Paper ID: ICMIME2024_XXX

Smart Waste Management System for Drainage Networks: Detection, Removal, and Notification

Arpon Sarkar[1], Hossain Mahmud Tonmoy[1], Dr. Md. Rokunuzzaman[1], Dr. Syed Mamun R Rasid[1]
[1] Rajshahi University of Engineering & Technology, Rajshahi, Bangladesh
E-mail: arpon.mecha.99@gmail.com, mahmudtonmoy67@gmail.com, rzaman@me.ruet.ac.bd, mamun@me.ruet.ac.bd, amimuleahsanzaki@gmail.com

Abstract

The exponential growth in population, in conjunction with inadequate waste management strategies, has intensified the obstruction of drainage lines, resulting in recurrent inundation of roadways and surrounding regions during monsoon periods. The aforementioned pervasive problem leads to significant harm to infrastructure and a decline in production as a consequence of disturbed working hours. In response to this difficulty, we suggest developing and executing a cutting-edge system with the objective of identifying solid waste in drainage lines and effectively eliminating the recognized garbage from the channel. The system includes a mechanism to gather the garbage that has been taken out and store it in a specific basket. It also sends notifications when the basket is completely filled. Through the implementation of this system, we expect substantial enhancements in the upkeep of drainage lines, decreased occurrences of floods, and mitigated socio-economic losses linked to infrastructure deterioration and disruptions in productivity.

Keywords: wastewater, stormwater, ultrasonic sensor, GSM (global system for mobile communications) module.

1. Introduction

An operational drainage system is essential for a livable and healthy city. The main purpose of constructing a drainage system is to efficiently control wastewater and stormwater flow in order to avoid flooding, waterlogging, and erosion, therefore safeguarding infrastructure, properties, and the environment.[1] This guarantees the well-being, hygiene, and ease of communities by upholding adequate sanitation, minimizing water-related harm, and safeguarding water purity.[2]

A survey published on August 17, 2020, by The Financial Express reveals that 78% of Dhaka WASA's (Water Supply and Sewerage Authority) 360 sq. km service area lacks a specialized storm drainage system. This issue is further compounded by clogged surface drains spanning nearly 1,500 km, posing significant challenges, particularly across greater Dhaka's 1,528 sq. km expanse. [3] These vital drainage channels are often obstructed by solid waste and washed-in debris, particularly non-degradable plastic products like polythene, bottles or jars, old feminine hygiene products, medical waste etc., reflecting a concerning lack of civic responsibility in waste management and under maintenance of the drainage system. According to a report, 30% of the country's plastic waste, which equals about 17,000 tons annually, often ends up clogging the sewers in major cities.[4] Therefore, it is crucial to constantly remove plastic waste from our drainage system in order to maintain its unobstructed flow.

Presently, drainage inspection and cleaning in our country are conducted manually by municipal organizations, a process that is labor-intensive, infrequent, and often inaccurate. Moreover, drainage systems are mostly cleared only once a year, and that too if the area happens to be near main thoroughfares.[5] Furthermore, a substantial proportion of the municipal corporation's budget is dedicated to the manual upkeep of the drainage system, but This approach yields limited results, underscoring the need for an efficient automated system to detect and remove blockages while ensuring real-time reporting to relevant authorities for smoother sewage flow.

This paper presents a system for detecting and removing solid waste from drainage lines, collecting it in a designated basket, and notifying the municipality for efficient waste management. The core concept of the proposed setup is to enable the control of a DC motor—starting and stopping—through sensor inputs or preset delay intervals, facilitated by a microcontroller. The proposed mechanism is designed to function as an automated strainer within a drainage system, efficiently removing debris from the sewage flow and transferring the collected waste into a designated container.

2. Methodology

2.1. System overview

The primary objective of this project is to create an autonomous system that would clean drainage channels and collect garbage, depositing it into a nearby waste basket. Additionally, the system will notify the relevant authorities, streamlining the drain cleaning procedure and enhancing its efficiency and dependability. In order to achieve this goal, two distinct approaches have been considered: 1. Drainage channel cleaning based on detection (System 1) 2. Cleaning of drainage channels with an interval period (System 2).

Figure 1 depicts the system architecture designed for the automatic cleaning of drainage channels by utilizing a trash detecting technique. Ultrasonic sensors are used to identify the existence of solid trash. The processing unit then sends a command to the relay module, instructing it to activate the motor. The motor moves the lifting platform, which in turn removes the identified garbage from the drainage lines.

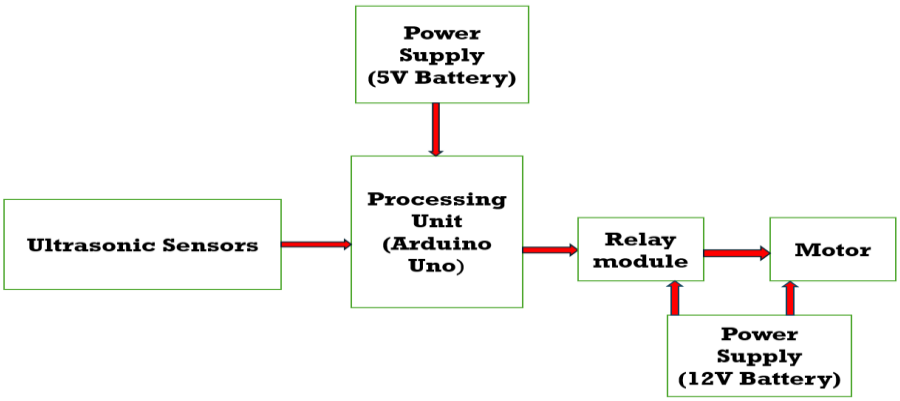


Fig.1. Proposed system architecture of drainage line cleaning based on solid waste detection (System 1).

Figure 2 illustrates the system architecture that has been developed for the purpose of automatically cleaning drainage channels, incorporating a wait time. The processing unit measures time and triggers the motor using a relay module once a specific duration has elapsed. The motor then operates for a designated period to clean the drainage lines automatically

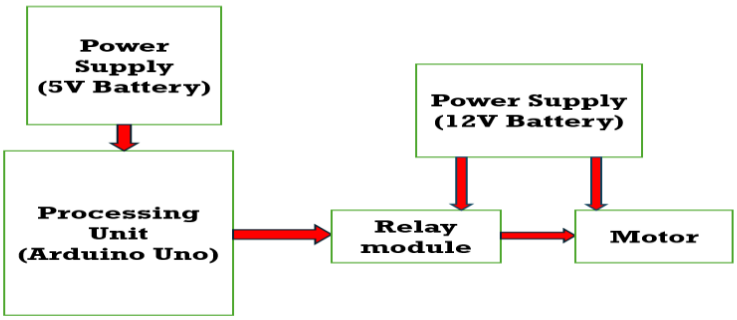


Fig.2. Proposed system architecture of drainage line cleaning using a delay period (System 2)

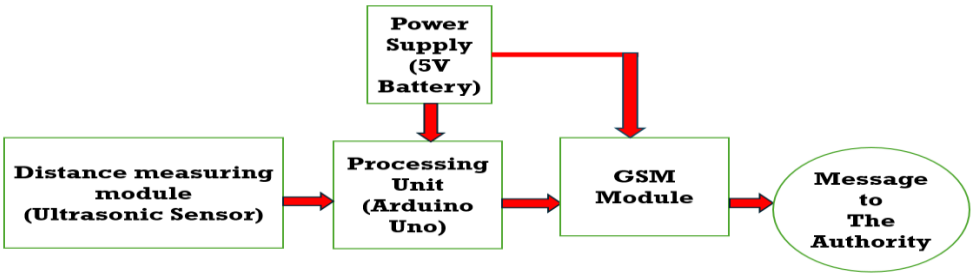


Fig.3.Proposed system architecture for reporting system.

Figure 3 illustrates the proposed architecture of the reporting system. The reporting system will utilize an ultrasonic sensor positioned beneath the lid of the waste basket to measure the distance between the waste and the

lid. When a predetermined distance is exceeded, the processing unit will activate the GSM module and send a message to the relevant authorities.

2.2. Design of the Experimental Setup

The robust waste detection and removal system for drainage channels has been designed in accordance with the system's architecture and flowchart. The prototype's dimensions are determined by measuring an open drainage line, and scaling is done to moderate the size of the prototype considering cost and ease of experimentation. Figure 4 shows the final drawing of the prototype.

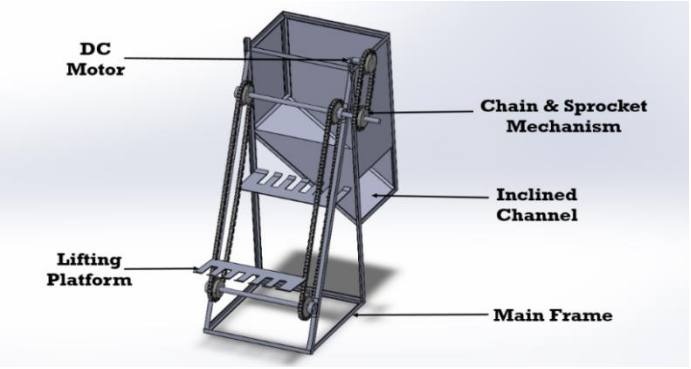


Fig.4. Final drawing of the Prototype.

2.3 Experimental Setup

The experimental setup has been constructed in accordance with the findings obtained during the design phase. A 12V 37GB550 Gear Motor High Torque 60 RPM' having 20kg-cm torque is selected as the motor for the project with accordance with the calculation of the design phase. The implementation of the design plan for the production of the Prototype is executed effectively. Figures 5, depicts the ultimate rendering and ultimate appearance of the Prototype subsequent to its manufacturing.



Fig.5. The developed Prototype**.**

2.4. Required hardware

The project uses various hardware to implement the system prototype. Inexpensive and precise hardware are selected for the system in such a way that it is economical and available without compromising the quality of the components. The list of hardware is as follows:

1. Arduino Uno 2. R3 Sonar Sensor (HC-SR04) 3. 1 Channel 5V relay module 4. GSM module (SIM 800L)
5. Li-ion Battery (12V & 5V) 6. DC Motor 7. Chain and Chain Sprocket 8. Lifting Platform
9. Bearing 10. Shaft

2.5 Controlling System Design

In Figure 6, the wiring diagram illustrating the necessary components for detecting solid waste in drainage channels and establishing subsequent connections to initiate the motor for the purpose of removing solid waste from said channels is depicted.

Three ultrasonic sensors (Sonar HC-SR04) are utilized for the purpose of detecting solid waste. These sensors are coupled to an Arduino Uno, which serves as the processing unit. Here, a single-channel relay module functions as a switch and is connected to both the motor and Arduino Uno. The relay module activates or deactivates the motor based on the sensor data and commands received from the processing unit.

There are three Ultrasonic Sensor strategically positioned on the net just above water level of the drainage channel. When a solid waste material is in close proximity to one or more sensors, it is detected and the distance of the waste from the net is measured. The motor is activated by the processing unit when solid waste is within 20 cm range. Consequently, the lifting platform, positioned directly beneath the accumulated waste, begins to move, and transport the garbage to the inclined channel of the Prototype. The trash is then disposed of in the waste bin located next to the drainage line near the mouth of the inclined channel. Once the waste has been removed, the system

undergoes a reset, enabling it to identify and eliminate any additional blockages that may arise in the drainage line.

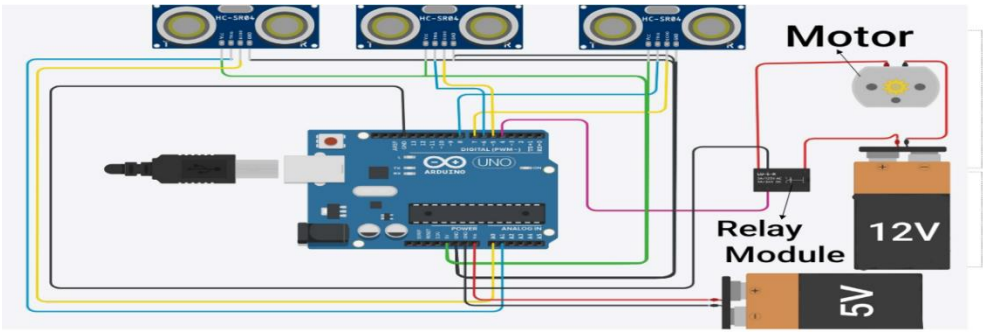


Fig.6. Circuit diagram of the garbage detection and removal system (System 1).

Figure 7, illustrates the wiring schematic of the control system, demonstrating the motor's activity for a brief period after a predetermined delay.

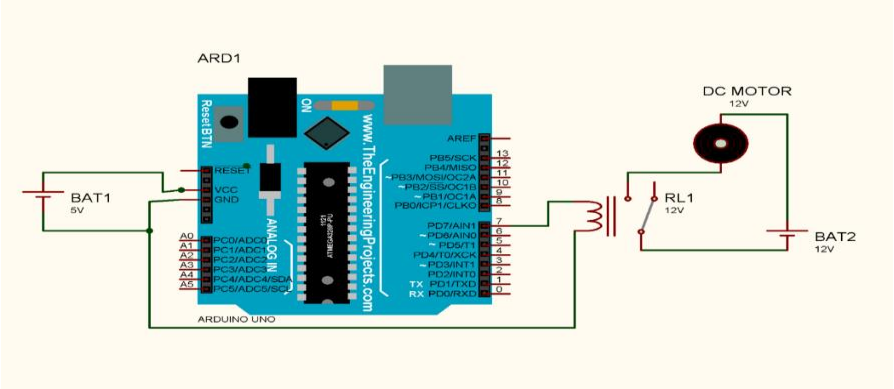


Fig.7. Circuit diagram of the waste removal system using delay period (System 2).

In this setup, a 12V direct current (DC) motor is linked to the processing unit, specifically an Arduino Uno, through a single channel relay module that functions as a switch. The Arduino receives the delay period and running time through coding. The Arduino Uno microcontroller is responsible for timekeeping and motor control, allowing for autonomous movement and stopping of the lifting platform. The Arduino Uno, acting as the processing unit, measures time and controls the motor by enabling or disabling it through the relay module.

2.6. Reporting System Design

The primary concept of the reporting system is depicted in Figure 8, The waste bin's lid will be kept partially covered, and it will be equipped with an ultrasonic sensor and GSM module. Ultrasonic sensor detects when the bin has been nearly filled and transmits a message to a predetermined number via a GSM module with help of Arduino Uno.

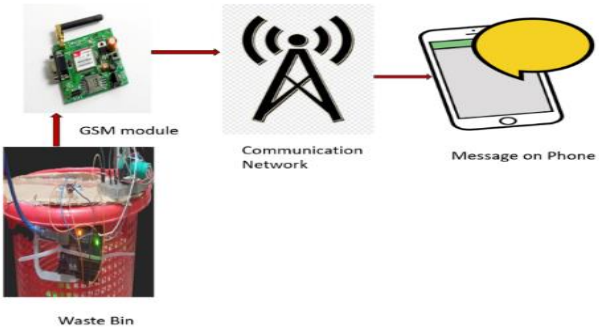


Fig.8. Communication network of the reporting system.

The bin collects waste from the prototype with its uncovered portion. The ultrasonic sensor continuously measures distance of accumulated waste from the lid of the bin. Once the distance between them becomes two cm or less,

Arduino will send a previously recorded text message to the predefined user via GSM module. The successful execution of this procedure relies on the transfer of the appropriate code to the Arduino Uno platform. The code includes both the message intended for the authority and the mobile number of the recipient.

3. Performance Test

3.1 Experimental Scenario

The experiment was done in a control environment, where prototype was placed in the 12 feet long, 24 inch wide and 17-inch-deep open channel. This channel was dug for the purpose of the experiment and serving as a substitute for actual drainage canals. Figure 9 demonstrates the prototype in the experimental scenario and shows prototype in various stages of drainage channel cleaning procedure. After placing the prototype, the channel was filled with water, and waste materials such as polyethylene bags, juice packs, plastic bottles, and leaves were introduced. Artificial flow was used to bring the waste closer to the prototype to evaluate its performance. The removal of garbage from the drainage channel to the waste basket has been taken as a successful trial. The ratio of number successful trials to total number of trials is taken as success rate for the developed systems.



Fig.9. Experimental Scenario.

3.2. Notification

A notification is transmitted from the SIM in GSM module to the assigned number when the trash bin is approaching maximum capacity. This mechanism guarantees regular maintenance of the bins and the cleanliness of drainage lines. This mobile SMS allows for the identification of full waste bins based on their unique identity number. The identification of each bin's location can be determined by this number, as the authority will own a datasheet with the locations of these bins according to their respective identity numbers. Figure 11 illustrates sent notification by the reporting system.

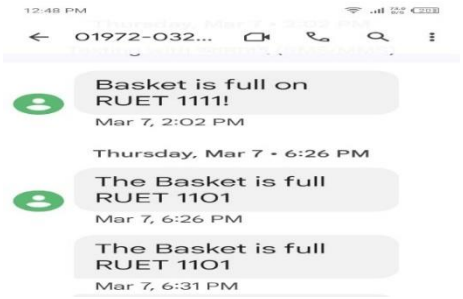


Fig.11.Notification Through Mobile Message.

3.3. Results

The data collected are shown and success rate is determined in the table below:

Type of Waste	System 1	Success Rate	System 2	Success Rate
One 2-liter bottle	√		√	
Two 2-liter bottles	√		√	
One 1-liter bottle	×		√	
Mixed (polythene bags + large bottle)	√		√	
Aluminum Cans	×		√	
Juice packs	×	**27 %**	√	**82 %**
Polythene bags	×		×	
Mixed (polythene bags + leaves + empty packets)	×		×	
One 250 ml bottle	×		√	
Three 1-liter bottle	×		√	
Mixed (bottles of various size)	×		√	

In the above table successful attempts are denoted by '√' symbol and failed attempts are denoted by '×' symbol. From the trial runs done in the control environment the efficiency of the garbage detection and removal system for drainage line cleaning was found to be around 27%. The other method considered for automated drainage cleaning fared much better compared to it. The efficiency of waste removal system using delay period for drainage line cleaning was found to be around 82%.

3.4. Discussion

A prototype for an automated drainage channel cleaning and reporting system was developed, facing key challenges during design and fabrication. Circuit design and malfunctions posed difficulties in the design phase, while attaching the Lifting Platform to the chain through welding was a challenge during fabrication. Testing in water-filled channels proved difficult, as ultrasonic sensors had to detect floating solid waste without contacting water. Additionally, water backflow and scattering caused by the Lifting Platform's motion hindered effective operation. The poor detection and removal efficiency, largely due to the water sensitivity of the ultrasonic sensors, could be improved by utilizing water-resistant proximity sensors.

The drainage channel cleaning method using time intervals to control the motor was successful, with minor issues resolved by extending the net length. However, wet polyethylene bags occasionally stuck to the inclined passageway, failing to discharge automatically but were later removed when dried or with incoming heavier trash. The reporting system performed effectively, consistently delivering notifications when the waste bin neared full capacity.

4. Conclusions

In summary, the project outcomes demonstrate that the developed prototype effectively detects solid waste in drainage channels, although repeated testing revealed reduced sensor accuracy due to the ultrasonic sensor's sensitivity to water. The prototype autonomously cleans drainage channels by detecting waste or operating on a scheduled basis. Its design enables direct transfer of waste from the channel to a designated waste basket, and a reporting system notifies authorities when the basket approaches full capacity. Future improvements for the project include integrating water-resistant proximity sensors or camera-based image processing to enhance waste detection. The addition of solar panels as a renewable energy source would improve sustainability and reduce reliance on external power. Further refinement of the lifting mechanism could increase the prototype's efficiency and reliability, ensuring more effective waste removal from drainage channels. These enhancements would improve both the performance and durability of the system, making it a more viable long-term solution for managing waste in drainage channels.

5. References

[1] "Purpose of Urban Drainage and Objectives of Urban Drainage System." https://www.aboutcivil.org/purpose-objectives-urban-drainage

[2] D. Merrett, "What Are The Advantages And Disadvantages Of Drainage System," DC Merrett, May 27, 2023. https://dcmerrett.co.uk/advantages-and-disadvantages-of-drainage-system/

[3] M. ZAMIR, "Our drainage system needs immediate attention," thefinancialexpress.com.bd, The Financial Express, Aug. 17, 2020. Accessed: Mar. 26, 2024. [Online]. Available: https://thefinancialexpress.com.bd/views/views/our-drainage-system-needs-immediate-attention-1597592522

[4] O. Ahmad, "Plastic chokes Dhaka's drainage," Dialogue Earth, Jan. 06, 2021. https://dialogue.earth/en/pollution/plastic-chokes-dhakas-drainage/

[5] " Introduction, why drainage is important - ROADEX Network," ROADEX Network, Mar. 26, 2024. https://www.roadex.org/e-learning/lessons/drainage-of-low-volume-roads/introduction-why-drainage-is-important