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Automatic Drainage Cleaning Robot

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Abstract: ***Manually cleaning sewer lines and obstructing drainage pose a major hazard to human health, safety, and the environment. Traditional drainage cleaning methods expose workers to harmful vapors, dangerous circumstances, and dangerous bacteria. This study builds an Internet of Things- enabled drainage cleaning robot using an ESP32 microcontroller and a multi-sensor integration approach. A motor-driven garbage collection system, proximity sensors for waste identification, servo motors for accurate collection arm control, gear motors for mobility, and gas sensors for hazardous gas detection are all part of the system.***

The self-governing robot continuously checks drainage tubes for solid waste and dangerous gas concentrations. The motor driver module ensures efficient control of DC gear motors for directed movement while the garbage collection mechanism removes debris from the drainage stream. The ESP32 microcontroller's wireless monitoring and control features allow operators to supervise activities from a distance.

This gadget provides an alternative to human drainage cleaning that is safer, less expensive, and uses less energy. The proposed approach aims to improve sanitation efficiency, increase worker safety, and decrease human intervention. Future advancements could include AI-based garbage recognition, camera-based monitoring, and cloud-based data logging for predictive maintenance of urban drainage systems.

Keywords—Drainage Cleaning Robot, ESP32 Microcontroller, Proximity Sensor, Gas Sensor, Garbage Collection Mechanism, Motor Driver, Gear Motor, Servo Motor, IoT-Based Monitoring, Smart Sanitation System, Autonomous Cleaning Robot, Hazardous Gas Detection, Wireless Control, Embedded Systems, Urban Drainage Maintenance.

I. INTRODUCTION

Rapid urbanization and population growth have significantly increased the burden on municipal drainage systems. Blocked drainage pipelines due to plastic waste, sludge, and solid debris are common problems in urban and semi-urban areas. Poor maintenance of drainage systems can lead to waterlogging, environmental pollution, and the spread Of waterborne diseases.

Traditionally, drainage cleaning is performed manually, which exposes workers to toxic gases such as methane and hydrogen sulfide, leading to severe health risks and even fatalities.

Manual scavenging and sewer cleaning remain hazardous tasks despite technological advancements. Workers are often required to enter confined drainage spaces, where oxygen deficiency and the presence of harmful gases create life- threatening situations. These challenges highlight the urgent need for an automated, safe, and efficient drainage cleaning system that minimizes human involvement

To address these issues, this project proposes the development of a Drainage Cleaning Robot based on the ESP32 microcontroller. The robot integrates multiple hardware components to ensure effective detection and cleaning operations. A proximity sensor is used to detect garbage or obstacles inside the drainage system. A gas sensor continuously monitors the presence of harmful gases to ensure safe operating conditions. The movement of the robot is controlled using DC gear motors driven by a motor driver module, enabling smooth forward, backward, and directional motion.

Additionally, a servo motor-operated garbage collection mechanism is implemented to lift and remove waste materials from the drainage channel. The ESP32 microcontroller acts as the central processing unit, coordinating sensor inputs and actuator outputs while enabling wireless communication for monitoring and control. The system is designed to operate efficiently in narrow drainage pipelines and harsh environmental conditions.

The primary objective of this project is to design a low- cost, reliable, and efficient robotic system that enhances safety and operational efficiency in drainage maintenance. By integrating sensors, actuators, and IoT-based control, the proposed robot offers a modern solution to sanitation challenges in smart cities. This project contributes toward automation in municipal services and promotes safer working conditions through technological innovation.

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II. LITERATURE REVIEW

TABLE I LITERATURE REVIEW SUMMARY

Ref no.	Author(s) and Title	Contribution
1	Hemalatha– *Artificial Intelligence-based smart drainage cleaning robot*	In order to increase productivity and safety, the paper describes an AI-based drainage cleaning robot that uses a robotic arm and sensor-based automation to automatically identify and remove impediments.
2	Sarosh Baig. – *A Review on Automated Drainage Cleaning System*	In order to improve sewage waste removal and reduce manual labor, the study looks at and recommends a semi-automated drainage cleaning technique.
3	Abhijit B. Shinde– *Drainage cleaning robotic system*	In order to safely and effectively automate pit latrine and drainage garbage collection, the article introduces a Bluetooth-controlled drainage cleaning robot with a robotic arm and gripper..
4	R. M. Madhumathi– *Development of Cleaning Device for In-pipe Robot Application*	In order to efficiently remove trash and increase pipeline maintenance efficiency, the paper describes the design and implementation of a cleaning device that is paired with an in-pipe robot.
5	Mohammed Suhail M – *Implementation of Cleaning Device for In-Pipe Robot Application*	In order to improve automated debris removal and the efficiency of pipeline inspection and maintenance, the study suggests and develops a cleaning mechanism for an in-pipe robot.

III. OBJECTIVES

1) To design and develop an automated drainage cleaning robot to reduce manual scavenging.
2) To detect garbage and obstacles inside drainage systems using a proximity sensor..
3) To monitor harmful gases in drainage pipelines using a gas sensor for safety. .
4) To implement a motor-driven garbage collection mechanism for efficient waste removal. To enable wireless monitoring and control of the robot using the ESP32 microcontroller.

IV. BLOCK DIAGRAM

The block diagram shows the ESP32 as the main controller, which receives input from the proximity and gas sensors and controls the motors and garbage collection mechanism for automated drainage cleaning.

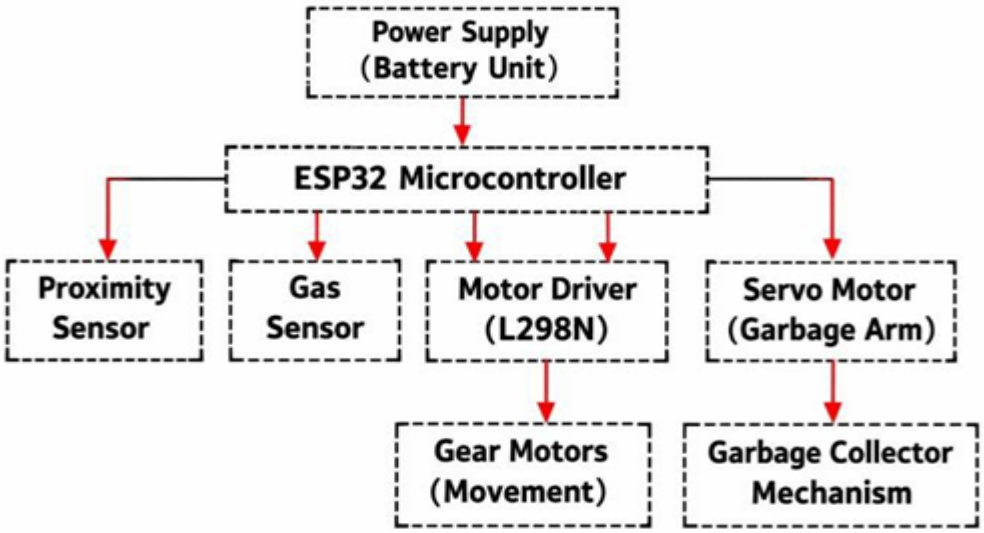


Fig. 1. Block Diagram

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V. METHODOLOGY

A. *Project Goals*

1) The development of an automated drainage cleaning robot that will reduce the need for hazardous sewage cleaning duties performed by humans.
2) Proximity and gas sensors will be incorporated for real- time waste and hazardous gas detection to ensure safe and efficient operation.
3) To install a motor-driven mobility and waste collection system that effectively removes waste by utilizing servo motors, gear motors, and motor drivers.
4) To use the ESP32 microcontroller to improve drainage maintenance's operating efficiency, wireless monitoring, and intelligent control.

B. *Components*

1) *ESP32:* The ESP32 is a low-power, cost-effective system-on-a-chip (SoC) series that features dual-mode Blue- tooth and Wi-Fi. It includes the ESP32-D0WDQ6 SoC, which has a dual-core 32-bit LX6 CPU, and the ESP32-S0WD SoC, which has a single-core LX6 CPU. The ESP32 is widely used due to its low power consumption, rich set of peripherals, and compact size [12]

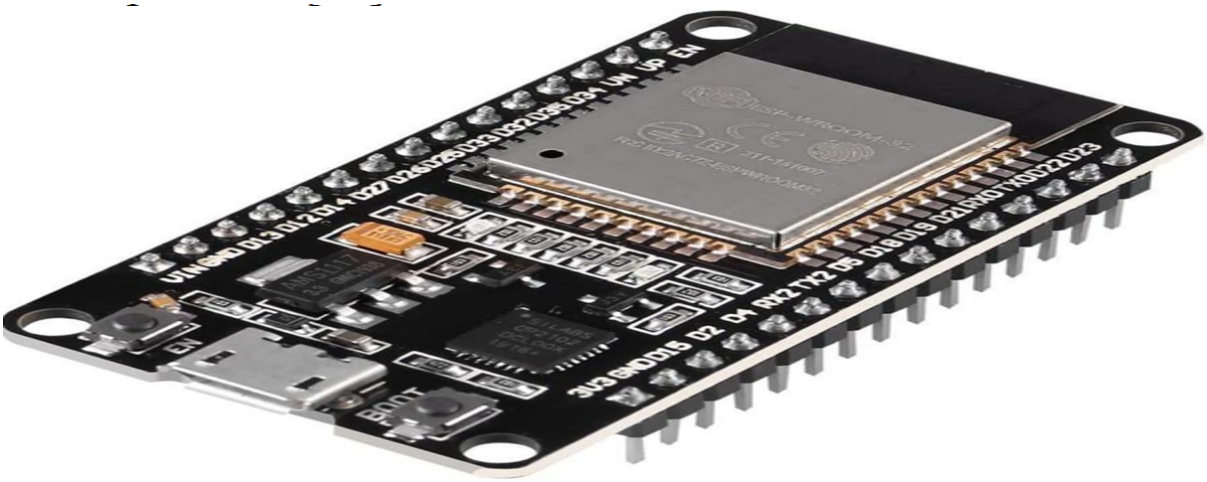


Fig. 2. ESP-32

2) *DC motor:* Through the pipeline, DC motors power the drainage cleaning robot. They may move forward, backward, and in other directions thanks to a motor driver that is connected to the ESP32.These motors supply the motion and torque needed for limited drainage systems to operate effectively. A stator and a rotor are the two primary parts of DC motors. Permanent magnets or electromagnets are usually found in the stator, whereas a wire coil or set of windings is found in the rotor. A magnetic field produced by current passing through the coil or windings combines with the magnetic field of the stator to produce spinning. They provide a variety of speed and torque control options, simplicity, and dependability [3]



Fig. 3. DC motor

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3) *Proximity Sensor:* This sensor is used by the suggested drainage cleaning robot to identify obstructions or debris within the drainage pipeline. The early detection of solid waste is made possible by its ability to identify objects in the vicinity without making physical contact. The garbage collection procedure is initiated by the ESP32 microcontroller following data interpretation and real-time inputs from the sensor. This part boosts automation, enhances cleaning effectiveness, and reduces collisions in areas with limited drainage.



Fig. 4. Proximity Sensor

4) *Gas Sensor:* To detect hazardous gases in sewer networks, a gas sensor is integrated inside the drainage cleaning robot. It continuously checks the gas concentration levels and sends real-time data to the ESP32 microcontroller for processing. If hazardous gases exceed allowable levels, remedial action can be taken to ensure operational safety. In addition to improving worker safety, this component encourages safe autonomous drainage cleaning.



Fig. 5. Gas Sensor

5) *Motor Driver:* This device controls the drainage cleaning robot's DC gear motors. It provides the current and voltage needed for the motors to operate properly by acting as an interface between the ESP32 and the motors. The robot may move through the drainage system with direction control and speed change thanks to the motor driver. To move the motor in the required direction and speed, the IC motor driver converts instructions from a microprocessor or other control circuitry into the proper signals

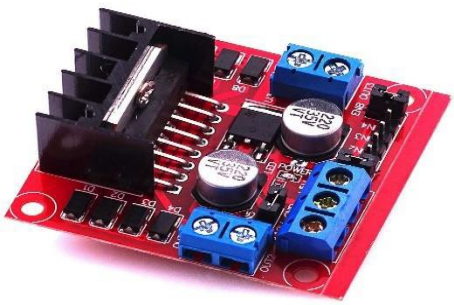


Fig. 6. Motor Driver

6) *Servo Motor:* This function enables the garbage collecting arm to operate the drainage cleaning robot. Waste items can be precisely lifted, retained, and released from the drainage system because to its precise angular movement. The ESP32 generates PWM signals that the servo motor uses to achieve accurate and stable positioning. This precise control boosts cleaning effectiveness and enables reliable automatic rubbish disposal in confined areas.



Fig. 7.Servo Motor

C. Working Principle:

The drainage cleaning robot operates through a systematic process to ensure efficient waste detection, safe operation, and automated garbage removal. The key stages are:

1) Initialization of Sensors and System Setup:

The system initializes the following components using the ESP32 microcontroller:

- -Proximity Sensor: Detects the presence of garbage or obstacles inside the drainage pipeline.
- -Gas Sensor (MQ Series): Monitors harmful gases present in the drainage environment.
- -DC Gear Motors: Enable movement of the robot.
- -Servo Motor: Controls the garbage collection mechanism.

2) Sensor Data Processing and Threshold Evaluation:

- -Proximity Sensor: The ESP32 continuously reads sensor input to identify nearby waste or blockage. If garbage is detected within a predefined distance, the cleaning mechanism is activated.
- -Gas Sensor: The ESP32 analyzes gas concentration levels. If the gas level exceeds the predefined safety threshold, an alert condition is triggered to indicate a hazardous environment.

3) Detection and Cleaning Stage:

- -Garbage detection occurs when the proximity sensor identifies an obstacle in the drainage path. Upon detection:
- -The robot stops its forward motion.
- -The servo motor activates the garbage collection arm.
- -The collected waste is lifted and removed from the drainage path.

If harmful gas levels are detected, the system indicates unsafe conditions before continuing operation.

4) Actuator Control and Movement Mechanism:

- -The Motor Driver receives control signals from the ESP32 to operate the DC gear motors.
- -The robot moves forward, backward, or turns based on programmed logic.
- -The servo motor ensures precise angular movement for accurate garbage handling.

5) Continuous Monitoring:

The ESP32 continuously monitors sensor readings and system status to ensure real-time detection, safe operation, and efficient cleaning performance throughout the drainage process.

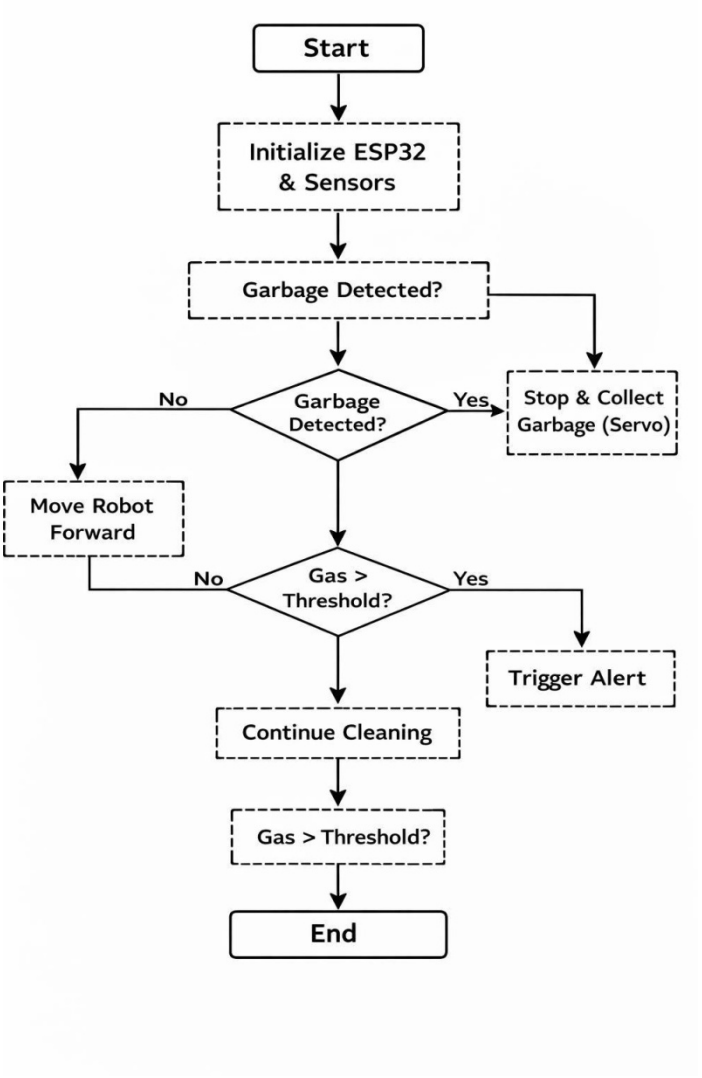


Fig.8. System Working Principle

HARDWARE CONNECTIONS

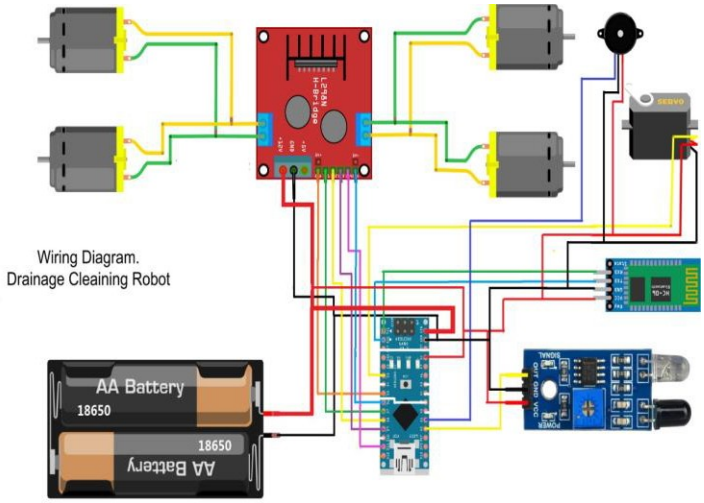


Fig.9. Hardware Connection

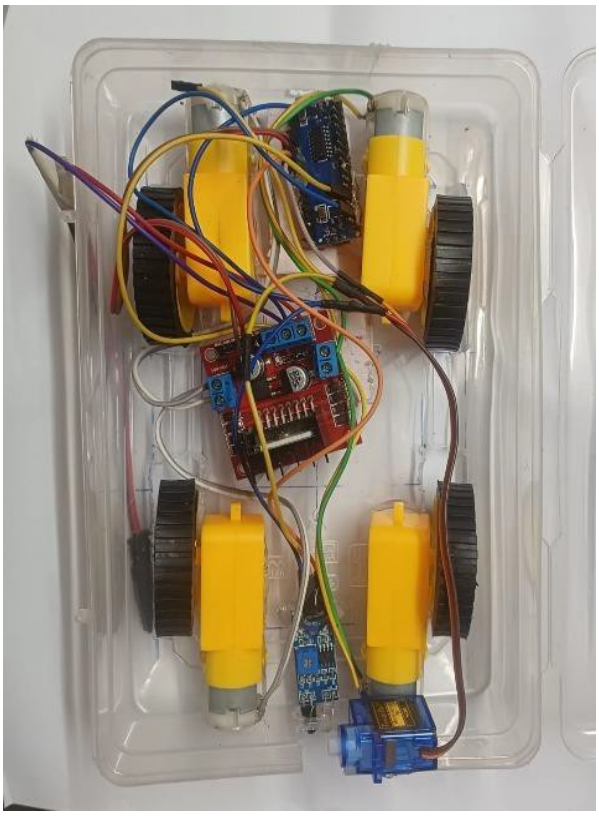


Fig. 9: Hardware Interfacing

VI. RESULTS

TABLE I: Proximity Sensor Readings & Garbage detection

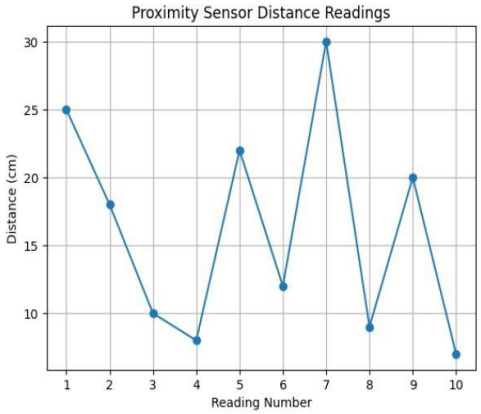
Reading	Temperature (°C)	Humidity (%)
25	No	Move forward
18	No	Move forward
10	Yes	Stop & collect
8	Yes	Stop & collect
22	No	Move forward
12	Yes	Stop & collect
30	No	Move forward
9	Yes	Stop & collect
20	No	Move forward
7	Yes	Stop & collect

TABLE II: MQ-2 Gas Sensor Readings and Safety Status

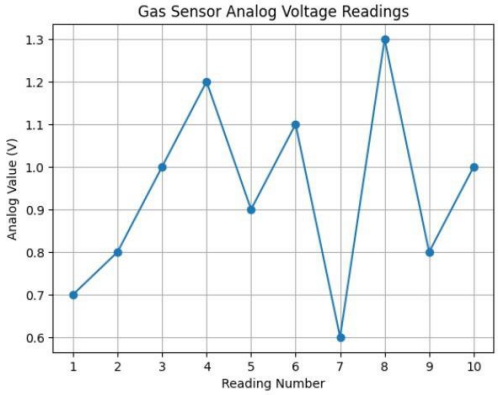
Reading	Analog Value (V)	Air Quality Level
1	0.7	Safe
2	0.8	Moderate
3	1.0	High
4	1.2	Hazardous
5	0.9	Moderate
6	1.1	High
7	0.6	Safe
8	1.3	Hazardous

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9	0.8	Moderate
10	1.0	High



Graph 10: Proximity Sensor Distance Readings



Graph. 11: Gas Sensor Distance Readings

VII. CONCLUSION

In this project, we have developed an Automated Drainage Cleaning Robot using ESP32, a proximity sensor, a gas sensor, DC gear motors, a motor driver, and a servo-based garbage collection mechanism. The technology guarantees effective waste identification and safe operation by continuously monitoring the presence of trash and dangerous gas levels inside drainage pipelines. The robot increases sanitation efficiency and lessens the need for human involvement in dangerous sewage conditions. The suggested system could develop into a completely independent, Internet of Things-enabled smart drainage maintenance system that is appropriate for managing industrial and urban infrastructure in the future with additional improvements.

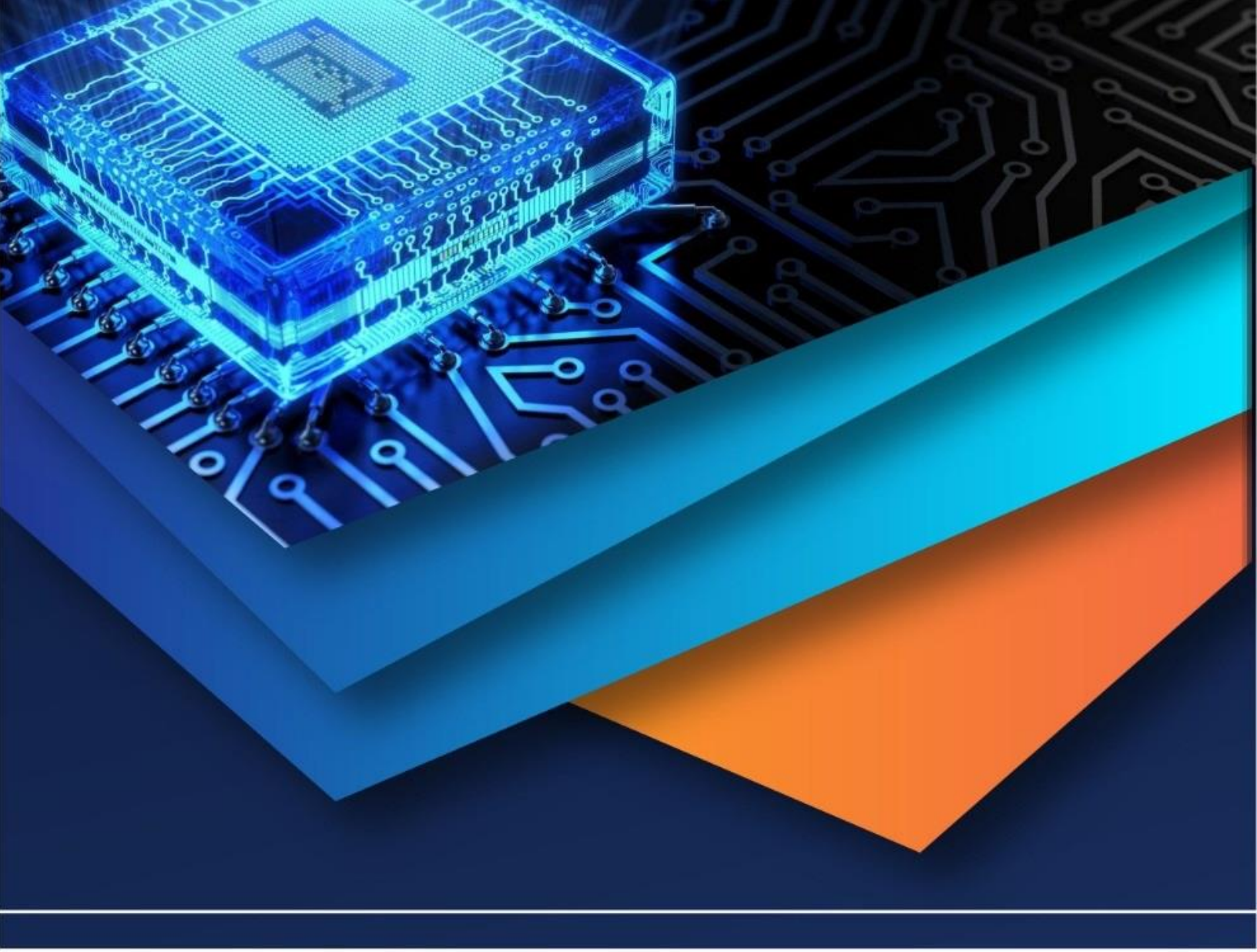
VIII. FUTURE SCOPE

1) Integration of a camera module for real-time video surveillance of drainage conditions.
2) Implementation of AI and image processing algorithms for automatic waste classification and optimal cleaning.
3) Integration of IoT-based cloud connectivity for remote monitoring and logging of data.
4) Integration of advanced cleaning systems such as water-jet or suction systems for effective sludge removal.
5) Development of fully autonomous navigation systems using advanced sensors for fully autonomous operation.

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