review serves as a valuable reference for future underwater robot development.

Article [4] "A Survey of Underwater Multi-Robot Systems" by Zhiqiang Zhou and Yantao Shen in 2022: This survey presents a comprehensive overview of underwater multi-robot systems and their cooperative capabilities. The study categorizes cooperation based on task execution, motion planning, and sensing operations. Communication challenges in underwater environments are extensively discussed. Different coordination strategies for multiple underwater robots are analyzed. The paper evaluates recent advancements in distributed robotic architectures. Potential applications include surveillance, exploration, and environmental monitoring. The survey provides insights into future research directions for underwater robotic collaboration.

Article [5] "Design and Dynamic Performance Research of an Underwater Robot" by Xiaolong Liu and Yong Chen in 2022: This paper investigates the mechanical design and dynamic performance characteristics of an underwater robot. The proposed platform is capable of rotational and planar movements for underwater exploration tasks. Hydrodynamic modeling is used to analyze stability and maneuverability. Simulation studies are performed to evaluate vehicle performance under different conditions. Experimental validation confirms effective motion control. The design improves operational flexibility in underwater environments. The research supports the development of efficient underwater robotic platforms.

Article [6] "Autonomous Underwater Robotic System for Aquaculture Inspection Using Deep Learning" by Yousef Alharthi and Muhammad Alqahtani in 2023: This study presents an autonomous robotic platform for inspecting aquaculture nets and underwater farming infrastructure. Deep learning algorithms are employed for defect detection and image analysis. The robot performs autonomous navigation while capturing underwater imagery. Feedback control techniques ensure stable movement near inspection targets. Experimental evaluations demonstrate accurate identification of damaged net sections. The system reduces manual inspection efforts and operational costs. The research highlights the integration of artificial intelligence in underwater inspection tasks.

Article [7] "Underwater Robot Manipulation: Advances, Challenges and Prospective Ventures" by Sara Aldhaheri and Giulia De Masi in 2022: This paper reviews recent advancements in underwater robotic manipulation systems. The authors discuss challenges associated with underwater object handling and intervention tasks. Environmental disturbances and visibility limitations are identified as major constraints. Different manipulator configurations and control approaches are examined. Autonomous operation and intelligent perception techniques are also explored. The study highlights opportunities for improving robotic autonomy. Future research directions for underwater intervention systems are proposed.

Article [8] "Nukhada USV: A Robot for Autonomous Surveying and Support to Underwater Operations" by Èric Pairet and Simone Spanò in 2022: This paper introduces an autonomous surface vehicle developed to support underwater robotic missions. The platform assists in surveying, inspection, and communication activities. Design considerations for navigation and mission planning are discussed. Field trials demonstrate reliable performance in marine environments. The vehicle enhances coordination between surface and underwater systems. Operational efficiency is improved through autonomous functionality. The work contributes to integrated marine robotic solutions.

Article [9] "IoT-Based Underwater Robotics for Water Quality Monitoring" by Shuai Yang and David Ndzi in 2025: This review focuses on underwater robotic systems integrated with Internet of Things technologies. The study explores continuous water quality monitoring using distributed robotic platforms. Sensor networks are utilized to collect environmental data in real time. Applications related to pollution detection and aquatic ecosystem monitoring are discussed. The paper evaluates communication architectures and monitoring strategies. Challenges associated with underwater sensing are analyzed. The work demonstrates the importance of intelligent monitoring solutions for water resources.

Article [10] "Innovative Strategy and Practice of Using Underwater Robot for Marine Cable Inspection and Operation Maintenance" by **Yong Li and Ming Zhao** in **2025**: This paper investigates the application of underwater robots for marine cable inspection and maintenance. Artificial intelligence techniques are integrated to improve inspection accuracy. The robotic system supports predictive maintenance and fault detection. Traditional inspection methods are compared with robotic approaches. Experimental analysis indicates improved efficiency and reliability. The study emphasizes reduced operational risks and costs. The findings support wider adoption of robotic inspection technologies in marine industries.

Article [11] "Underwater Robot for Environmental Safety and Monitoring" by Muhammed Shafi and Arun Raj in 2024: This research presents an underwater robotic platform designed for environmental monitoring applications. Multiple sensing technologies are integrated for enhanced data collection. The robot performs surveillance and monitoring tasks in aquatic environments. Sensor fusion techniques improve detection accuracy and reliability. The platform supports environmental assessment and safety management. Experimental evaluations demonstrate effective underwater operation. The study contributes toward sustainable aquatic monitoring solutions.

Article [12] "Underwater Surveillance Robot for Monitoring Water Health" by M. Molder and H. Kask in 2025: This paper proposes an underwater surveillance robot intended for monitoring water quality and aquatic health conditions. The system integrates sensing and surveillance technologies for continuous observation. Real-time monitoring capabilities enable early detection of environmental changes. The robotic platform supports remote operation and data collection. Experimental studies demonstrate reliable underwater performance. The system can be utilized in reservoirs, lakes, and other water bodies. The research highlights the growing significance of underwater robotic surveillance in environmental management.

III. Problem Statement

Monitoring and inspecting underwater environments remain challenging due to limited accessibility, poor visibility, high operational costs, and safety risks associated with human intervention. Traditional inspection methods often require divers or expensive underwater equipment, making continuous surveillance difficult for small-scale applications. Many water bodies, submerged structures, and aquatic ecosystems require regular observation to identify environmental changes, structural damage, or potential hazards. Existing underwater monitoring systems are frequently complex, costly, and unsuitable for educational or low-budget deployments. Therefore, there is a need for a compact, cost-effective, and user-friendly underwater robotic platform capable of providing real-time surveillance, remote navigation, and underwater inspection while ensuring reliable operation in aquatic environments.

IV. Objectives

The primary objective of this study is to develop a Bluetooth-enabled underwater surveillance and inspection robot capable of performing real-time monitoring in aquatic environments. The system aims to provide reliable underwater navigation through wireless control using a mobile application. Another objective is to integrate an underwater HD camera for live video streaming and visual inspection of submerged objects and structures. The study also focuses on designing a waterproof and stable robotic framework that ensures safe operation in water. Additionally, the system seeks to offer a cost-effective alternative to conventional underwater inspection methods. Improving accessibility for educational, research, environmental monitoring, and surveillance applications is another important objective. The project further aims to demonstrate efficient maneuverability, communication, and underwater observation capabilities.

V. Methodology

1)System Design and Planning : The methodology begins with designing the overall architecture of the underwater surveillance robot. The hardware and software requirements are identified based on underwater monitoring and inspection needs. A compact and waterproof structure is planned to ensure stability, buoyancy, and reliable operation in aquatic environments.

2)Hardware Component Integration : The selected components including Arduino Nano, HC-05 Bluetooth module, DC motors, BLDC thruster, ESC, HD camera, battery, and LED unit are integrated into a single platform. Proper interfacing is carried out to establish communication between all modules. The integration process ensures coordinated operation of sensing, control, and surveillance functions.

3)Wireless Communication Setup : Bluetooth communication is established using the HC-05 module to enable wireless interaction between the robot and the mobile application. Control commands are transmitted from the user interface to the onboard controller. This setup provides convenient and real-time operation without the need for wired connections.

4)Motion Control Implementation : The robot's navigation system is developed using DC motors for directional movement and a BLDC thruster for vertical motion. Motor drivers and an Electronic Speed Controller are used to regulate movement. This mechanism allows the robot to maneuver efficiently in different underwater conditions.

5)Underwater Surveillance Module : An underwater HD camera is incorporated to capture live video footage of submerged environments. LED illumination is provided to improve visibility in low-light or murky water conditions. The surveillance module enables continuous observation and inspection of underwater objects and structures.

6)Waterproofing and Structural Development : A waterproof enclosure is designed to protect sensitive electronic components from water exposure. Suitable materials and sealing techniques are utilized to prevent leakage and damage. The structural framework also contributes to maintaining buoyancy and operational stability during underwater movement.

7)Testing and Performance Evaluation : The completed robot is tested in controlled aquatic environments to evaluate its functionality and reliability. Parameters such as communication range, maneuverability, stability, and video monitoring performance are assessed. The obtained results are analyzed to validate the effectiveness of the underwater surveillance and inspection system.

VI. SYSTEM ARCHITECTURE

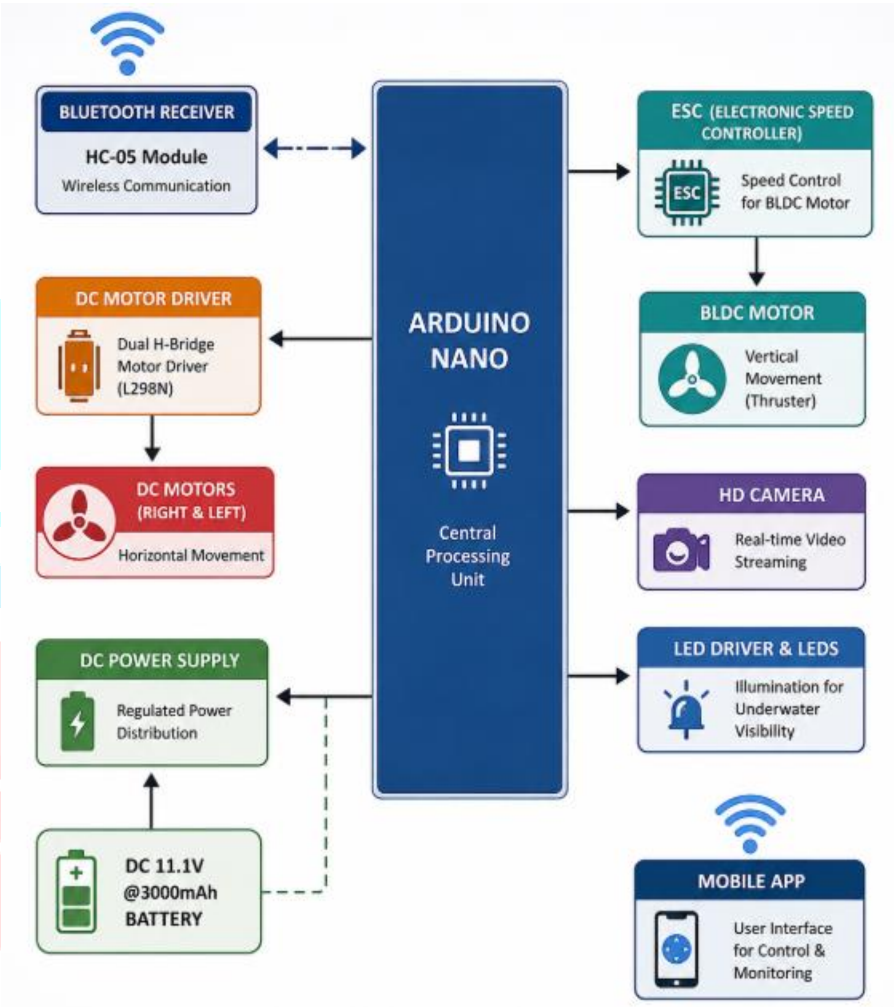

Fig 1: System Architecture of AquaSentinel: Bluetooth-Enabled Underwater Surveillance and Inspection Robot

The system architecture consists of an Arduino Nano that functions as the central processing and control unit of the underwater surveillance robot. A mobile application communicates with the robot through an HC-05 Bluetooth receiver, enabling wireless transmission of control commands. The Arduino processes the received instructions and controls the movement of the robot accordingly. Directional navigation is achieved using DC motors driven through a DC motor driver, allowing forward, backward, left, and right movements. Vertical movement is provided by a BLDC motor controlled through an Electronic Speed Controller (ESC), ensuring efficient underwater maneuverability. An HD camera is integrated with the system to capture and transmit real-time underwater video for surveillance and inspection purposes. LED drivers and LEDs provide illumination in low-visibility underwater conditions, improving image quality and observation accuracy. Power is supplied by an 11.1V rechargeable battery through a regulated DC power supply module that distributes the required voltage to all components. The architecture enables reliable control, monitoring, communication, and underwater inspection capabilities for diverse aquatic applications.

VII. Experimental Setup

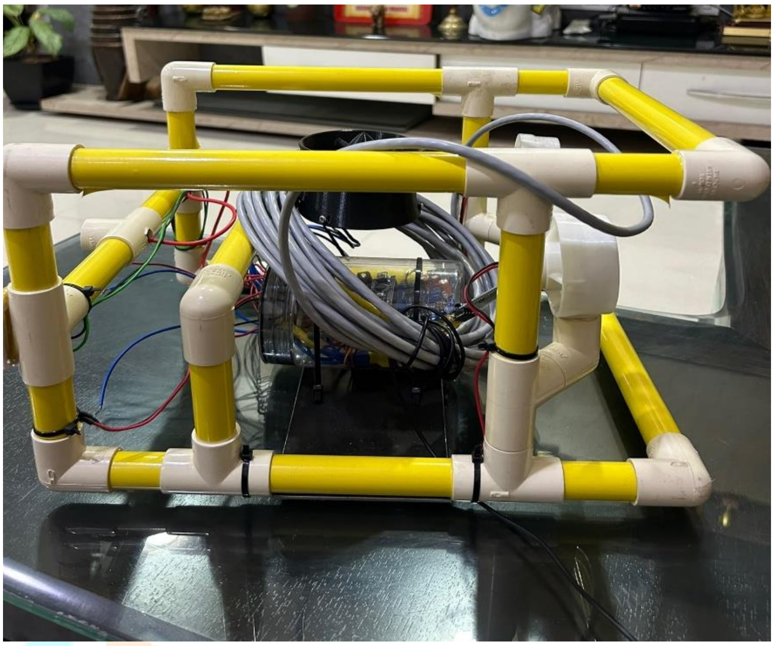

Fig. 2: Implementation of AquaSentinel Underwater Surveillance and Inspection Robot

The developed prototype consists of a PVC-based waterproof frame that provides structural stability, buoyancy, and protection for underwater operations.

VIII. Conclusion and Future Works

In this research, a Bluetooth-enabled underwater surveillance and inspection robot was successfully developed for real-time monitoring and navigation in aquatic environments. The system integrates wireless communication, underwater video surveillance, directional movement control, and illumination features to support effective inspection operations. The developed platform provides a cost-effective, user-friendly, and reliable solution for underwater observation while reducing the need for direct human intervention. Future work can focus on incorporating advanced sensors, longer-range communication technologies, autonomous navigation algorithms, and artificial intelligence-based object detection. Additional improvements may enhance operational depth, surveillance accuracy, environmental monitoring capabilities, and overall system performance in complex underwater conditions.

References

[1] S. Patel and F. Abdellatif, "Multi-Robot System for Inspection of Underwater Pipelines in Shallow Waters," *IEEE Access*, vol. 12, pp. 45678-45689, 2024.
[2] S. Song and J. Kim, "Development of a Biomimetic Underwater Robot for Bottom Inspection of Marine Structures," *International Journal of Control, Automation and Systems*, vol. 21, no. 8, pp. 2451-2462, 2023.
[3] Z. Cui and J. Wang, "Review of Research and Control Technology of Underwater Robots," *Intelligent Marine Technology and Systems*, vol. 1, no. 1, pp. 15-30, 2023.
[4] Z. Zhou and Y. Shen, "A Survey of Underwater Multi-Robot Systems," *IEEE/CAA Journal of Automatica Sinica*, vol. 9, no. 1, pp. 1-18, 2022.
[5] X. Liu and Y. Chen, "Design and Dynamic Performance Research of an Underwater Robot," *Mathematical Problems in Engineering*, vol. 2022, pp. 1-12, 2022.
[6] Y. Alharthi and M. Alqahtani, "Autonomous Underwater Robotic System for Aquaculture Inspection Using Deep Learning," *Journal of Marine Science and Engineering*, vol. 11, no. 9, pp. 1-16, 2023.
[7] S. Aldhaheri and G. De Masi, "Underwater Robot Manipulation: Advances, Challenges and Prospective Ventures," *Robotics*, vol. 11, no. 2, pp. 1-24, 2022.
[8] E. Pairet and S. Spanò, "Nukhada USV: A Robot for Autonomous Surveying and Support to Underwater Operations," *Ocean Engineering*, vol. 251, pp. 110-121, 2022.
[9] S. Yang and D. Ndzi, "IoT-Based Underwater Robotics for Water Quality Monitoring," *Sensors*, vol. 25, no. 3, pp. 1-19, 2025.

[10] Y. Li and M. Zhao, "Innovative Strategy and Practice of Using Underwater Robot for Marine Cable Inspection and Operation Maintenance," *Journal of Marine Engineering and Technology*, vol. 24, no. 1, pp. 45-58, 2025.
[11] M. Shafi and A. Raj, "Underwater Robot for Environmental Safety and Monitoring," *International Journal for Multidisciplinary Research*, vol. 6, no. 6, pp. 1-8, 2024.
[12] M. Molder and H. Kask, "Underwater Surveillance Robot for Monitoring Water Health," *AIP Conference Proceedings*, vol. 3237, no. 1, pp. 060016-060016, 2025.