



BioBlitz Bot: A Comparative Analysis of Cleaning Efficiency in Marine Environments

Gugan RK¹, Harshavardini J², Nivethaa P³, Nandini K. M.E.⁴,

^{1,2,3} Students, and ⁴ Faculty
Dept. of Robotics and Automation,
Easwari Engineering College,
Chennai, India.
niveponraj7@gmail.com

Abstract: Ship hull maintenance is critical for prolonging vessel lifetime and ensuring operational efficiency. Traditional inspection and cleaning processes pose risks to human operators and are time-consuming. To address these challenges, robotic solutions have been introduced, yet many lack full autonomy, requiring human intervention. This paper presents a review of robotic systems for ship hull maintenance, focusing on mechanical design, control systems, autonomy, and inspection capabilities. Experimental trials demonstrate the efficacy of the presented robot in climbing and autonomously cleaning metal hull, reducing human effort in real-time. Additionally, the paper discusses the use of autonomous cleaning robots for removing biofouling from niche areas of ship hulls, with experimental results indicating significant biofouling removal and recovery rates. Furthermore, it explores research areas aimed at improving ship energy efficiency, including hull form, structure, cleaning and lubrication. The review also examines the current state and future trends of underwater hull cleaning technology, emphasizing its multidisciplinary nature and potential applications in environmental management. This comprehensive overview contributes to understanding the advancements in ship hull maintenance technology, identifying research gaps, and guiding future research towards sustainable solutions.

Keywords: ship hull maintenance, autonomous robots, biofouling removal, ship energy efficiency, underwater cleaning technology.

1. INTRODUCTION:

Biofouling, the accumulation of organisms on boat hulls and marine infrastructure, poses significant challenges for vessels of all types, from large tanker ships to personal watercraft. Not only does biofouling impact vessel performance and fuel efficiency, but it also has the potential to introduce invasive species to new environments. To combat biofouling, ships traditionally undergo drydocking for hull cleaning and maintenance, a costly and time-consuming process. Additionally, manual hull cleaning methods involving divers are not only expensive but also pose risks to human and versatility. The proposed architecture, safety and the marine environment. The emergence of autonomous or semi-autonomous hull cleaning robots presents a promising solution to these challenges. By utilizing robotics and sensing technology, these robots can efficiently and safely clean hulls underwater, reducing the spread of invasive species and improving fuel efficiency. We will delve into the structural design, cleaning methods, navigation systems, and environmental interaction of hull cleaning robots, highlighting their versatility and effectiveness in various ship and water environments. Through this review, we aim to provide insights and inspiration for the continued research, development, and practical implementation of hull cleaning robotics, ultimately enhancing maritime operations while mitigating environmental impact and human risks.



2. MECHANICAL STRUCTURE:

The semi-automatic underwater hull cleaning equipment is designed to be user-friendly, allowing staff to operate it easily according to their needs, regardless of location or time. Its functionality is facilitated by a climbing robot, specifically engineered for specialized inspection tasks, featuring a compact yet robust mechanical structure. With dimensions measuring 200 mm × 300 mm × 200 mm and a weight of 1 kg, this robot is optimized for efficient inspection and cleaning operations. Its key components include a neodymium magnet adhesion mechanism, locomotion mechanism, sturdy body frame, and a sophisticated inspection system tailored for metal thickness analysis. Of particular note is the chassis frame, meticulously crafted from 1 mm thick aluminium, which ensures both lightweight manoeuvrability and structural resilience. Four wheels maintain constant contact with the target area of the ship hull throughout the operation. To achieve this stability, neodymium magnets is strategically placed at the centre of the chassis to exhibit magnetic adhesion forces. This comprehensive design approach merges precision engineering with practical functionality, resulting in a versatile solution applicable to a variety of inspection scenarios.

3. ROBOTICS PLATFORM DESCRIPTION:

The Bioblitz Bot, is designed to revolutionize cleaning operations on metal surface. With a sophisticated architecture and advanced components, this robot offers unparalleled performance illustrated in Figure 1, outlines the components involved.

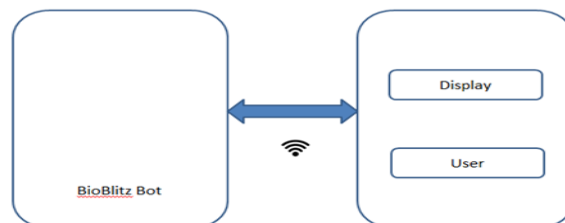


Figure 1 Overview of Proposed System

Here's a breakdown of the key components integrated into the system:

- 1)Controller: Powered by the ESP8266 microcontroller, this unit serves as the brain of the robot, orchestrating its overall operations and ensuring seamless functionality.
- 2)Motor Control: Utilizing the L298N motor driver, our robot features precise control over its movement, allowing for smooth and efficient navigation across surfaces.
- 3) Power Source: Equipped with a reliable 7.4V lithium-ion battery, supplemented by a 12V adapter for tethered power, our robot ensures extended operational time without compromising on performance or mobility.



4)Sensing Capability: Incorporating neodymium magnets and sensors, our robot can accurately detect and navigate metal surfaces, ensuring thorough and effective cleaning operations.

5)Vision System: Featuring an ESP32 cam, our robot captures high-quality live video feed, providing real-time visual feedback to users via the accompanying HMI app.

6)Communication Medium: Facilitating seamless interaction, our robot employs an FTDI programmer and Ethernet adapter for reliable data transmission and connectivity.

7)Auxiliary Components: Including a 6V pump, 5V relay module, 9V capacitor, and DC socket, our robot is equipped with additional functionalities for enhanced performance and versatility.

The Human-Machine Interface (HMI) App features a divided screen layout. The upper segment displays the live video feed captured by the robot's camera, offering real-time visual feedback. In contrast, the lower portion provides controls and status updates, allowing users to monitor the robot's movements and operational parameters.

The physical structure of the robot incorporates a 1mm thick aluminium sheet as its base, ensuring stability and durability on the metal surface. The Central Computing Unit is powered by a ESP8266, managing the overall operations of the robot. The sensor unit includes a camera and motors, enabling navigation and locomotion. Furthermore, the communication unit facilitates connectivity, utilizing an ethernet adapter for seamless data transmission.

4. CLEANING METHODOLOGY:

The evolution of underwater cleaning methods has seen a shift from manual operations to the adoption of mechatronic equipment, particularly for large vessels. Various tools and systems have been developed, including handheld cleaners, large vacuum equipment and high pressure water blasting. For efficient cleaning, large rotary brush devices equipped with single, double or multiple brushes powered by gear or hydraulic motors are utilized. These brushes can effectively clean flat or slightly curved areas of the hull, while smaller brushes are employed for more precise cleaning of propellers.

Unpowered cleaning brushes play a crucial role in removing deposits from ship surfaces. Nylon brushes are effective for removing mud and sea grass, while steel brushes are suitable for eliminating barnacles, heavy grass and zebra mussels. Selection of the appropriate cleaning brush depends on the hull construction material, with nylon or non-metallic brushes preferred for fiberglass, wood, aluminium, and steel vessels, and metallic brushes for aluminium or steel constructions.

Powered rotating brush devices are available in handheld configurations with single, double, or multiple brush heads. These devices generate an adsorption force as the brush units rotate, adhering them to the hull surface. Divers can adjust the cleaning direction and brush rotation speed according to the cleaning area. In addition to hydraulic brushes, electric powered devices are used for cleaning the ship hull .



5. CONTROL ARCHITECTURE:

The control architecture of the designed system operates within the Robot Operating System (ROS) framework. It facilitates communication with physical modules to gather sensor data and serves as an interface for motor drivers to execute locomotion commands. This architecture is structured as a set of state machines, illustrated in a flow chart (Figure 2)

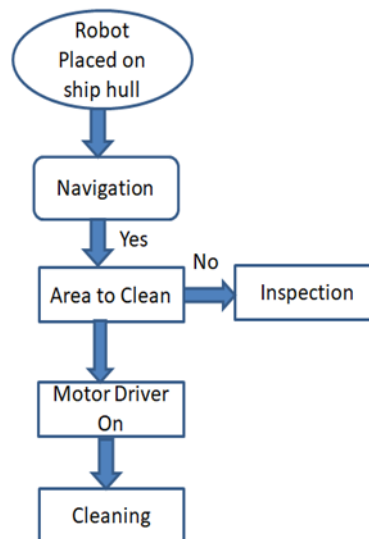
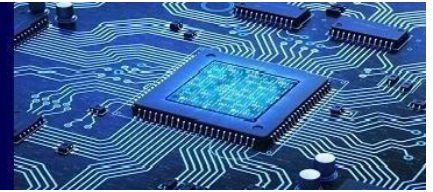


Figure 2 Flowchart for Proposed System

In manual mode, the user remotely controls the platform using direction control buttons on a mobile app. A Wi-Fi module integrated into the Main Controller (ESP8266) enables communication with the robot. Control signals are then transmitted to the speed controller to generate command velocities for the robot's wheels. Once the human operator confirms the robot's positioning, the cleaning process can commence.



6. RESULT:

The project aims to significantly reduce human intervention in ship hull cleaning processes by developing an advanced ROV system is capable of adhering to the hull surface. The ROV, depicted in Figure 3, represents a groundbreaking advancement in maritime maintenance practices, offering precise, efficient, and damage-free cleaning through optimized brushing techniques. Controlled via a user-friendly mobile application, the ROV system enhances operational ease and accessibility, further streamlining the cleaning process. The mobile application interface allows operators to remotely control the ROV's movements, facilitating precise maneuvering along the metal surface of the hull. This innovative control mechanism ensures that the ROV adheres to the hull surface with precision, enabling thorough cleaning while minimizing the risk of damage.

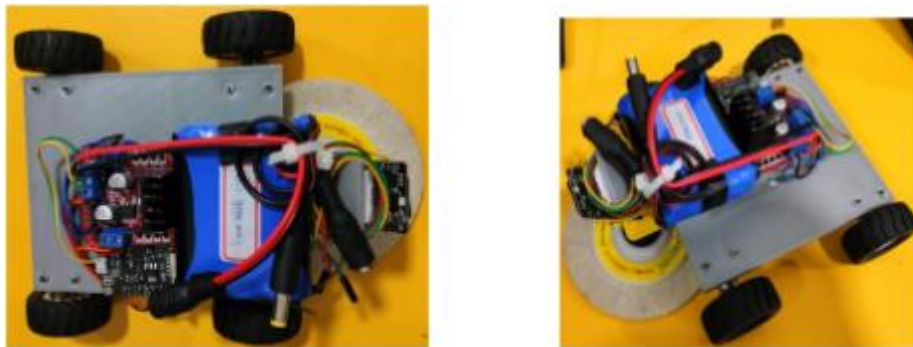


Figure 3 Image of BioBlitz Bot

The implementation of this technology promises a revolutionary shift in maritime maintenance practices. By achieving seamless adhesion and enhancing cleaning efficiency, the ROV system offers unparalleled cleaning performance, setting new standards for effectiveness and reliability. Moreover, the adoption of this advanced technology minimizes labor requirements, reducing operational costs and promoting environmental sustainability. The ROV system is specifically designed to clean the ship hull by adhering to the metal surface with remarkable precision. Utilizing advanced brushing techniques, the ROV effectively removes fouling and debris, ensuring that the hull remains free from contaminants that can impact vessel performance. This innovative approach to hull cleaning minimizes the need for manual labor and reduces the risk of damage to the ship's structure, ultimately contributing to enhanced operational efficiency and longevity of the vessel. The ROV's operation is facilitated through a user-friendly mobile application, powered by a Node MCU controller, shown in Figure 4.

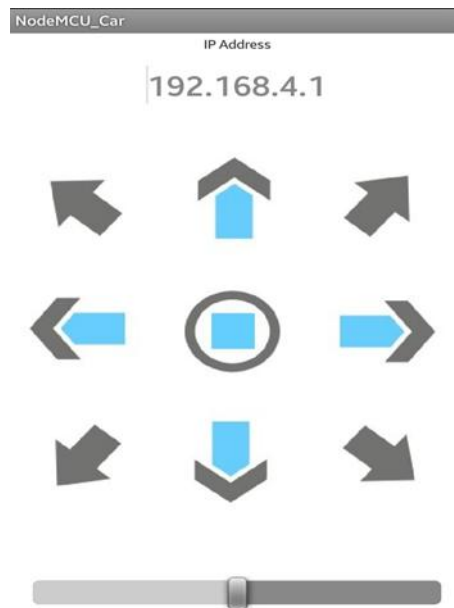


Figure 4 NodeMCU Controller

This app allows operators to remotely control the ROV's movements, adjust cleaning parameters, and monitor the cleaning progress in real-time. By leveraging the capabilities of the Node MCU controller, operators can ensure precise control over the ROV's actions, optimizing cleaning performance while minimizing the risk of errors or accidents. The development and implementation of the advanced ROV system represent a significant advancement in maritime maintenance technology. By offering precise, efficient, and damage-free cleaning capabilities, the ROV system promises to revolutionize ship hull cleaning processes, leading to reduced operational costs, improved environmental sustainability, and enhanced vessel performance.

7. CONCLUSION:

After a thorough analysis of various underwater cleaning robots, several conclusions emerge. First, robotic underwater cleanup technology offers significant potential to alleviate the burden on human divers and conduct tasks in challenging environments. Second, advancements in robotics, artificial intelligence, and sensor technology have markedly improved the accuracy and efficiency of these robots. However, challenges such as battery life, remote control, and cost necessitate further research and development.

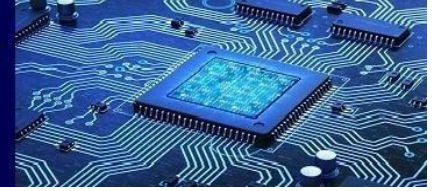
Looking ahead, increased investment in research and interdisciplinary collaboration will propel underwater cleaning robots into broader roles across fields such as environmental protection, resource exploitation, and scientific research. To achieve these goals, additional research and financial support are imperative. Given the substantial economic costs associated with docking repairs, future development efforts will likely focus on establishing comprehensive service systems for underwater hull cleaning robots, presenting substantial market potential.



Notably, advancements in ultrasonic and laser cleaning technologies show promise for compacting underwater robot cleaning systems. The integration of unmanned underwater vehicles with cleaning devices has significantly driven the advancement of underwater cleaning technology. Additionally, ongoing research into bio-inspired adhesion technologies and the optimization of cleaning robot systems through artificial intelligence and multi-robot cooperation are critical for enhancing efficiency and reducing power requirements in future applications.

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