



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: III Month of publication: March 2025

DOI: <https://doi.org/10.22214/ijraset.2025.67891>

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Sewage Cleaning Robot

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Abstract: *This paper presents the development of a semi- autonomous sewage cleaning robot designed to operate in hazardous and wet environments, minimizing human involvement and enhancing safety. Equipped with a robotic arm, ultrasonic sensors, and a high-pressure water system, the robot effectively removes debris, blockages, and sediments from sewer pipelines. The robotic arm, powered by a hydraulic system, assists in manipulating objects, while rotating brushes and high-pressure water jets ensure thorough cleaning. Controlled by an Arduino microcontroller and a Fly-Sky transmitter, the robot features real-time monitoring through an onboard camera, allowing remote operation with live video feedback. Designed for underwater functionality and energy- efficient operation using a DC motor, the system provides a cost-effective, sustainable solution to traditional manual cleaning methods. The prototype demonstrates successful performance in clearing sewage blockages, contributing to safer, more efficient sewer maintenance with potential for further automation advancement.*

Keywords: *Sewage Cleaning Robot, Robotic Arm, Ultrasonic Sensors, Hydraulic System, Arduino Microcontroller, High-Pressure Water System, Remote Operation, Obstacle Detection. insert(key words)*

I. INTRODUCTION

Urban sewage systems are essential infrastructures designed for effective wastewater management. However, manual cleaning methods are inefficient, hazardous, and labor- intensive, exposing workers to toxic gases, pathogens, and other harmful conditions. The need for a safe, efficient, and automated system has driven the development of sewage cleaning robots. These robots aim to eliminate human intervention by performing cleaning tasks through advanced mechanical designs and sensor integration.

Recent advancements in robotics, control systems, and sensor technology have enabled the development of semi- autonomous systems capable of navigating complex environments and performing cleaning tasks with high precision. This project proposes a semi-autonomous sewage cleaning robot capable of detecting, maneuvering, and cleaning debris from sewer systems using a combination of robotic arms, high-pressure water jets, ultrasonic sensors, and a real-time monitoring system.

The proposed system is intended to reduce human exposure to hazardous environments, improve cleaning efficiency, and provide a cost-effective solution to traditional methods. The system is controlled by an Arduino microcontroller and a Fly-Sky transmitter, providing remote control capabilities for enhanced safety.

II. BENEFITS

Research in the field of automated cleaning systems has been continuously evolving, driven by the necessity to replace hazardous manual operations with efficient robotic mechanisms. Various researchers have attempted to enhance the performance of robotic systems through improved sensor integration, control mechanisms, and path planning algorithms. The work by Wang and Zhang (2024) demonstrated fault diagnosis of robotic arms using dynamic simulation and domain adaptation techniques, which is highly relevant to our effort to enhance the precision of robotic arm operations in our sewage cleaning robot. Furthermore, Elara et al. (2018) presented a Tetris-inspired floor cleaning robot designed to achieve efficient area coverage, an approach that influenced our mechanism for ensuring comprehensive cleaning of sewer pipes.

Another significant contribution is by Miao et al. (2020), who proposed a multi-cleaning robot framework designed for handling large-scale cleaning operations through map decomposition. While their approach focused on floor cleaning, the concept of dividing the operational area for efficient coverage has inspired the implementation of systematic navigation algorithms in our system. Similarly, the work by Mohan and Sivanantham (2021) on social density monitoring using perception systems highlights the potential of integrating multi-sensor data fusion for enhanced object detection and avoidance.

Huber et al. (2024) introduced obstacle avoidance algorithms focused on navigating concave obstacles, a crucial aspect in sewage cleaning robots due to the irregular structures present in sewer pipelines. These contributions provide valuable insights into developing a robust system architecture for the proposed sewage cleaning robot, emphasizing reliability, efficiency, and safety.

III. SYSTEM ARCHITECTURE

The proposed sewage cleaning robot comprises a robotic arm, ultrasonic sensors, high-pressure water jets, and a camera module. The central control unit, an Arduino microcontroller, coordinates all subsystems, enabling effective communication between various components. The robotic arm, powered by a hydraulic system, is designed to manipulate debris and assist in cleaning operations. Its precision is achieved through servo motors that enable smooth movement and efficient handling of objects.

Ultrasonic sensors are integrated into the system for real-time obstacle detection, ensuring the robot can navigate complex environments without collision. The high-pressure water jets serve as the primary cleaning mechanism, efficiently removing stubborn debris and sediments from sewer pipelines. The entire system is operated using a Fly-Sky transmitter, providing remote control functionality and enhancing operational safety by reducing human exposure to hazardous environments.

The camera module offers live video feedback, enabling the operator to monitor the cleaning process accurately. This visual data is processed by the Arduino microcontroller to assist in real-time decision-making. Additionally, the power supply is provided by a 12V rechargeable battery, allowing for prolonged operation and efficient energy management. The architecture is designed to be modular, making it adaptable to various cleaning scenarios and easy to upgrade.

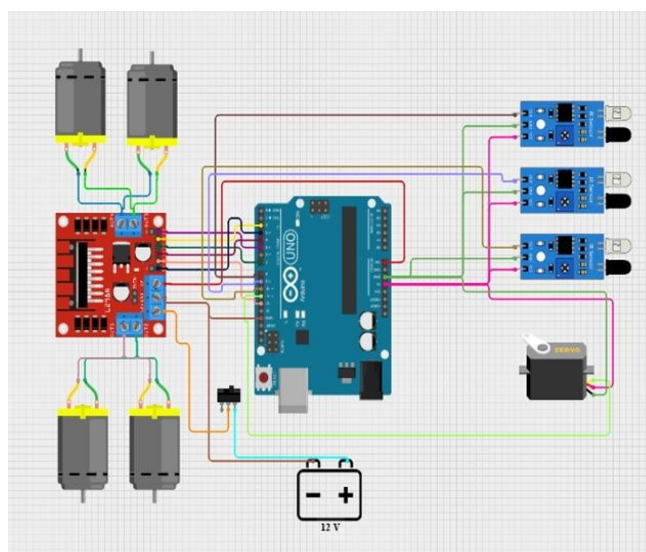


Fig.1.Circuit Diagram of the momentary part of the robot

Fig. 1. demonstrates the integration of multiple sensors, motors, and the Arduino Uno. The system is powered by a 12V supply and utilizes an L298N motor driver to control the movement of four DC motors responsible for driving the robot. Ultrasonic sensors are incorporated to detect obstacles, ensuring safe navigation within the sewage pipeline or confined environment. Additionally, a servo motor is attached for precise manipulation tasks, further enhancing the robot's ability to clean complex areas. The overall circuitry emphasizes modularity, making it easier to assemble and maintain. Furthermore, the use of Arduino Uno provides a robust and flexible platform for controlling various components, allowing easy modification and upgrading of the robot's functionalities as needed.

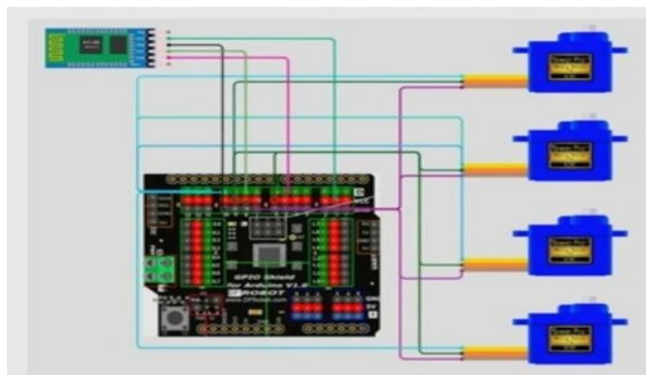


Fig.2.Circuit Diagram of ARM

The circuit diagrams of the manually controlled sewage cleaning robot (Fig. 2.) are designed to efficiently control and operate the various components involved in the cleaning process. The first diagram illustrates the interfacing of servo motors with the Arduino board through a GPIO shield. The Bluetooth module is also connected, enabling wireless communication and control of the servos. The servos are responsible for operating mechanical parts such as robotic arms and cleaning brushes, which are essential for the collection and removal of debris.

IV. ALGORITHM AND CONTROL SYSTEM

The control system for the sewage cleaning robot is governed by a well-defined algorithm aimed at achieving precision, efficiency, and adaptability. The algorithm begins with the initialization phase, where all components, including sensors, motors, and communication systems, are powered up and tested for functionality. Once initialized, the Fly-Sky transmitter establishes a reliable communication link with the Arduino microcontroller, enabling remote control operations. The ultrasonic sensors continuously monitor the surrounding environment, providing real-time feedback to the controller.

Based on sensor data, the control system identifies obstacles and adjusts the robot's path accordingly. The robotic arm, controlled via servomotors, is then activated to collect larger debris, while high-pressure water jets are used to dislodge smaller particles and clean surfaces effectively. The camera module provides live video feedback, allowing the operator to oversee the cleaning process and make real-time adjustments if necessary. The cleaning operation continues iteratively until the entire area is thoroughly cleaned.

The flowchart illustrated in Fig. 3. Shows the step-by-step operation of the manually controlled sewage cleaning robot, presenting a systematic approach to achieve efficient cleaning. The process begins by initializing the system and establishing communication between the Fly-Sky transmitter, receiver, and Arduino. This setup ensures accurate control over the robot's movement and functionality.

Once communication is established, the robot navigates through the designated area using DC motors. Ultrasonic sensors are employed to detect obstacles in the path. When an obstacle is detected, the robot avoids it and continues navigation. If no obstacle is present, it proceeds with the cleaning operation. The cleaning process involves the activation of rotating brushes and water jets, which dislodge and collect waste particles. The debris is then stored in a designated compartment for proper disposal. Additionally, a hydraulic arm is used for manual debris removal, ensuring thorough cleaning even in challenging environments.

The robot monitors its progress in real-time using a camera, providing valuable feedback to the operator. After the cleaning operation is complete, the robot returns to its starting point, where the collected waste is safely disposed of. The flowchart provides a comprehensive overview of the robot's workflow, highlighting its systematic approach to sewage cleaning.

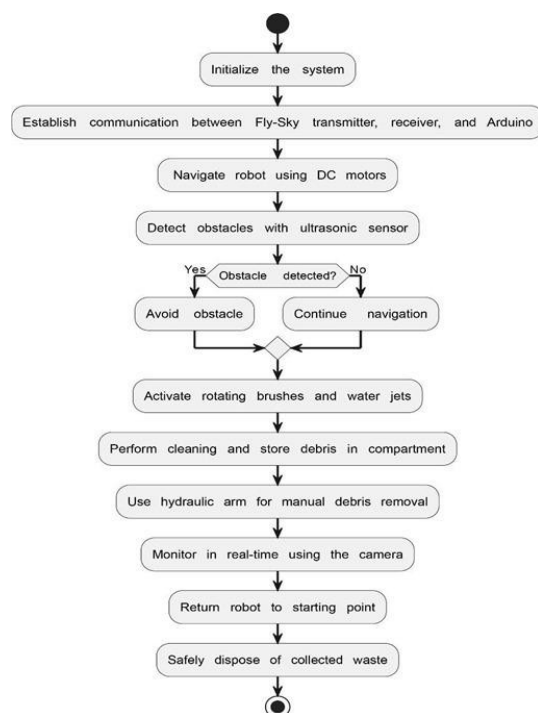


Fig.3.Flowchart of the working of robot

V. METHODOLOGY

A. Initialization

- Powering all essential components including the Arduino, Fly-Sky transmitter, motors, sensors, and actuators.
- System self-check to ensure connectivity and functionality.

B. Establish Communication

- Pairing the Fly-Sky transmitter and receiver for stable, interference-free communication.

C. Navigation and Obstacle Detection

- Ultrasonic sensors continuously monitor the environment for obstacles.
- If obstacles are detected, the control system adjusts the robot's path to avoid collisions.

D. Cleaning Process

- Activation of rotating brushes and high-pressure water jets.
- Robotic arm assists in removing large debris and collecting waste.

E. Real-Time Monitoring

- Camera feedback allows remote observation and control.

F. Data Processing and Feedback Loop

- Sensors and camera data are processed to enhance decision-making accuracy.

VI. PROPOSED SYSTEM

A. System Overview

The proposed system consists of a robotic arm, ultrasonic sensors, high-pressure water jets, and a camera for real-time monitoring. The system is controlled by an Arduino microcontroller and operated through a Fly-Sky transmitter, providing wireless communication for remote operation.

B. Components

1) Robotic Arm:

- A hydraulic-powered arm designed for grasping and manipulating debris.
- Controlled by servomotors providing precise movement.

2) Ultrasonic Sensors:

- Used for obstacle detection and environmental mapping.
- Sends distance data to the Arduino for path adjustments.

3) High-Pressure Water Jets:

- Designed to dislodge and remove stubborn debris from sewer pipelines.

4) Arduino Microcontroller:

- The central processing unit controlling all components.
- Receives input from sensors and transmits output to actuators.

5) Fly-Sky Transmitter:

- Enables wireless control of the robot, enhancing safety and user-friendliness.

6) Camera Module:

- Provides real-time monitoring and visual feedback to the operator.

7) DC Motor:

- Powers the movement of the robotic arm and cleaning mechanisms.

8) Power Supply:

- 12V rechargeable battery providing energy-efficient operation.

VII. BENEFITS

The proposed sewage cleaning robot offers several benefits:

1) Safety Enhancement:

- Minimizes human exposure to hazardous conditions by allowing remote operation.
- Reduces the risk of accidents related to manual cleaning.

2) Efficiency Improvement:

- High-pressure water jets and rotating brushes effectively clean sediments and debris.
- Robotic arm assists in precise manipulation of waste material.

3) Cost-Effective Solution:

- Reduced labor costs and operational expenses.
- Low maintenance and energy-efficient design.

4) Sustainability:

- Environmentally friendly cleaning method using water jets instead of chemicals.
- Designed for energy-efficient operation with a rechargeable 12V battery.

5) Versatility:

- Capable of functioning in various environments, including wet and underwater conditions.
- Can be adapted for other industrial cleaning applications.

VIII. RESULTS AND DISCUSSION

The prototype shown in Fig. 4. demonstrated effective cleaning capabilities under various conditions. The robotic arm efficiently manipulated debris, while high-pressure water jets provided comprehensive cleaning. However, challenges such as limited battery life and difficulty navigating complex environments remain. Future work will focus on improving autonomy, sensor accuracy, and system durability.



Fig.4.a.Final Prototyping

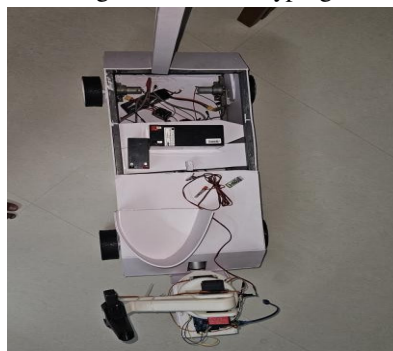


Fig.4.b.Top View

IX. APPLICATIONS

- 1) Sewer maintenance.
- 2) Industrial waste cleaning.
- 3) Disaster recovery.
- 4) Hazardous environment exploration.

X. LIMITATIONS

- 1) Limited autonomy.
- 2) High power consumption.
- 3) Difficulty navigating narrow or irregular sewage pipelines.

XI. CONCLUSION

The sewage cleaning robot offers a viable solution for efficient and safe cleaning of sewer pipelines. By integrating advanced sensors, robotic arms, and control systems, the robot minimizes human involvement while enhancing cleaning efficiency. Future improvements will focus on enhancing autonomy, robustness, and real-time monitoring capabilities.

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