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Automated Canal Waste Collection System (ACWaCoS) for Canal Maintenance

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Abstract- The study aimed to develop a prototype of an automated canal waste collection system. Specifically, it sought to determine the ultrasonic sensor's capability to detect waste, servo motor's spin to collect waste, system's ability to update the serial monitor when the bin is full, average amount of time taken to complete a waste collection cycle, and average amount of waste detected and collected by the system for a certain period. The prototype used Arduino Uno R3, HC-SR04 ultrasonic sensors, MG995 servo motor, SG90 servo motor, jumper wires, breadboard, and a powerbank. The data were analyzed using frequency distribution, percentage, mean and Mann Whitney U-test. The results showed that the automated canal waste collection system prototype was 100% successful across three indicators; the prototype takes an average time of 14.6 seconds to complete a waste collection cycle; it detects an average amount of 7.50 wastes and collects an average amount of 7.20 wastes. The amount of waste detected and collected does not significantly differ. This means that the prototype can collect a significant amount' of detected wastes in the canal without human intervention. With these, the automated canal waste collection system has the potential in its functionality and consistency. Additionally, the device needs an IoT-based notification system for real-time monitoring.

Index Terms-canal waste collection, Arduino Uno R3, ultrasonic sensor, servo motor, SIM800L GSM Module

I. INTRODUCTION

Canals have been integral to the development of many cities and agricultural regions, serving diverse purposes from transporting goods and managing stormwater to enhancing urban landscapes. However, the increasing problem of improper waste disposal has rendered many canals ineffective. Non-biodegradable plastics and hazardous chemicals in this case disposed through canals lead to massive water flow blockages, resulting in environmental and public health implications. Accumulations of waste materials—ranging from plastics to industrial by-products—clog these channels, obstructing their function and causing adverse effects such as increased flooding and deteriorating water quality. It presents a challenge that must be addressed effectively with waste management solutions and innovations to see canals return to their utility levels.

The world produces enormous amounts of waste every year. According to Kaza et al. (2018), the amount of waste generated worldwide is expected to increase alarmingly from 2.01 billion tons annually to 3.40 billion tons in 2050. Tjia (2020) found that rapid urbanization and land use growth in Kumani, Ghana's rapidly growing city, has increased the intensity and frequency of flood episodes. Plastic wastes clog sewers and rivers, causing flooding of open spaces, streets, and homes when heavy rain falls. Similarly, in Nigeria, plastic pollution clogs drainage channels, fills up vacant areas, and causes erosion and floods, which worsens the state of roadways (Kehinde et al., 2020). Improper disposal of waste is also the major cause of flooding in informal areas with poorly maintained drainage systems like Bwaise, an urban slum in Kampala, Uganda (Haerani & Budi, 2019).

Similar to other developing nations, the Philippines has faced significant challenges with solid waste management for the past years (Atienza, 2011). Improper garbage disposal exacerbates floods by clogging drainage systems, causing water blockages, and raising flood risk in urban areas (Gaudiel, 2023). The country's rapid urbanization, modernization, and population growth have all contributed to a marked rise in garbage production, particularly in urban areas. Some areas in Baguio City, the highest metropolitan city in the nation, experienced gutter-deep floods due to the accumulation of trash, mostly discarded face masks and plastic face shields in drainage systems, clogging water inlets (Balota et al., 2023). In a study conducted by Baguio et al. (2024) in Barangay Basak, Lapu-Lapu City, 38.82% of residents noted inappropriate garbage disposal as a main cause of drainage overflow, increasing flooding problems.

Davao City is an area experiencing rapid population, insufficient waste disposal infrastructure, and expansion. Urban flooding is a significant issue affecting its residents, with improper disposal of domestic waste noted as a major factor (Mendoza, 2022). When such garbage builds up, drainage systems usually get severely clogged, which causes significant water logging during heavy downpours. In the same year, the chief of the City Engineer's Office reminded the residents to observe proper waste disposal to prevent clogged waterways and reduce flooding in the city. Additionally, the chief noted materials such as driftwood and pointed out that garbage disposed at collection points is sometimes not collected immediately and may get washed away in open canals after heavy rain (Kehinde et al., 2020). The problem emphasizes how important it is to have efficient waste management plans to reduce the risk of flooding and increase urban resilience.

To combat the issue, officials take proactive measures to deal with the main cause, improper waste disposal, and lessen reliance on non-recyclable materials. Concurrently, certain organizations focus on cleaning canals by systematically collecting waste that clogs these critical waterways. Multiple have explored the use of robotics for waste collection, aiming to enhance efficiency and reduce safety risks. Researchers have shown interest in creating and proposing automated gutter or drain cleaning systems that can catch large solid wastes with limited human intervention (Dattatray et. al, 2021; Kothe et. al, 2022; Balashanmgam & Sivakumar, 2022). However, they face several practical gaps that need addressing to improve their effectiveness including the lack of real-time notification, bin accessibility, and maintenance challenges. With that, the researchers aim to combine concepts of existing technologies and automated tools to develop a system that could consistently operate to collect wastes that pass through a specific point at the canal, addressing the gaps stated.

Statement of the Problem

This research aimed to develop an automated canal waste collection system (ACWaCoS) for canal maintenance to aid with improper waste disposal in canals. Specifically, it sought to answer the following questions:

- What is the percentage of successful trials of using an automated canal waste collection system in terms of:
- ultrasonic sensor's capability to detect waste;
- servo motor's spin to collect waste;
- system's ability to update the serial monitor when the bin is full; and
- accuracy of the bin capacity notification via the SIM800L GSM Module?
- What is the average time taken for the automated canal waste collection system to complete a waste collection cycle?
- What is the average amount of waste detected and collected by the system for a certain period (two minutes)?
- Is there a significant difference in the amount of waste detected and the amount of waste successfully collected for a certain period?

Hypothesis

The study was tested at a 0.05 level of significance.

- **Ho:** There is no significant difference in the amount of waste detected and the amount of waste successfully collected.
- **Ha:** There is a significant difference in the amount of waste detected and the amount of waste successfully collected.

Significance of the Study

The study will create an intervention for the effect of improper waste disposal in canal areas. It can offer an effective and affordable system that will help local communities, environmental agencies, the City Government of Davao, and future researchers.

Local Communities. The study is helpful to them in terms of reducing the effect of improper waste disposal in canals, keeping them from being clogged and causing floods by ensuring solid wastes are collected and relocated. By automating the collection process, communities will experience cleaner canals and minimized flooding risks.

Environment Agencies. The study aids these organizations by providing a cutting-edge tool for monitoring and managing waste in waterways, complying with environmental regulations and protecting water resources. It backs initiatives aimed at keeping canals free of waste.

City Government of Davao. The city government can use the technology to conduct efficient handling of waste. By reducing flooding and maintaining clean canals, the government can improve public health outcomes, enhance urban aesthetics, and potentially lower infrastructure repair costs.

Future Researchers. The study sets the stage for future research into robotics in waste collection. They can explore the effectiveness, adaptability, and integration of such technologies in various urban settings. Additionally, they may adapt this research and modify it to make it more efficient for the environment.

Scope and Delimitation of the Study

The scope of the research was the development of an automated canal waste collection system that can detect and collect floating wastes in canals, with the limited goal of assisting authorities and agencies in managing them. This system would help ensure proper water flow, preventing blockages that can lead to flooding during heavy rains. By employing automated technology, the project aims to maintain clearer waterways, ultimately enhancing urban resilience against flooding events.

The device could automatically collect the floating waste upon detection, reducing the need for human intervention. The servo motor serves as the main system for collection, with a microcontroller controlling its degree of spin and speed.

The study was limited to a miniature canal model as further study is required to create a prototype efficient enough to be installed, effectively proving and supporting the research.

Definition of Terms

Ultrasonic sensor's capability to detect waste refers to the emission of sound waves that bounce off objects, measuring the time taken for the waves to return to determine their distance and identify the presence of floating debris.

Motor's accuracy in response to the ultrasonic sensor and collecting refers to its ability to reliably initiate a collection action after a five-second delay once the sensor detects floating waste, ensuring precise alignment for effective retrieval.

Ultrasonic sensor's ability to update the serial monitor when the bin is full is based on its capability to identify the proximity of objects, triggering a signal when waste reaches a certain level, indicating that the bin is full.

Waste collection cycle refers to the process wherein, once Ultrasonic Sensor 1 detects floating wastes in the canal, it will spur the motor to scoop up the waste and transport it to the collection bin, while Ultrasonic Sensor 2 will check if it's full.
Average amount of waste collected by the system for a certain period refers to the average quantity of waste captured during a specific two-minute time interval, measured to evaluate the effectiveness and efficiency of the system in waste removal over short time frames.

Amount of waste detected refers to the total number of waste detected by the ultrasonic sensors in a collection cycle, regardless if it was successfully collected or not.

Amount of waste successfully collected refers to the total quantity of waste that was scooped and transported to the collection bin, indicating the effectiveness of the system in removing detected waste from the canal.

II. METHODS

This section presented the method of the study, which contains four (4) phases: phase I – preparation and assembling of the automated canal waste collection system (mechanical and frame design); phase II – testing of indicators; phase III – data collection and analysis, phase IV – aesthetics. All the tests and experimental procedures were conducted at Carlos P. Garcia Senior High School.

Research Design

The study applied an experimental research method to gather relevant data and information. According to Knight (2010), as referenced by Sirisilla (2023), an experimental study design allows researchers to carry out their research aims with greater clarity and transparency. A proper experimental design serves as a road map for the study methodology, helping readers to better understand how the data were acquired and, as a result, assisting them in completing an appropriate analysis of the findings.

This study utilized experimental design to describe the logic of this system. In this system, the ultrasonic sensor detects the presence of objects at set distances and sends a signal for the motor to spin.

According to Cruz et al. (2023), using the automated waste system would benefit people living in low-lying areas who are vulnerable to flood risks by helping maintain the flow of drainage waters. This automation would benefit both the people and the environment by effectively collecting waste from the canals.

Phase I. Designing and Assembling the Automated Canal Waste Collection System Prototype

Materials. The prototype consisted of 15 materials, specifically Arduino Uno R3, two HC-SR04 ultrasonic sensors, MG995 servo motor, SG90 servo motor, SIM800L GSM Module, jumper wires, breadboard, powerbank, and recycled materials like wood, PVC pipes, used nails, plastic, metal, and paper.

Building System Wiring

Presented in Figure 1 are the connections of the system. The researchers created connections to the HC-SR04 ultrasonic sensors, Arduino UNO R3, and MG995 servo motor; Arduino UNO R3 allows the sensors to detect the presence of objects in set distances and sends a signal for the motor to spin.

To increase the length of the wires, multiple jumper wires were connected according to the length needed. Then, electrical tape was placed on the bare wires. Finally, components are arranged in storage for organization.

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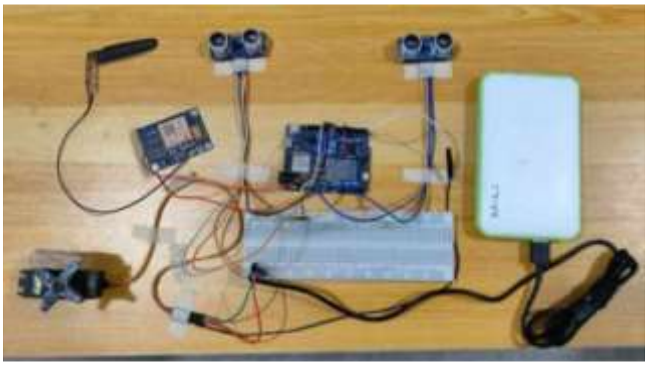

Figure 1. System Wirings

Building Up of Wheel

The wheel to be used for collection has a specific design fully intended for its purpose. The outside layer is equipped with four scoops to collect floating debris. Finally, it is connected to the MG995 servo motor. Presented in Figure 2 is its final form.

Figure 2. Collector Wheel

Testing the Components

The function of the main three components—two HR-SR04 ultrasonic sensors and one MG995 servo motor—were tested individually to assure that they did not malfunction.

Attaching the Components

The main three components—two HR-SR04 ultrasonic sensors and one MG995 servo motor—were attached to their tentative spots. Presented in Figures 3.1, 3.2, and 3.3 are the components in their respective positions.

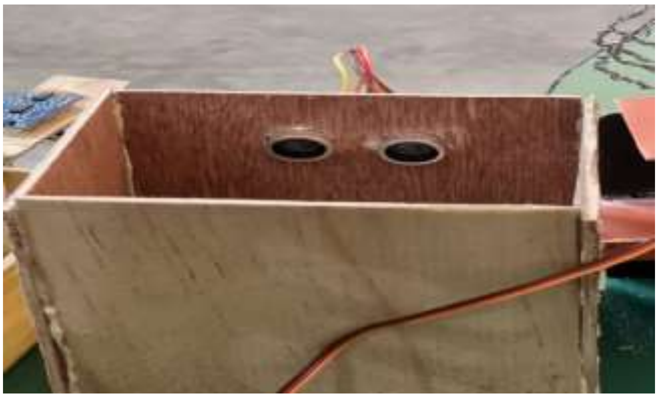

Figure 3 HR-SC04 Ultrasonic Sensor 1 in Bin

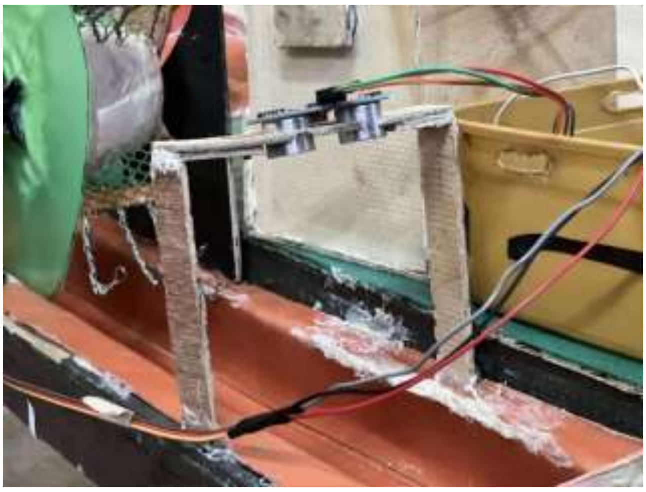

Figure 4. HR-SC04 Ultrasonic Sensor 2

Figure 5 Motor, Wheel, and Receiver

Attaching the Pins

Pin configurations of the components were attached to Arduino Uno and the power supply.

Coding

Presented in Figure 4 is the circuit design of the automated canal waste collection system prototype. The system was programmed using Arduino IDE software. The Arduino Uno microcontroller checked the presence of floating waste in water, then spun the motor after a five-second delay to collect it. Then, another ultrasonic sensor detects if the bin is full and ready for collection.

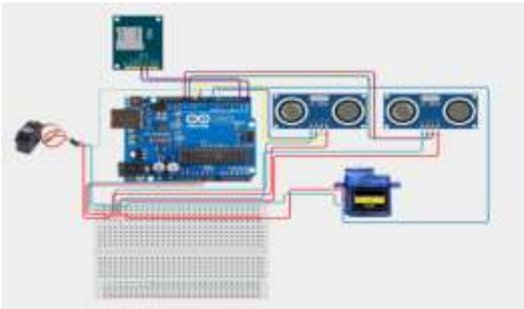

Figure 6. Circuit Design of Automated Canal Waste Collection System

Phase II. Testing of Indicators

Presented in Figure 4 is the schematic diagram of the automated canal waste collection system prototype. The automated canal waste collector system was tested using an ultrasonic sensor. Once the sensor determines the garbage, it will fully function as expected. Then, the motor will be selected for testing.

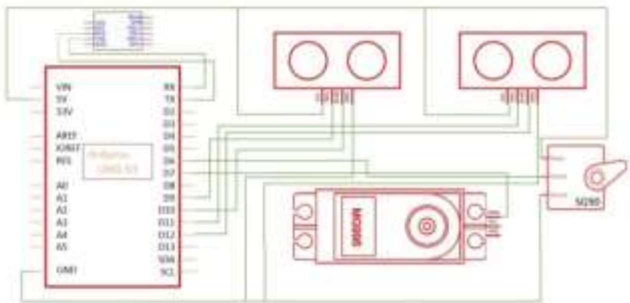

Figure 7 Schematic Diagram of Automated Canal Cleaning System

Input and Output Connection

Table 1 shows the input and output pins used in the machine to simplify the debugging process and easily differentiate the pins used.

Component - Function	In/Out – Pin
HC-SR04 Ultrasonic Sensor	Input – D9, D10, D11, D12
MG995 Servo Motor	Input – D6
SG90 Servo Motor	Input – D7
SIM800L GSM Module	SIM_TXD – RX0 SIM_RXD - TX1

Detecting the Presence of Floating Waste

The first ultrasonic sensor is placed to detect garbage in the canal. The microcontroller interfaces with the Arduino board, and programming is performed and uploaded using the Arduino Cloud Editor. The sensor sends out ultrasonic waves which bounce back the moment it hits an object. Next, the time it takes to go back to the ultrasonic sensor is calculated, then, converted to centimeters, allowing the system to measure the distance of the object from it. If the garbage is identified by the sensor within a pre-set range, there will be a delay of 5 seconds to confirm the detection before the mechanism of collection of waste is put to action.

Detecting Error in the System

When the detection of floating waste fails for three consecutive trials, it means that no collection of said waste is done, thus, there is an error in the system.

Phase III - Data Collection and Analysis

Presented in Figure 5 is the flowchart of the automated garbage collection system. After finishing the coding and implementation, the system was tested for problems. The prototype was deployed using a miniature setup to check whether the concept and wiring actually work. Next, the first demonstration deployment of the system was carried out. There were functional testing and usability testing performed. The entire system developed was able to pass all the test cases.

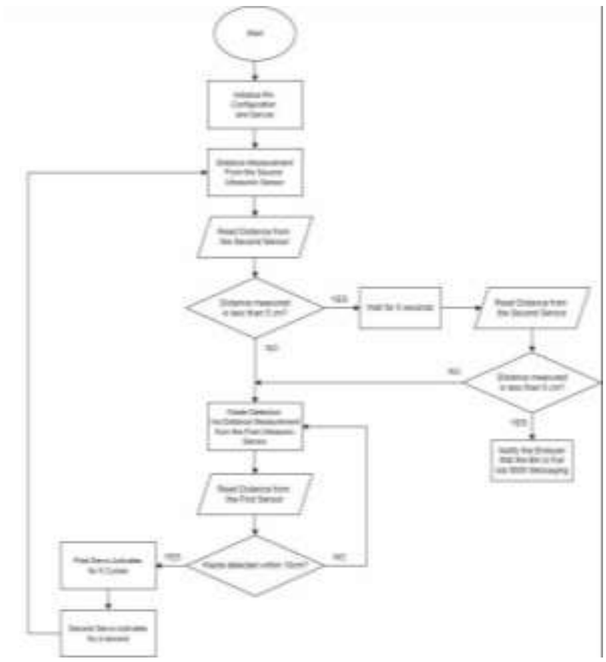

Figure 8. Flowchart of Automated Canal Waste Collection System

Phase IV. Aesthetics
Presented in Figure 6 is the aerial view of the automated canal waste collection system prototype. The prototype was designed after preparation, assembling, and testing of indicators. A miniature canal model was built to showcase how the system works.

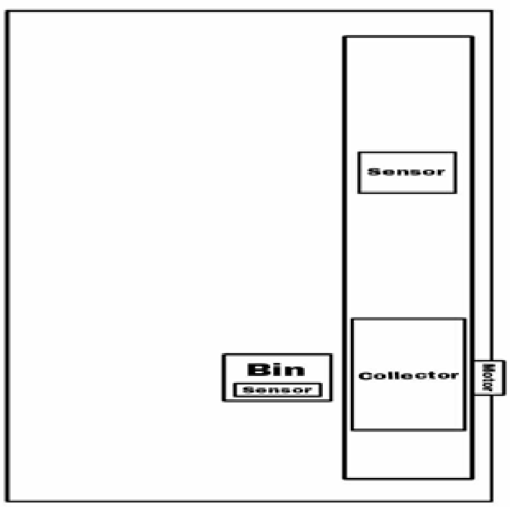

Figure 9. Aerial View of Automated Canal Waste Collection System Prototype

Waste Disposal
All damaged materials, debris, and dust were placed in a sealed container with the proper label. The researchers sent the waste materials to the Material Recovery Facility of Barangay 28-C, Davao City. Meanwhile, useful materials were recycled.

Data Analysis
The following statistical tests were used to analyze the data:

Frequency Distribution. This was a system used to determine the amount of waste collected in the canal.

Percentage. This was used to determine the successful trials that the automated garbage collector system prototype can perform according to the following indicators: ultrasonic sensor's capability to detect waste, motor's spin to collect waste, and ultrasonic sensor's ability to update the SMS when the bin is full.

Mean. This was used to determine the average amount of trash detected and collected in one minute.

Mann Whitney U-test. This was used to determine if there is a significant difference between the amount of waste detected and amount of waste successfully collected.

III. RESULTS

This section presents the findings based on the data gathered. The presentation is organized in four sections: 1) successful trials of the automated canal waste collection system; 2) average time taken for the automated canal waste collection system to complete a waste collection cycle; 3) average amount of waste detected and collected by the system for a certain period (two minutes); and 4) difference in the amount of waste detected and collected by the system.

Successful Trials of Automated Canal Waste Collection System
Presented in Table 2 is the successful trials of the automated canal waste collection system when tested according to the four (4) parameters.

Table 2: Successful Trials of the Automated Canal Waste Collection System

Parameters	T1	T2	T3	T4	T5	T6	Percent of Success
Ultrasonic sensor's capability to detect waste	√	√	√	√	√	√	100%
Servo motor's spin to collect waste	√	√	√	√	√	√	100%
System's ability to update the serial monitor when the bin is full	√	√	√	√	√	√	100%
Accuracy of the bin capacity notification via the SIM800L GSM Module	√	√	√	√	√	√	100%

Table 2 shows that the automated canal waste collection system prototype successfully performed by 100 percent across six (6) trials in terms of ultrasonic sensor's capability to detect waste, servo motor's spin to collect waste, the system's ability to update the serial monitor when the bin is full, and the accuracy of the bin capacity notification via the SIM800L GSM Module. This means that the automated canal waste collection system prototype is able to detect and collect wastes, and able to update the serial monitor when it is full of garbage.

Average Time Taken for the Automated Canal Waste Collection System to Complete a Waste Collection System

Presented in Table 3 is the average time taken for the automated canal waste collection system to complete a waste collection cycle.

Table 3

Parameters	Time (in seconds)						Mean
	T1	T2	T3	T4	T5	T6	
Time taken for the system to complete a waste collection cycle	14.96	12.88	17.77	12.87	14.25	14.50	14.54

Table 3 shows that the automated canal waste collection system takes an average time of 14.54 seconds to complete a waste collection cycle, with a standard deviation of 1.645 seconds. This means that the system is 70% consistent in its waste collection cycle. The time taken for a waste collection cycle is affected by the flow of the water, which influences the time it takes for the detected waste to reach the motor for collection.

Average Amount of Waste Detected and Collected by the System for a Certain Period

Presented in Table 4 is the amount of waste detected and collected by the system for a certain period (two minutes).

Table 4: Average Amount of Waste Detected and Collected by the System for a Certain Period

Parameters	Amount						Mean
	T1	T2	T3	T4	T5	T6	
Amount of waste detected by the system	8	7	8	8	8	7	7.67
Amount of waste successfully collected by the system	7	7	7	8	7	7	7.17

Table 4 shows that for two minutes, the automated canal waste collection system detects an average amount of 7.67 wastes and collects an average amount of 7.17 wastes. This shows that the amount of waste detected is slightly higher compared to the amount of waste collected.

Difference in the Amount of Waste Detected and Amount of Waste Successfully Collected by the System for a Certain Period

Presented in Table 5 is the result of the test of difference of the amount detected and successfully collected by the system for a certain period (two minutes), using the Mann-Whitney U test.

Table 5: Difference in the Amount of Waste Detected and Amount of Waste Successfully Collected by the System for a Certain Period

Indicators	Mean	W	p-value	Decision on Ho
Waste Detected	7.67	4.5	0.16	Failed to Reject
Waste Collected	7.17			

Level of Significance: 0.05

Table 5 shows that the system detected an average amount of 7.67 wastes and collected an average amount of 7.17 wastes. It also shows that at the 0.05 level of significance, the amount of waste detected and collected do not significantly differ (W = 4.5, p-value = 0.16 > 0.05). Therefore, the study failed to reject the null hypothesis. This means that the amount of waste detected by the system does not have a significant difference from the amount of waste successfully collected, indicating that the system is effective in its function.

IV. DISCUSSION

Caused the miniature waste to stick to it. This made the collection process inefficient and time-consuming. Secondly, it was observed that the slope of the waste collector was not steep enough, causing the waste to slide prematurely towards the receiver and the bin before the collection process was complete. This resulted in spillage and incomplete waste collection. Lastly, the ultrasonic sensor designed The automated canal waste collection system prototype successfully passed the test in terms of its functionality, indicating that it has the potential to aid with canal maintenance in larger settings. The findings agree with Desai and Parimala (2017), who claim the potential of the application of automation in waste management and recent trends. It also has the same goal as the project conducted by Vemulapalli et al. (2023), which is to lessen sewage obstruction in urban canals without human intervention. It is supported by Abkar et al. (2023), who found that automated technology minimizes waste, optimizes resource utilization and reduces environmental impact of urban processes, further emphasizing the potential of the system to serve its use.

Moreover, the sensors of the automated canal waste system can detect waste or debris in the water. The time it takes to gather recognized garbage varies according to water flow speed. This allows a smart system to monitor the water flow and alter the motor's collection mechanism as needed. Similarly, the findings of Kamarudin et. al (2021) indicated that the quantity of garbage collection was different each time because, at times, the garbage was far away from the water garbage collector. Additionally, Cruz et al. (2023) found that, over 15 trials, their device had different time intervals for each collection, with a 13.5-second difference between collections with and without loads. Shamsuddin et al. (2020) reported varying times to collect garbage. In the first trial, it took 5 seconds to collect garbage at 0 meters. In the second trial, the time was 10 seconds at 0 meters, indicating that their device had different time intervals for collection.

The study of Grigorova and Yankova (2020) agrees with the result, stating that one of the advantages of an automated waste collection system is its high efficiency in its functions. The result also supports this claim as the waste detected and collected does not significantly differ. Moreover, the study by Desnanjaya and Nugraha (2021) compared the ultrasonic sensor and the VL52L0X for waste detection, resulting in a 6.6% error value for the ultrasonic sensor and a 12.3% error value for the VL52L0X. This indicates that the ultrasonic sensor is more efficient in waste detection. Lastly, regarding collection, the study by Kamarudin et al. (2021) demonstrated the successful operation of a water surface garbage collector. The device was tested to collect garbage in a pool, and it managed to collect up to 192g of garbage within a 4.5-meter by 2.0-meter pool area. The prototype was proven to be effective in garbage collection.

The study by Kadarkarai et al. (2021) presented a novel automated device called the "GARAGE MONITORING SYSTEM USING GSM." This system uses an ultrasonic sensor; if the distance to the bin is less than 5 cm, the signal is transmitted to the Arduino, which then sends the signal to the GSM module. The GSM module, in turn, transmits the signal to an authorized person. This system is highly efficient as it uses the GSM module to inform the user when the bin is full. Shebu et al. (2020) employed an ultrasonic sensor to detect the waste level, sending a signal to an Arduino Uno (Atmega328) to inform the user about the bin's status. Furthermore, Surbhure (2024) proposed a garbage monitoring system based on the GSM module. In this system, the level of garbage in the bin is measured, and information about the amount of garbage collected is sent as an SMS to the user. IR sensors are used to measure the trash levels, which are then compared with the depth of the garbage bin.

However, during the trials, several issues were encountered with the waste collection system. Firstly, the scoop used to collect and transport the waste was found to be rough and uneven, which to detect incoming waste was found to be overly sensitive, as it was also detecting the movement of water in the device's canal. This led to the unintended triggering of the waste collector and its spin, even when no waste was present, resulting in unnecessary energy consumption and wear on the device.

These issues contrast with the study by Trinadha et al. (2024), which revealed that their device effectively collected floating trash from the water surface using a spinning wheel and conveyor belt, allowing for efficient scooping of the trash. Additionally, Haldorai et al. (2024) agree that their device can accurately detect floating trash, with a 100% success rate in debris identification. Lastly, the study by Bansal et al. (2019) aligns with these findings, as they introduced a fully automatic system for garbage detection and collection. The Automatic Garbage Detection and Collection (AGDC) system uses image-based object detection and a prototype robotic arm for garbage collection.

V. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the findings of the study, the following conclusion are drawn by the researchers:

- The automated canal waste collection system successfully passed the sensitivity tests in terms of ultrasonic sensors capability to detect waste, servo motors spin to collect waste, the system's ability to update the serial monitor when the bin is full, and the accuracy of the bin capacity notification via the SIM800L GSM Module. It indicates that the system is effective in aiding with canal maintenance.
- The automated canal waste collection system takes an average time of 14.6 seconds to complete a waste collection cycle. It is affected by the time it takes for the detected waste to reach the motor for collection.
- For two minutes, the automated canal waste collection system detects an average amount of 7.50 wastes and collects an average amount of 7.20 wastes. The amount of waste detected is the more than the amount of waste collected.
- The amount of waste detected and collected is the has no significant difference. This means that the amount of the waste detected by the system Is the same as the amount of waste collected, indicating its potential to aid with canal maintenance.

Recommendations

Based on the conclusions presented, the following recommendations are given:

- Use materials with a smoother surface for the scoop to ensure that no ridges allow the wastes to stick.
- Make the slope of the wheel steeper for the waste to roll to the receiver.
- Harness renewable energy using solar power to save electricity costs.
- Use a high-quality camera for detecting incoming wastes because the ultrasonic sensor cannot detect the submerged wastes, and it also detects the water level which triggers the collector to rotate without waste around.

Acknowledgment

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