

Design of Real-Time Automatic Drainage Cleaning and Monitoring System using IoT

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Abstract: Urban drainage systems are vital for maintaining sanitation by transporting wastewater away from residential and commercial areas. However, the frequent accumulation of solid waste such as plastics and debris often leads to blockages, resulting in waterlogging, environmental pollution, and health hazards. Traditional manual cleaning methods are hazardous and inefficient. To address these challenges, this project proposes a Real-Time Automatic Drainage Cleaning and Monitoring System using IoT technology. The system employs mechanical waste removal combined with IoT based monitoring through sensors and real-time data transmission. It utilizes the ESP 8266 Wi-Fi module to send drainage condition data to a cloud platform, while the Blynk application provides a user-friendly interface for real-time monitoring and alerts. When waste levels reach a critical threshold, notifications are sent to municipal authorities for prompt action. This automation enhances operational efficiency, ensures worker safety, and minimizes environmental risks. Cost-effective, scalable, and easy to implement, the proposed system offers a sustainable solution for modern drainage management and urban sanitation improvement..

Keywords: *Drainage cleaning, Urban sanitation, ESP8266, Blynk application, Sensors, User friendly, Cost effective*

I. INTRODUCTION

From simple household wastes to the commercial waste of businesses, proper disposal of them matters. These wastes, whether discarded intentionally, are simply blown overboard, contributing to increasing effects on the environment. Many effects such as soil contamination, air contamination, and water contamination occur due to this sewage. Improper disposal of waste into the sewages may have a bad impact on human health due to the stagnated water etc. There may be contamination of drinking water

while the sewage passes by them. The Automatic Drainage Cleaning System is an innovative solution to urban sanitation challenges. By integrating mechanical waste removal with IoT-based monitoring, it minimizes blockages, prevents waterlogging, and ensures proper drainage maintenance. This system enhances worker safety by reducing the need for hazardous manual cleaning while improving efficiency in waste management. Its cost-effective and scalable design makes it suitable for implementation in cities, contributing to cleaner and healthier environments. By automating drainage maintenance and enabling real-time

monitoring, this system not only improves urban sanitation but also supports sustainable waste management practices, making it a vital advancement in modern infrastructure development.

II. SYSTEM DESIGN AND ARCHITECTURE

The proposed system for real-time automatic drainage cleaning and monitoring integrates Internet of Things (IoT) technology with an automated cleaning mechanism to ensure the efficient functioning of drainage systems. The methodology involves several crucial steps, including system design, hardware selection, software development, and implementation. The primary objective is to create a self-sustaining mechanism that detects blockages, removes debris, and ensures smooth water flow in drainage networks. The system uses various sensors to collect real-time data on drainage conditions, transmitting this information to a cloud-based monitoring platform for further analysis. This allows for predictive maintenance and real-time alerts, reducing the need for manual intervention and enhancing operational efficiency.

The hardware architecture consists of a combination of IoT-enabled sensors, a motorized cleaning mechanism, a waste collection system, and a control unit. The drainage system is equipped with ultrasonic sensors to monitor water levels and detect any abnormalities caused by blockages. Infrared sensors and moisture detectors further enhance detection accuracy by identifying solid waste accumulation and differentiating between wet and dry waste. A microcontroller acts as the processing unit, receiving sensor data and triggering appropriate actions based on predefined thresholds. The cleaning mechanism, inspired by the prototype shown in the image, consists of a rotating arm or conveyor system that actively removes debris and directs it into designated collection bins. The bins are classified for wet and dry waste segregation, promoting an efficient waste disposal system.

The software implementation involves the development of an embedded system that processes

sensor data, executes automated cleaning functions, and communicates with a remote monitoring platform. The microcontroller is programmed using embedded C or Python to interpret real-time data and control motorized cleaning components. The IoT module facilitates wireless communication, sending live updates to municipal authorities via a cloud-based dashboard or mobile application. This dashboard displays drainage conditions, alerts, and historical data analytics, enabling authorities to plan preventive maintenance effectively. Additionally, machine learning algorithms can be integrated into the system to predict potential failures based on historical trends, further improving drainage management efficiency.

The data processing and analysis component plays a critical role in ensuring optimal system performance. Sensor data is collected at regular intervals and transmitted to a cloud server for real-time monitoring. If abnormal patterns, such as sudden water level rise or prolonged waste accumulation, are detected, the system automatically triggers an alert and initiates the cleaning mechanism. The collected data is further analyzed to generate predictive insights, helping municipal authorities optimize cleaning schedules and reduce operational costs. The system can be integrated with artificial intelligence-based analytics to enhance its decision-making capabilities, making the entire process more autonomous and adaptive.

III METHODOLOGY

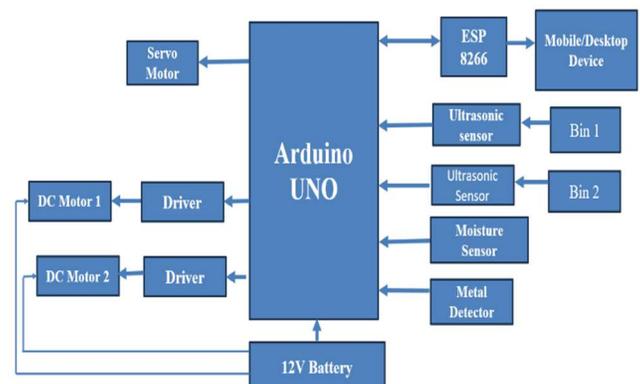


Fig1: Block diagram of the system

The above figure is the detailed block diagram of the project, which comprises of an 12v battery, motors, microcontrollers and various sensors , the detailed explanation of the blocks are as follows;

The Arduino UNO is a widely used microcontroller board for automation projects, particularly in waste segregation systems. Its numerous input and output pins allow it to handle multiple sensors and actuators simultaneously, making it ideal for sorting waste efficiently. In an automatic waste segregation system, the Arduino UNO processes data from various sensors to classify waste into different categories, such as wet, dry, and metallic waste. Once categorized, the system directs the waste into designated bins using mechanical actuators, reducing manual labor and improving recycling efficiency.

A DC motor plays a crucial role in an automatic waste segregation system by providing the necessary mechanical movement for sorting waste efficiently. Motor 1 rotates at a speed of 30 rpm and Motor 2 at 10 rpm. The waste segregation system relies on multiple components, including sensors, actuators, and microcontrollers, to classify and separate waste into different categories. These drivers enable the microcontroller to regulate motor speed and direction efficiently. The motor speed can be adjusted depending on the rate of waste processing, ensuring smooth operation without jamming or overflow. Motor drivers play a vital role in an automatic waste segregation system by enabling microcontrollers, such as the Arduino UNO, to control DC motors, servo motors, and stepper motors efficiently. Since microcontrollers operate at low power and cannot directly drive motors that require higher current and voltage, motor drivers act as intermediaries, providing the necessary power and control signals.

A servo motor plays a crucial role in an automatic waste segregation system by providing precise control of movement for sorting mechanisms such as flaps. Unlike DC motors, which rotate continuously, servo motors can rotate to a specific angle based on control signals, making them ideal for directional waste sorting and gate control in the system. A servo motor consists

of a DC motor, a gear system, a position sensor, and a control circuit. The control system sends a PWM (Pulse Width Modulation) signal to the servo motor, determining its rotation angle. The servo motor's internal position sensor continuously monitors the shaft's position and adjusts it as needed to maintain accuracy.

Two ultrasonic sensors are deployed in the system to monitor the fill levels of two separate bins—Bin 1 and Bin 2. These sensors work by emitting ultrasonic waves and measuring the time it takes for the echo to return after bouncing off an object. The measured time is then converted into a distance, allowing the Arduino to determine how full each bin is. When a bin reaches a predefined threshold, the Arduino can trigger an action such as sending a notification via the ESP8266 or redirecting waste to a different bin using a servo motor. These sensors are crucial for automating waste management by enabling real-time level detection, which reduces the need for manual inspection and ensures timely collection or sorting. An ultrasonic sensor plays a crucial role in an automatic waste segregation system by detecting the presence, level, and distance of waste materials. It helps in monitoring waste bin levels, detecting waste objects on conveyor belts, and triggering sorting mechanisms.

IV IMPLEMENTATION

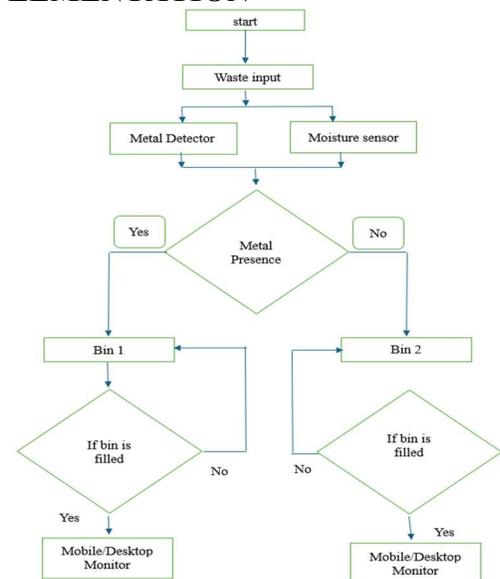


Fig 2: flow diagram of the system

The Figure 2 presents the operational flow of the system the "Start" block marks the initialization of the waste management process. It signifies the moment the system is activated or powered on, either manually or through an automated scheduler. This step sets all sensors, actuators, and communication modules into a ready state. Upon system start, the Arduino MEGA initializes communication protocols, configures sensor pins, and resets any prior data from previous operations.

This block is crucial because it ensures that all components are functioning correctly before actual waste input is processed. For example, the system may run internal checks to confirm sensor calibration, motor responsiveness, and connectivity with the ESP8266 module. This diagnostic approach improves reliability and reduces errors during operation.

During startup, the system can also begin collecting ambient or idle-state sensor data to establish a baseline. This data can be useful for noise filtering or adjusting thresholds for moisture detection and metal sensing. Essentially, it sets a clean slate for each new operation cycle. In automated environments such as smart homes or public facilities, the start block can be triggered by motion detection, scheduled timers, or even remote commands via mobile or desktop devices. Once initiated, the system is ready to receive waste input for classification and processing

The "Waste Input" block represents the physical act of introducing waste into the system. This is typically the user interaction point where mixed waste items are deposited into the smart bin or onto a conveyor system. The materials can vary—organic, metallic, plastic, or a mix of these—and this block acts as the handoff point to the sensors for further analysis.

In this stage, the waste must be positioned such that it can be effectively scanned by the moisture sensor and metal detector. The design of the input system (e.g., a funnel, chute, or conveyor) ensures that each item passes in a way that guarantees accurate sensing. Controlled input methods help prevent data corruption and misclassification.

The "Metal Detector" block is responsible for identifying metallic substances within the waste. This sensor operates using electromagnetic induction principles, where a magnetic field is generated and then monitored for disturbances caused by metal objects. When a metallic item passes through or near the sensor's coil, it alters the electromagnetic field, triggering a signal to the Arduino. The Arduino receives this signal and interprets it as the presence of metal. Based on this detection, the system determines the routing of the waste item. Metal detection plays a critical role in automated waste segregation, as metals are recyclable and valuable for reuse, making them a priority in recovery operations. The effectiveness of the metal detector is dependent on the sensitivity and calibration of the sensor. It must distinguish between ferrous and non-ferrous metals while ignoring environmental noise.

The "Moisture Sensor" block identifies the water content in waste material. It works by measuring the resistance between two conductive probes; high moisture levels decrease resistance, producing higher conductivity and analog voltage output. This data is read by the Arduino to determine whether the waste item is wet or dry. The moisture sensor operates alongside the metal detector but serves a different purpose. It helps in classifying organic waste, which usually contains moisture, versus dry materials like plastic or paper. Accurate moisture sensing allows the system to route waste to the appropriate bin, aiding composting or landfill decisions.

This decision block evaluates the output from the metal detector to determine if the waste contains metal. It functions as a conditional logic step—if metal is detected, the system will follow one path; if not, it will follow another. This binary decision is critical for routing the waste to the correct bin.

When metal is detected, the waste is directed to Bin 1. This bin is specially allocated for metallic waste, allowing for easy recovery, sorting, and recycling. Bin 1 is physically placed so that metal-containing waste can be mechanically or electronically diverted into it by a servo motor or diverter mechanism. Bin 1 is

typically monitored by an ultrasonic sensor that measures its fill level. When the bin is full, the sensor sends a signal to the Arduino, which triggers an alert to the mobile or desktop monitoring device. This ensures timely emptying and prevents overflow, which could disrupt operations. If no metal is detected, the waste is directed to Bin 2. This bin primarily collects non-metallic waste such as organics, paper, or plastics, as determined by additional conditions like moisture content. Bin 2 is crucial for handling the bulk of domestic and industrial waste that does not include metals. Bin 2 is also monitored using an ultrasonic sensor to detect when it reaches its fill limit. This real-time monitoring allows the system to notify users for timely disposal or replacement.

The mobile or desktop monitoring block serves as the user interface for the system. It receives real-time updates from the Arduino through the ESP8266 module regarding bin status, waste classification events, and sensor health. This enables remote supervision and control of the waste management system.

The interface could be a web dashboard, app, or desktop program that displays bin levels, system errors, and alerts. Users can receive notifications when bins are full or when unusual sensor behavior is detected. This promotes proactive maintenance and minimizes downtime. Remote monitoring also facilitates data logging for analysis and optimization. Users can review historical trends such as waste generation rates, bin filling patterns, and maintenance frequency. This data is valuable for planning, budgeting, and improving sustainability goals.

V RESULTS

The prototype successfully demonstrated the collection of solid waste using a motorized conveyor belt mechanism integrated within the drainage cleaning system. As the system moved along the drainage line, waste materials such as plastic wrappers, leaves, and small metal objects were detected and collected efficiently. Upon detection, the servo motor was activated to direct the waste toward the conveyor belt,

which then transported the debris into an attached collection bin. This continuous operation was aided by sensors that identified the presence of waste and automatically initiated the collection process without requiring manual intervention.

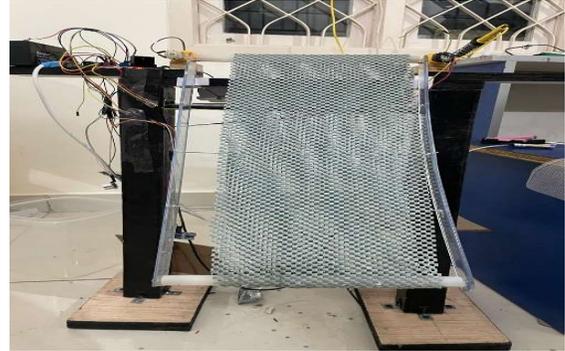


Fig 3 : working of conveyer belt

The system's performance in detecting metallic waste and measuring depth was validated through real-time data outputs, as captured during testing. The inductive proximity sensor effectively identified the presence of metal debris within the drainage channel, triggering the servo motor to rotate right, indicating an operational response to metal detection. Simultaneously, the ultrasonic sensor consistently measured the water depth in the container, displaying a stable reading of 35 cm. The synchronized response of both the metal detector and the depth sensor demonstrates the successful integration and functionality of the sensors. This real-time feedback ensures that the system can autonomously monitor drainage conditions and respond accordingly, forming a crucial part of its predictive maintenance and automation capabilities.



Fig 4: output for metallic waste

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The experimental results showcased the system's effective integration of sensing and actuation components for water detection and response. When the soil moisture sensor detected a water content exceeding the preset threshold, the system successfully interpreted this input and categorized the sample as containing water. This triggered a mechanical response — the servo motor rotated to the left — to direct the waste into the appropriate container, as confirmed by the message “Water Detected – Servo Left” on the serial monitor. This behavior illustrates that the decision-making logic implemented in the microcontroller worked as intended, translating sensor readings into actionable motor commands.



Fig 5: output of the wet waste

Additionally, the ultrasonic sensor played a vital role in continuously monitoring the depth of the water within the container. During this operation, it recorded a stable water depth of 42 cm, affirming the sensor's accuracy and the system's capability to monitor environmental parameters in real-time. Overall, the results validate the potential of automated systems to streamline maintenance processes, enhance operational efficiency, and reduce reliance on manual intervention.

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Depth Container 1: 21 cm
Depth Container 2: 21 cm
No Water and No Metal Detected
Depth Container 1: 21 cm
Depth Container 2: 21 cm
No Water and No Metal Detected
Depth Container 1: 21 cm
Depth Container 2: 21 cm
No Water and No Metal Detected
Depth Container 1: 21 cm
Depth Container 2: 21 cm
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Depth Container 2: 21 cm
No Water and No Metal Detected
Depth Container 1: 21 cm
Depth Container 2: 21 cm
No Water and No Metal Detected
Depth Container 1: 21 cm
Depth Container 2: 21 cm

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Fig 6: output of no detection

The image displays the real-time serial monitor output from the waste segregation system, indicating the consistent detection status of materials passing through the sensors. In this particular observation, the system repeatedly reports “No Water and No Metal Detected,” confirming the absence of both moisture and metallic components in the scanned waste. Simultaneously, the depth readings from both containers remain constant at 21 cm, which suggests that no additional material has been deposited during this cycle. This steady data stream validates the system's ability to monitor conditions accurately when no qualifying waste is present, reinforcing its reliability and stability in differentiating material types and maintaining real-time status updates.

VI CONCLUSION

In conclusion, the development of a real-time automatic drainage cleaning and monitoring system

using IoT technology presents a transformative solution to long-standing urban sanitation challenges. The integration of mechanical filtration with smart sensors enables continuous monitoring and autonomous removal of solid waste, significantly reducing the risk of waterlogging, environmental contamination, and health hazards. By utilizing components such as ultrasonic sensors, moisture detectors, metal detectors, and microcontrollers, the system ensures that drainage networks remain clear and functional with minimal human intervention. Furthermore, the inclusion of wireless communication modules and a cloud-based dashboard allows for real-time alerts and data analytics, facilitating proactive maintenance and reducing reliance on manual labor. This innovation not only improves the operational efficiency of municipal waste management but also contributes to public health and environmental sustainability in urban and semi-urban areas.

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