Design and Development of Water Tank Cleaning Robot

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Abstract: Water tanks are vital for domestic, commercial, and industrial water systems, ensuring a steady supply for various uses. Over time, sediment, algae, and debris can contaminate stored water, posing health risks and reducing efficiency. Regular cleaning is crucial to maintain water quality and tank longevity. Traditional cleaning methods are labor-intensive, time-consuming, and expose workers to health risks. Automation and robotics provide efficient, safer solutions, reducing manual effort and improving cleaning processes.

I. INTRODUCTION

Water tanks are indispensable components of water storage systems for households, industries, and commercial establishments, ensuring a consistent supply of water for various needs. Despite their significance, the maintenance and cleaning of water tanks remain arduous, time-consuming, and often hazardous tasks, primarily due to confined spaces and exposure to contaminants. The robot is built on a lightweight PLA rectangular framework measuring 35 cm x 25 cm x 3 cm, designed for easy maneuverability and robust functionality. At the heart of the system lies the Arduino Uno microcontroller, enabling centralized control of various components. Navigation and obstacle detection within the tank are achieved through the integration of TF-LUNA LIDAR sensors and HC-SR04 Ultrasonic sensors strategically placed around the framework. These sensors ensure precise real-time monitoring and adaptability to various tank geometries.

II. MOTIVATION

Maintaining water quality in storage tanks is crucial for domestic, commercial, and industrial uses.

Contaminants like algae, debris, and sediment accumulate over time, posing serious health risks. Traditional cleaning methods rely on manual labor, which is time-consuming, labor-intensive, and unsafe. Workers are often exposed to unhygienic and hazardous conditions during manual cleaning. These challenges demand a more efficient, automated approach to ensure effective and safe cleaning. Automation and robotics present promising solutions to overcome the drawbacks of traditional methods. An automated water tank cleaning system can enhance cleaning efficiency, reduce health risks, and minimize human effort significantly. This study focuses on designing and developing a robot to address these challenges effectively. By integrating advanced technologies, the system aims to maintain water quality and tank durability. The research contributes to safer, innovative solutions for water tank cleaning systems.

III. PROBLEM STATEMENT

Water tanks play a vital role in ensuring a reliable water supply for various domestic, commercial, and industrial applications. Over time, sediment, algae, and debris accumulate, leading to contamination and potential health risks. Regular cleaning is necessary to maintain water quality and extend the lifespan of tanks. However, traditional cleaning methods are manual, time-consuming, labor-intensive, and pose significant health and safety hazards to workers. These methods also lack consistency, often resulting in incomplete cleaning and inefficiencies. The growing reliance on water tanks calls for a more efficient solution to overcome these limitations effectively. An automated water tank cleaning system offers a promising alternative, reducing manual effort, enhancing cleaning consistency, and improving safety.

This research seeks to address the pressing need for a reliable, innovative solution through the design and development of a robotic cleaning system tailored to meet the demands of diverse tank cleaning scenarios.

IV. OBJECTIVE

- Design an automated system for cleaning water

tanks to improve efficiency and safety.
- Develop a robotic mechanism capable of navigating diverse tank geometries and surfaces.
- Ensure effective removal of sediment, algae, and debris to maintain water quality.
- Reduce manual intervention to minimize health risks and labor intensity.
- Incorporate advanced sensors for real-time monitoring and control of the cleaning process.
- Optimize the system for energy efficiency and operational reliability.
- Test and validate the robot's performance under various environmental conditions.
- Create a cost-effective solution suitable for domestic, commercial, and industrial applications.

V. PRELIMINARY SURVEY

A detailed survey of existing water tank cleaning methods highlights key challenges and gaps. Traditional approaches involve manual cleaning, which is labor-intensive, unsafe, and time-consuming. Workers are exposed to contaminated water, increasing health risks and creating unfavorable working conditions. Several studies have explored automated systems for tank cleaning, but many lack the flexibility to adapt to varying tank sizes and complex geometries. Robots designed for industrial tanks often fail to meet the cost-efficiency and simplicity required for domestic applications. Additionally, limited focus on real-time monitoring and autonomous navigation hampers effectiveness. Technological advancements in robotics and automation present significant opportunities to overcome these limitations. Current research explores integrating sensors for precise detection of debris and dirt, along with mechanisms for efficient cleaning action. However, most existing designs are application-specific, leaving a need for a versatile, universal solution. This study investigates these gaps by analyzing various robotic cleaning systems, evaluating their capabilities, and identifying scope for improvement. The findings from this survey serve as a foundation for developing an innovative, adaptable cleaning robot that addresses the diverse needs of water tank users.

VI. LITERATURE SURVEY

1. Sharma, V.K., et al. highlighted how IoT technologies can enhance the functionality and efficiency of automated water tank cleaners through real-time monitoring capabilities. Their research focuses on integrating sensors and connectivity features that allow for remote operation and data collection, enabling users to monitor tank conditions and cleaning progress via mobile applications. The study discusses potential improvements in maintenance schedules based on data analytics derived from IoT systems.

2. Singh, H.A., et al. detailed an autonomous robotic system designed to enhance both efficiency and effectiveness in water tank cleaning operations through innovative design principles that allow it to adapt to various shapes and sizes of tanks. Their research includes a thorough analysis of the robot's navigation capabilities and obstacle detection mechanisms, which are crucial for operating in unpredictable environments.

3. Singh, K.J., et al. presented innovative robotic designs aimed at revolutionizing traditional methods used in water tank cleaning through advanced engineering practices that prioritize both functionality and ease of use. Their paper discusses various design iterations that led to improvements in maneuverability and cleaning efficiency, along with user feedback that informed subsequent design choices.

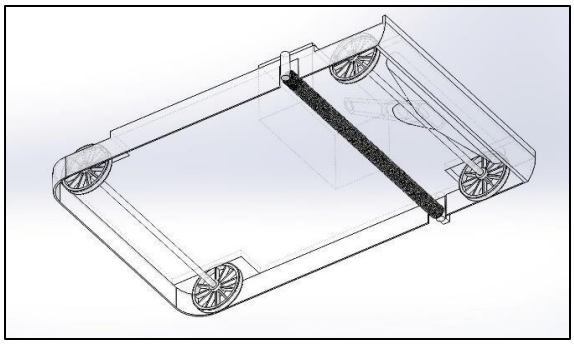
4. Jadhav, M.R., et al. presented an automated system specifically designed for domestic water tanks with features aimed at reducing manual labor while ensuring optimal cleanliness. Their paper discusses the engineering challenges faced during the design process, such as navigating confined spaces within tanks and effectively removing sediment and algae buildup. The authors provide experimental results demonstrating the system's effectiveness in various tank scenarios.

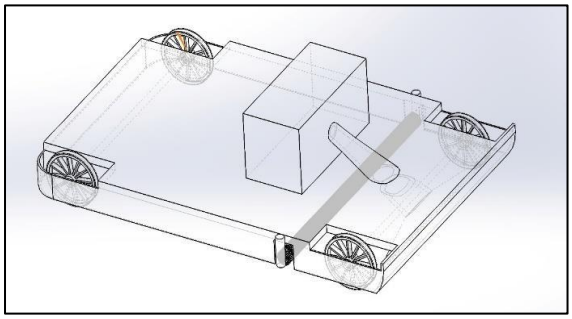
VII. PROJECT SCOPE

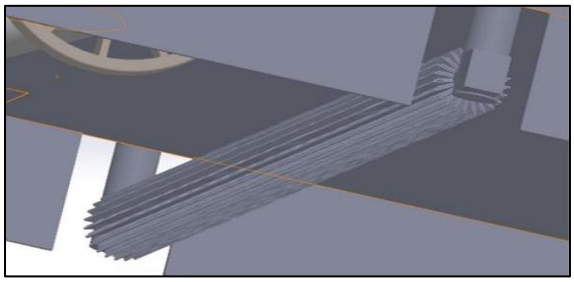
The scope of this project involves designing and developing a robotic system for cleaning water tanks, addressing domestic, commercial, and industrial applications. The robot will be capable of navigating various tank shapes and sizes to perform thorough cleaning. It will feature automated mechanisms to remove sediment, algae, and debris efficiently, ensuring high water quality and hygiene standards. The system will incorporate advanced sensors for detecting contaminants and guiding the cleaning process. Real-time monitoring capabilities will

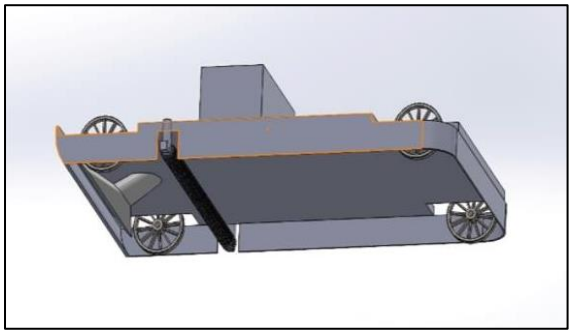
enhance accuracy and provide operational insights for users. The robot will be designed to operate autonomously, minimizing manual intervention and reducing associated health risks. The project also aims to ensure energy-efficient and cost-effective operation, making the system viable for a wide range of users. Testing under different conditions will validate the robot's performance, ensuring reliability and adaptability across applications. By addressing gaps in existing cleaning methods, this project will deliver an innovative, practical, and scalable solution for water tank maintenance.

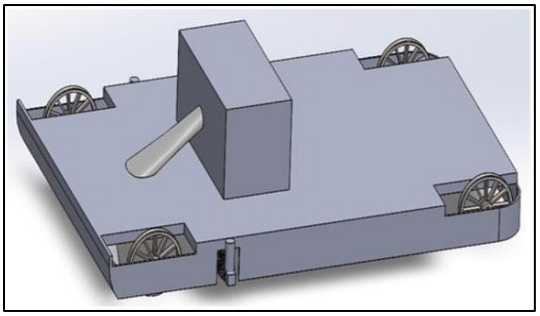
VIII. CAD MODEL





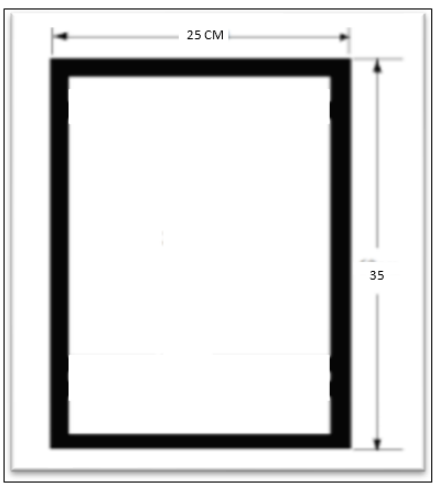






IX. SYSTEM DESIGN AND COMPONENTS

The design of the water tank cleaning robot centers around a rectangular framework constructed from PLA material, measuring 35 cm x 25 cm x 3 cm. PLA is lightweight and durable, offering the required resistance for underwater operations. This compact structure houses all the key components and ensures easy maneuverability in various tank environments. The robot is controlled by an Arduino Uno microcontroller, which serves as the central processing unit (CPU). It coordinates the functionality of the sensors, motors, and cleaning mechanisms to enable autonomous operation. The robot operates efficiently, detecting obstacles and navigating the tank while ensuring thorough cleaning.



For mobility and cleaning, the robot incorporates four wheels with a 4 cm diameter, driven by two 12V DC motors. These motors provide reliable movement, allowing the robot to cover the tank's surface area. A 12V DC vacuum pump generates 80 KPa suction pressure for removing fine debris and sediments. Additionally, the robot features a cylindrical brush with a 1–2-inch diameter made from high-density nylon bristles. This brush is powered by a 12V DC motor and rotates to scrub algae and dirt off the tank surfaces. Together, these systems ensure that the robot can handle both fine and large debris.

The robot also integrates advanced sensor systems to aid in navigation and obstacle detection. TF- LUNA LIDAR sensors and HC-SR04 ultrasonic sensors are strategically placed on each side of the robot's framework. These sensors detect obstacles and help the robot avoid collisions, providing real- time environmental feedback to the Arduino microcontroller. At the rear end of the robot, a shoveling attachment measuring 25 cm x 3.5 cm collects larger debris. A debris collection box is mounted on the top of the framework, providing a storage solution for collected waste, ensuring continuous cleaning without the need for frequent interruptions.

X. SENSOR INTEGRATION

The water tank cleaning robot relies on precise sensor integration for effective navigation and cleaning operations. The robot is equipped with TF-LUNA LIDAR sensors and HC-SR04 ultrasonic sensors, strategically positioned on all sides of its rectangular framework. These sensors work in tandem to enhance the robot's ability to detect obstacles, avoid collisions, and efficiently navigate within the tank environment. The TF-LUNA LIDAR sensor provides accurate distance measurements using laser technology, which helps map the robot's surroundings. This enables the robot to navigate around large obstacles and follow an optimized cleaning path.

In addition to the LIDAR sensor, the robot uses HC-SR04 ultrasonic sensors, which are mounted on the sides of the framework. These sensors emit sound

waves and measure the time it takes for the waves to bounce back after hitting an object. The feedback from these sensors is used to calculate the proximity of obstacles, ensuring the robot maintains a safe distance from the tank walls and other structures. The integration of both sensor types allows the robot to gather comprehensive environmental data, helping it navigate effectively in tight spaces.

The data from these sensors is processed by the Arduino Uno microcontroller, which acts as the central control unit. The microcontroller receives real-time inputs from the sensors, analyzes them, and uses the information to adjust the robot's movement and cleaning behavior. For example, if an obstacle is detected, the microcontroller commands the motors to change direction or stop, preventing collisions and ensuring the robot's safety. The microcontroller also uses sensor data to assist with path planning, ensuring thorough coverage of the water tank.

This sensor integration significantly enhances the robot's performance and autonomy. The combination of LIDAR and ultrasonic sensors allows for accurate mapping of the robot's surroundings, enabling it to avoid obstacles and clean the tank more efficiently. The sensors provide the necessary feedback to ensure that the robot can operate autonomously, adjusting its path in real-time without human intervention. This sensor-based approach ensures the robot can handle various cleaning challenges and adapt to the changing conditions of the tank environment.

XI. CLEANING MECHANISM

The cleaning mechanism of the water tank cleaning robot is designed to ensure thorough and efficient cleaning of the tank surfaces. The robot features a 12V DC vacuum pump that generates a suction pressure of 80 KPa, enabling the removal of fine debris and sediments. This vacuum system is crucial for cleaning the tank's surface, as it effectively pulls in dirt, dust, and other small particles, ensuring the tank remains clean and free from any contamination. The suction pressure is strong enough to clear the debris without disturbing the tank's water, keeping the environment stable.

In addition to the vacuum system, the robot incorporates a cylindrical brush powered by a 12V DC motor. The brush, with a diameter of 1-2 inches and made of high-density nylon bristles, rotates to scrub the tank's surfaces. The brush is particularly effective in dislodging algae, dirt, and other stubborn residues that the vacuum might not pick up. The rotation of the brush allows for a more aggressive cleaning action, especially on areas with more significant buildup, ensuring that the tank is thoroughly cleaned from every angle.

To collect larger debris that is dislodged during cleaning, the robot is equipped with a shoveling attachment positioned at the rear of the framework. This 25 cm x 3.5 cm shoveling mechanism helps gather and lift larger debris into the robot's debris collection box, which is mounted on top of the robot. The combination of the vacuum system, rotating brush, and shoveling attachment ensures that the robot is capable of cleaning both fine particles and larger objects, providing a comprehensive cleaning solution for water tanks.

XII. ADVANTAGES

- Enhanced Efficiency: Ensures thorough cleaning of tanks, reducing time and effort compared to manual methods.
- Improved Safety: Minimizes human exposure to hazardous conditions, reducing health risks for workers.
- Consistent Performance: Delivers uniform and reliable cleaning results across various tank geometries.
- Adaptability: Capable of handling diverse tank sizes and shapes in domestic, commercial, and industrial settings.
- Cost-Effective: Reduces long-term cleaning costs by decreasing labor needs and extending tank lifespan.
- Energy Efficiency: Optimized for low power consumption, making it environmentally friendly.
- Real-Time Monitoring: Integrated sensors enable precise control and real-time feedback during operations.
- Sustainability: Promotes better water hygiene and quality, supporting public health and environmental goals.

XIII. RESULTS

The water tank cleaning robot demonstrated effective performance in its designed tasks. The integration of TF-LUNA LIDAR and HC-SR04 ultrasonic sensors allowed the robot to navigate accurately, avoiding obstacles while covering the tank's entire surface. The

12V DC vacuum pump, generating 80 KPa suction pressure, efficiently collected fine debris and sediments from the tank floor, maintaining a clean environment. The cylindrical brush with high-density nylon bristles rotated smoothly, effectively scrubbing algae and dirt from the tank walls. The robot's mobility system, powered by two 12V DC motors, allowed it to move freely within the tank, maneuvering around corners and tight spaces. The shoveling attachment efficiently collected larger debris, depositing it into the debris collection box mounted on top. Overall, the robot successfully combined vacuuming, scrubbing, and debris collection to deliver a comprehensive cleaning solution. The system proved reliable and efficient, providing an automated method for maintaining clean water tanks.

XIV. CONCLUSION

In conclusion, the Design and Development of the Water Tank Cleaning Robot successfully met the objectives of automating water tank cleaning. The integration of TF-LUNA LIDAR and HC- SR04 ultrasonic sensors allowed for precise navigation, while the Arduino Uno microcontroller coordinated all systems effectively. The 12V DC vacuum pump, generating 80 KPa suction pressure, efficiently collected fine debris and sediments, maintaining clean water conditions. The cylindrical brush with high-density nylon bristles rotated effectively, scrubbing surfaces free from algae and dirt. The robot’s mobility system with two 12V DC motors enabled it to cover the entire tank area, reaching all corners and tight spaces. The addition of a shoveling attachment helped in collecting larger debris, and the debris collection box provided convenient waste storage. The robot proved to be a reliable, efficient, and autonomous solution for water tank cleaning, reducing human effort and ensuring a thorough cleaning process. The successful results indicate the potential for practical applications, offering an innovative method to maintain clean water storage systems.

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